Impacts of Immersive Technologies on Service Prototyping: Investigating the performance, experience, and acceptance of different service prototype forms

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T H È S E

“I see and I forget, I hear and I remember, I do and I understand”

Confucius

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Table of Abbreviations

Abbreviation	Word
XR	eXtended Reality
VR	Virtual Reality
AR	Augmented Reality
MR	Mixed Reality
HMD	Head Mounted Display
CAVE	Cave Automatic Virtual Environment
IVE	Immersive Virtual Environment
SI	Service Innovation
SE	Service Engineering
SD	Service Design
SP	Service Prototype
QoE	Quality of Experience
QoS	Quality of Service
UX	User eXperience
SX	Service Experience
CX	Customer Experience
SPX	Service Prototype eXperience
CSP	Conventional Service Prototype
VSP	Verbal Service Prototype
PSP	Paper Service Prototype
MSP	Mock-Up Service Prototype
SSP	Simulation Service Prototype
ISP	Immersive Service Prototype
VRSP	Virtual Reality Service Prototype
ARSP	Augmented Reality Service Prototype
MRSP	Mixed Reality Service Prototype
PX	Perceptual eXperience
EX	Emotional eXperience
CX	Cognitive eXperience
IX	Immersiveness (Immersive eXperience)
RWD	Real World Dissociation
ItA	Intention to Accept and Adopt
SPE	Service Prototype Effectiveness
SPX	Service Prototype experience
TCD	Task Completion Duration
EA	Errors Average Per Participant
EOR	Errors Opportunity Rate
EFR	Errors Frequency Rate
EI	Errors Intensity
XA	Explanation Requests Average Per Participants
XOR	Explanation Requests Opportunity Rate
XFR	Explanation Requests Frequency Rate
XI	Explanation Requests Intensity

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1. Introduction

1.1. Background, Purpose and Motivation

1.1.1. Prototyping

Prototyping is not something new. According to Budde et al. (1992), prototyping is a systematic approach for transforming ideas, drafts and concepts into a prototype that allow to anticipate and simulate its usage scenario along the system development process. The figure below depicts a generic prototyping approach having in input a product or process or service idea that transform it into an output represented by a corresponding prototype. This approach is not limited to specific objects like product, process or service but could be extended to any other object like a game for example, resulting into a game prototype. According to Christie et al. (2012) prototyping is a preliminary instantiation of a concept as part of a development process, where it is used by engineers to provide manufacturing data, investigate issues, and develop strategies. Christie et al. (2012) defined the prototyping strategy as the set of decisions that dictate what actions will be taken to accomplish the development of prototypes. There is a huge amount of investments in the research and development of prototypes especially with the industrial military complex; where the US Department of Defense has set aside $10 billion from its $25 billion defense R&D budget for prototyping and advanced development (Maucione, 2019, Federal News Network). According to the same article, prototyping and development had a large budget increase, while other areas' budget like basic research, applied research, science and technology and advanced technology development declined.

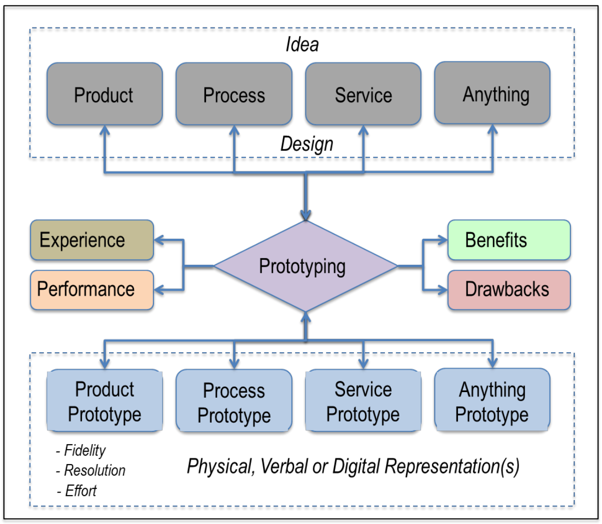

Figure 1.1 Prototyping Scheme

A prototype is not necessarily a physical object/mock-up produced by a traditional manufacturing process or 3D printer, known as additive manufacturing, in the case of rapid prototyping; it could be also a virtual or digital 2D or 3D object/mock-up produced by a specific software environment (e.g. Virtual Reality) as shown in Fig. (1.1). Prototypes have many benefits, such as: (1) reducing technical risks; (2) exploring alternatives for validating a design; (3) evaluating downstream processes; (4) validating cost estimates; (5) refining requirements; (6) reducing uncertainties (Medlej et al., 2017). They have also some drawbacks such as reduction of reliability and accuracy of measures as well as scalability and robustness (Baranov, 2019). The representation is mostly based on the fidelity and resolution of the prototype (Houde and Hill, 1997; Buchenau and Suri, 2000). Sefelin et al. (2003) add that the stakeholders might tend to comment more on graphical details rather than the interaction of the prototype. Mortiz (2005) argues that the simulations might need specific guidance to be used effectively and efficiently. Blomkvist and Holmlid (2012) explains that the predetermined actions of a prototype simulation can contradict with the inconsistent nature of services. The prototyping form can make a big difference in the time frame, cost and effectiveness of the prototype (Christie et al., 2012).

1.1.2.Product Prototyping

In an industrial context, prototyping is in the spotlight for decades due to its important role in the product design phase (Camburn et al., 2015). As stated by F. R. Barnard (1927), people often say "*A picture is worth a thousand words*", as everyone could get a better chance to understand what something is about in looking at a picture or drawing representing it instead of reading a textual description. More recently, it was reported by Balas (2018) that a former MIT professor, named John Meada, said: "*if a picture is worth a thousand words, a prototype is worth a thousand meetings*" (cited by Banfield et al. 2017). A prototype can be considered as an artefact that reproduces one or more aspects of a product, service or system (Otto, 2003). According to Mogensen (1994), prototypes have several facets: (a) they are used to clarify on design, requirements, and issues so that designers and engineers can modify the prototype until the final design is reached, as prototypes suggest what the future could be like; (b) their respective value is not only in the learning process it provides but also in the experience it creates for the stakeholders to learn through an experience; (c) they can serve as a bridge between analysis and design as it provides ideas about what could be changed and what could remain. In product design there are different maturity stages that require different forms of prototype, depending on whether it needs to provide a simple visualization or demonstrate some functionality, or checking different downstream aspects such as testability and manufacturability. Rapid prototyping is a term that embraces a range of new technologies for producing accurate representations of the design in a short period of time, with little effort (Pham and Gault, 1998). This allows designers and engineers to freely create their visions in a short amount of time and with little to no effort, to enable a co-creative development process.

Waterman and Dickens (1994) suggest that rapid prototyping can cut up to 70% of production costs, and reduce the time to market by 90%. Furthermore, Simo et al. (2013) suggest that rapid prototyping conveys benefits in terms of speed, accuracy and complexity over more traditional prototyping methods. One could conclude that prototyping is a valuable mean for all stakeholders, especially users, to quickly overcome collaborative distance barriers in reaching a mutual understanding of the design in order to undertake more appropriate collective decisions along design iterations (Pallot et al, 2017). For years, prototyping equipment, such as: 3D printers (additive manufacturing) and laser-based machines have demonstrated their capacity to quickly deliver 3D design representations or physical scale mock-ups of a product. Concurrently, Virtual Reality (VR) has become a popular digital prototyping environment in which to immerse collectively all stakeholders through the use of large wall-screens or CAVE or individually with Head-Mounted Display (HMD) while simulating some of the features and interactions. VR is widely used for assembly methods prototyping (Seth et al., 2011) and techniques for mechanical product development (Zorriassatine et al. 2003). Augmented Reality (AR) is being widely utilized in the production manufacturing industry (Ong et al., 2008). AR is also used in product design (Lee et al., 2005) as product prototyping through using markers and mobile devices to make product design more co-creative and improve the development experience. Mixed Reality (MR) is currently gaining traction as a powerful tool in product design, and with MR devices stakeholders can co-create design together and share them in an immersive yet real environment. MR is used in industrial design especially for aesthetics (Fiorentino et al. 2002) and product design assessment (Bordegoni et al. 2009).

1.1.3.Service Prototyping

More recently, scholars studied the transferability of the prototyping approach and benefits to the service sector. Simo et al. (2012) explains that due to service intangibility and market volatility new services introduction tend to fail, and by using tool like prototyping this might be improved. As traditional service engineering processes are too complex and lengthy than today's industrial services market expectancy (Cavalieri and Pezzotta, 2012). In recent studies, it was found that up to 40% of the newly developed services fail within the initial year (Castellion et al., 2013). As the service technologies evolve the service complexity and intricacy increase as well, where the main stakeholders can interact with one another and with different service processes leading to a more complex service system (Ostrom et al., 2015). Blomkvist and Holmlid (2011) suggest that rapid service prototyping approach means that prototyping is an ongoing design process activity.

In service design, designers use prototypes to gain insights on service aspects, to have a better understanding than from using only written explanations or visual presentations. Service design uses methods and tools derived from different disciplines to engage in a service design activity. Holmlid (2012) defines service design as the activity that, among other things, proposes behavioural configurations or "scripts" to the stakeholders interacting in the service and understanding how these patterns interconnect and sustain each other are vital facets aspects of design and service. Stickdorn et al. (2018) proposed six service design principles for real world application, as it has to be human cantered, collaborative, iterative, sequential, real and holistic. Aurich et al. (2004) proposed a service design approach inclusive of the product lifecycle and the customer and manufacturer's point of view for a more industrial oriented service design approach. Yet, there is a lack of common service prototyping procedures for the development and representation of services in both academic and industrial contexts. Studies shows that organizations are searching for a consistent, inexpensive and effective methodology to improve the service development process and increase the added value for their customers (van Husen et al., 2016). van Husen et al. (2019) uses service prototyping to co-creatively develop services by using immersive technologies as a tool for the collaborative service development process.

Immersive technologies are frequently used in the service industry sector as means to enhance the stakeholders' experiences (Buchenau and Suri, 2010). Industrial services need to be developed or re-developed; which increases the complexity of the development process (Ostrom et al., 2015). Consequently, there is a present tendency to use immersive technologies for service prototyping (Sämann et al., 2016). Service prototyping attempts to transform intangible service ideas into real experiences that enable service exploration, evaluation and communication according to van Husen et al. (2016). As such extending on the work of Blomkvist and Holmlid (2010), which states that prototyping uses prototypes to explore, evaluate or communicate in design. This transformation enables stakeholders to undertake informed decisions about different alternatives at the earliest developmental stage; based on stakeholders' feedback after using alternative service prototypes. Service prototyping allows businesses to bring to the market validated newly developed services, which may have a higher rate of potential adoption; hence, a higher rate of success. Marie-Rose et al. (2019) advices designers in their prototype form choice for testing to examine the user journey, the value-added services ideas and the technical challenges as the main focus in the development design phase. As such, we explore using immersive technologies to enhance the service prototyping process and experience.

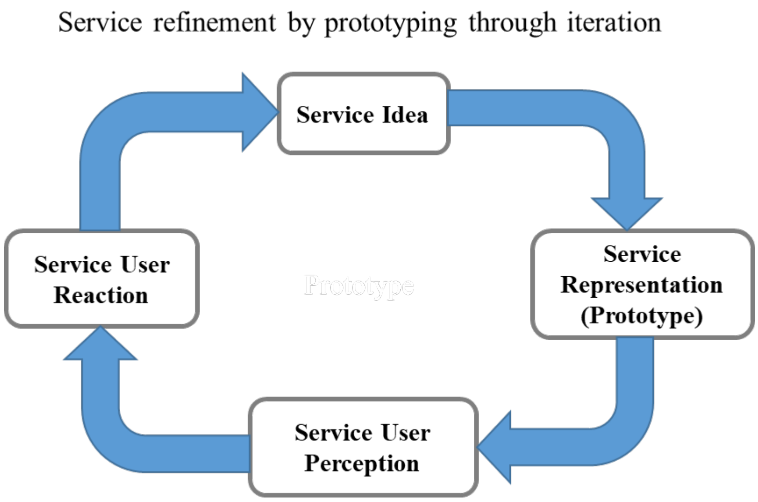

Figure 1.2 Current understanding of a service prototyping process

Fig. (1.2) represents a simplified graphical representation of a service prototyping process. It starts with the idea, which is then triggered by the action of engaging the stakeholders, either to explore a service idea or to improve on an existing service. The service representation, or the prototype itself, which engages the stakeholders' perception, emotions, and cognition, this prototype could come in various forms, ranging from verbal based to something more immersive. The service usage perception is when stakeholders, especially users, experiment the service through the use of the prototype, each SP form delivers a different experience. Through this experimentation an experience will arise, which results in a reaction or an evaluation of the prototype that produces feedback. The feedback feeds and supports the refinement and improvement of the service prototype. A possible hypothesis concerning the use of an immersive service prototype, instead of a flat 2D representation, delivering an immersive 3D eXperience, which will increase the user experience; hence, user's engagement and feedback.

1.1.4.Thesis Context and Motivation

In terms of context, back to early 2016, I was involved in a research team, at the Furtwangen University, working on service prototyping as an emerging new process of service design that could greatly impact the industrial service sector. In fact, our team was successful to get a new research project, named "dimenSion" (Multidimensional Service Prototyping), funded for 3 years by the German Federal Ministry for Education and Research. The Furtwangen University was research lead in this project, co-operating with a research partner, Karlsruhe Institute of Technology, and 7 industrial partners: three large enterprises and four SMEs. The research goal of the project was to explore service prototyping methods and tools to provide a practical applicability of industrial service prototyping; where we co-created service prototypes with each of the industrial partners. Involved industrial partners have defined their own application for their company-specific services. The industrial partners were from various fields, such as: mechanical engineering, industrial engineering, technical model toys, and information technology, bringing real-life issues and ideas to be prototyped with our co-creative service prototyping process. One of my contributions in this project, as a member of the service innovation team at the Furtwangen University, was to explore service prototyping, characterize and compare the different forms of service prototype, which became the PhD topic. At the beginning, we split all identified prototype forms into two categories, namely: (a) “conventional” for the traditional forms of service prototype like verbal-based, paper-based, mockup-based (physical, digital, and video) and simulation-based; (b) “immersive” for the ones using immersive technologies like VR, AR and MR (Abdel Razek et al., 2017). This research project has allowed gauging industrial needs and expectations for service prototyping and creating real life service prototypes for industrial applications. This helped in identifying and evaluating existing tools for service prototyping in collaborating with other researchers.

1.1.5.Purpose

This research should be seen as an early work to investigate the impact of immersive technologies on service prototypes, and the possibilities and drawbacks that arise accordingly. Immersive technologies, such as: Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), are said to be gaining popularity in different industrial service sectors and the prices of current devices and systems allow for a more affordable and accessible research and development for the industry. Dupont et al. (2018) evaluated different immersive collaborative environment platforms in order to foresee what solution could be more affordable for SMEs and start-ups. The motivation here is to gauge the impacts of these immersive technologies when they are applied in the service prototyping process. Service prototyping was conceived as an agile co-creative service design process that allows designing through iterations. We argue that immersive technologies enable service prototyping stakeholders to be immersed into a future service before it really exists. This allows stakeholders to explore, evaluate and communicate a service idea in a more effective and efficient way due to the reality like effect (Abdel Razek et al., 2017).

Holmlid and Evenson (2007) suggest that service prototyping should be chosen according to the position in the service development stages. They also suggested that service prototyping aims to improve the decision-making and to better assess alternatives when creating services. When using new technologies like VR, AR and MR, service stakeholders have a wider range of options in exploring, evaluating and communicating a new service. Immersive technologies enable the integration of different aspects in a prototype while providing more user insights especially for service processes like training and maintenance. Service Prototyping leverages 3D technologies in order to improve the service design process, and have less costly retroactive adjustments (Gauthier, 2013). Service organizations are using service prototyping as a tool to explore, communicate and evaluate service ideas, concepts, and designs for a co-creative service innovation process (van Husen et al., 2016; Sämann et al., 2016; Abdel Razek et al., 2017; Abdel Razek et al., 2018), which shows the level of industrial interest in service prototyping, and especially for immersive service prototypes.

The purpose of this dissertation is to reach a better understanding about service prototyping challenges and the role of immersive technologies in the capacity to create new forms of Service Prototype (SP). Therefore, there is a need to empirically investigate the impacts of immersive technologies, such as: VR, AR and MR, on service prototyping. In fact, there is a lack of published empirical studies on the different forms of prototypes, and on the description of the service prototyping experience. There is also a lack of empirical studies on immersive service prototyping and potential impacts on the service design process and quality of the service. As shown in Fig. (1.3) service prototyping is combining elements from service engineering, service design, and service innovation. Immersive technologies are among the technologies that could be used to potentially improve current service offerings whether by enhancing the usage experience and/or making it more efficient.

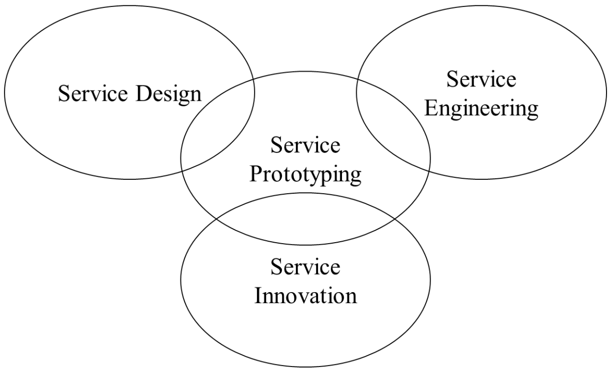

Figure 1.3 Initial Research scope

1.2. Objectives, Research Approach and Questions

1.2.1. Objectives

The objective of the study is to explore and study the impacts of using immersive service prototypes in regards to the user experience, acceptance and performance. The use of immersive technologies within service prototype is expected to improve support the transformation of intangible service ideas into a concrete experience; while insuring the proper level of sense making and mutual understanding among service stakeholders. To be able to identify what are the immersive technologies impacts on service prototyping, we must first define the constructs of immersive service prototyping. A comparative study to compare the different service prototype forms was conducted in the form of experiments and industrial focus group interviews. The main challenge is to get a clear scientific basis on different forms of immersive service prototype. This research could be considered in the first stage of innovation in the field of applying immersive technologies in service prototyping, pioneering the immersive service prototypes studies, aiming to be a part of the global open innovation process in service prototyping. The objectives of this thesis are the followings: (1) Identify the challenges to be tackled by the use of immersive technologies within service prototyping or service prototypes; (2) Categorize the different forms of service prototype; (3) Identify the factors impacting the SP experience, performance and adoption; (4) Compare the different forms of service prototype; (5) Evaluate the impacts of immersive technologies in Service Prototyping in terms of benefits and drawbacks.

1.2.2. Research Approach and Questions

Mixed methods approach is used in more and more studies, especially in UX studies (Ågerfalk 2013; Kruusimagi et al., 2017; Hebesberger et al., 2017; Krawczyk et al., 2017) but it is still marginal in relation to the UX published studies. The research method of a quantitative qualitative embedded survey, where the quantitative and qualitative data will be collected and analyzed at the same time; as the observations will elaborate on both the quantitative and qualitative results. The quantitative data offer a statistical analysis on the service prototypes performances, while the qualitative data provide explanation on their performances, experience and acceptance. This allows for a more assertive clarification of the results as well as early discovery of potential challenges with the reliability and validity of the survey instrument and the collected data.

1.2.3. Research Questions

RQ: What are the impacts of using immersive technologies on service prototyping? The first research question concerns investigating the impacts of using immersive technologies on a service prototyping process in an industrial service setting. The objectives are to (1) identify the impact factors of different service prototypes, and (2) assess those impacts in comparison with using conventional service prototype forms, i.e. paper service prototyping.

RQ.1: What are the impacts of immersiveness on SP stakeholders' perception of time, attentiveness to their surroundings and responsiveness to external events (Real-World Dissociation effect)? The first sub-question is investigating the impacts of immersiveness on the stakeholders on the real-world dissociation in terms of time, responsiveness, and attentiveness to surroundings. This will help us identify if the immersive technologies affect the ability to be aware of external factors (time, environment, sound) in an immersive state.

RQ.2: What are the impacts of immersiveness on the user experience of SP stakeholders (Service Prototyping eXperience)? The second sub question is about discussing the impacts of immersiveness on the stakeholders' service prototype experience, and how it will affect the SPX This will encompass the possibility of future adoption, re-use, and recommendation (to others) of that service prototyping form or process.

RQ.3: What are the impacts of immersiveness on the Ergonomic quality and Hedonic quality of the Service Prototype Effectiveness? The third sub question is discussing the impacts of immersiveness on the service prototype ergonomic and hedonic qualities in terms effectiveness of a service prototype. This will aid in understanding what kind of impacts immersive technologies may have on the effectiveness of the prototype.

RQ.4: What are the impacts of service prototype effectiveness on the Service Prototype eXperience? The fourth sub-question is investigating the impacts of service prototype effectiveness and efficiency on the stakeholders SPX. This will help us identify if the immersive technologies affect the stakeholders' SPX.

RQ.5: What are the impacts of Service Prototype eXperience on the intention to adopt? The fifth sub-question is investigating the impacts of SPX on the stakeholders' intention to use in terms of degree of acceptance and adoption. This will help us identify if the immersive technologies affect the intention to use, and as such the degree of adoption.

1.2.4. Hypothesis

There are several advantages of applying immersive technologies in service innovation, as shown from the literature, where a higher perceived service quality is observed (Marcus 1997), a better stakeholders' feedback and decision making while increasing service activity in the real world (Kim et al. 2008), a higher level of stakeholders' engagement and learning (Dede 2009), a more realistic stakeholders' service impression (Miettinen et al. 2012), and a more accurate depiction of how stakeholder's factors across time and space while providing a better testing of usability scenarios and an affordable and flexible mean for evaluation (Pallot and Pawar, 2012). Through analyzing the potential impacts of immersion and using immersive technologies in service innovation, we created hypothesis about ISP and the stakeholders' experience during an ISP process. As immersive technologies allow a more comprehensive representation of service experience leading to a far superior anticipation of the actual service experience. As such five hypothesis gyrating around the immersiveness, real world dissociation, service prototyping eXperience, service prototyping effectiveness and the intention to adopt were formulated. These hypotheses will be tested through a dedicated experiment and evaluated according to the analysis of collected data. The instrument to validate the hypotheses will compare conventional and immersive service prototypes in order to find out the impacts and variances in the application of the immersive technologies.

H1: The deeper the degree of immersiveness, the more effective the real world dissociation. The first hypothesis proposes that when using a service prototype, the higher the degree of immersiveness, the higher the dissociation to the real world. As the stakeholders will more immersed then their sense of time, surroundings and external factors will diminish with the increase in immersiveness.

H2: The deeper the degree of immersiveness, the more satisfying the SPX. The second hypothesis proposes the higher the degree of immersiveness, the better the Service Prototype eXperience. The stakeholders will have a more satisfying SPX that will increase the chances of convincing them to adopt it, or re-use it, and even recommend it to others.

H3: The deeper the degree of immersiveness, the higher the degree of effectiveness. The third hypothesis proposes that the higher the degree of immersiveness, the more effective the service prototyping process. The stakeholder will be more effective if they are more immersed as it will be very similar to a “real” experience.

H4: The higher the service prototype effectiveness, the more satisfying the Service Prototype eXperience. The fourth hypothesis proposes that the higher the effectiveness service prototyping process, the better the SPX. As the participant will enjoy the process more if they are more successful to accomplish the task without any help and mistakes and in the shortest duration possible.

H5: The more satisfying the Service Prototype eXperience, the higher the degree of stakeholders’ adoption of the prototyped Service. The fifth hypothesis proposes that the better the SPX the higher the degree of stakeholders’ acceptance and adoption. As the user will be more immersed then the stakeholder’s convincingness to adopt, willing to re-use, and the degree of recommendations to others with the increase in immersiveness, which leads to a better SPX.

1.3. Research Significance

There is an extensive research being done in immersive technologies and its applications within different industrial sectors, especially in fields where stakeholders’ experience is the focal point. While service prototyping does not receive the same research interest like some of the other service research streams; as it is a novel research approach. This study is dedicated to investigate service prototyping and prototypes, by exploring, then experimenting different service prototyping forms before evaluating them in regards to service experience, performance and degree of adoption. This includes studying how service prototype experience can affect the stakeholders’ eXperience, performance and acceptance degree. The significance of Service Prototype eXperience in relation to Service eXperience, User eXperience and Customer eXperience is shown in the literature review. There is an emerging interest for the development of service prototypes in the manufacturing industry, and in academia. Immersive technologies might have a significant impact in exploring and co-creating service prototypes with stakeholders, in allowing the collection of important observations and comments to create and refine a service idea, or to improve it after being immersed in it.

An immersive service prototyping co-creative process might aid engineers and designers to leverage the more comprehensive experience; resulting in enhanced feedback for brainstorming or for selecting a service idea. Evaluating a new service design by immersing stakeholders instead of supplying them with a 2D or a conventional service representation; enables better understanding of the service as they will be able to experience it instead of just see it. This could be vital for decision making, as service resources are scarce, and each cent saved from the costs is a cent gained; creating a service after evaluating its service prototype might not only increase the chances of service success but also increase profits and improve company's image. Communicating a service concept through an immersive experience builds a clear and holistic vision of a service, which might not even exist, by anticipating the services requirements and necessities. Communication is a key factor for service development processes, by using immersive technologies; designers and engineers can use more comprehensive service prototypes immersing stakeholders to communicate a service concept, which could be beneficial for complex services. Learning through an immersive service prototype instead of waiting till the launch of the service might be also useful. This allows stakeholders to experience a service or parts of it before it exists to increase the understanding of the service and its processes and improve the process through their feedback. One of the potential advantages in using immersive technologies on service prototypes that it allows stakeholders to explore complex service situations and environment, where it will be challenging to do the same with conventional methods. Also multidimensional services have intricate relationships and process that would be challenging to cover fully by only using conventional service prototypes.

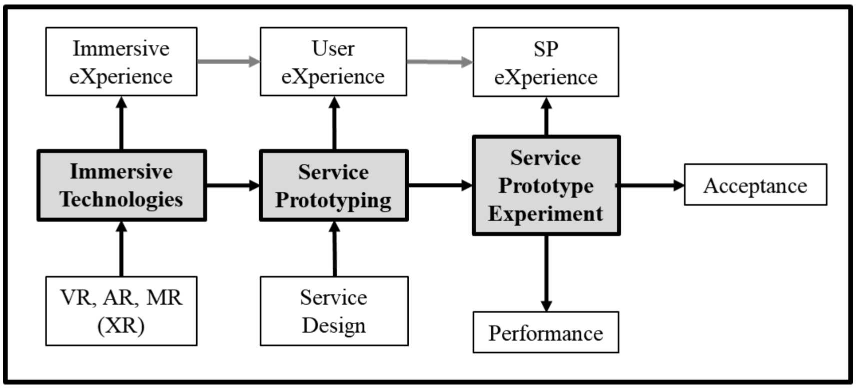

Figure 1.4 Graphical Representation of the investigation

Fig. (1.4) highlights the main concepts involved in this study aiming to provide a better understanding of the potential impacts of immersive technologies on service prototyping, which also outlines the research scope. The investigation on the impacts of immersive technologies on service prototyping, where we conduct comparative study on different forms of service prototypes. This study includes experiments, where each service prototype's performance, experience, and adoption degree are studied. The experiment results will be further discussed in an industrial workshop and focus discussion.

1.4. Thesis Structure

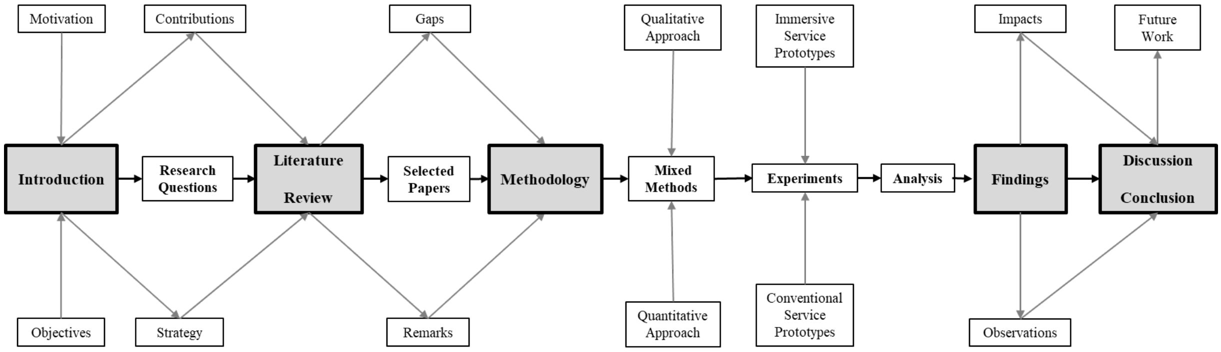

Figure 1.5 Visual representation of the Thesis Structure

The thesis structure is presented in Fig. (1.5), where each chapter appears as a darker box while each section appears in a light colored box. Chapter one covers the background, motivation of this research study from the industrial and academic viewpoints and its purpose. This chapter also covers the description of the research objectives, approach, questions and hypotheses. It also discusses the significance of such innovative concepts for a service development team. This chapter concludes with the presentation of the thesis structure and then provides a summary including a visual representation of the investigation that was carried out.

Chapter two covers the literature review on service innovation, immersive technologies, and immersive service prototyping especially in the service sector. We then present a summary of the scientific studies that have been done in service prototyping in the context of immersive technologies as well as an exposition of the fundamentals of immersive service prototyping. This is to demonstrate the literature gap of immersive service prototyping. The literature review also includes an extensive definition lists of the main research domains and sub-domains. This literature review then deals with exploring, communicating, and evaluating service ideas, concepts, and designs by using immersive technologies service prototyping, to understand the taxonomies of the impact on the stakeholders, and their experience; linked with the fundamental concepts of service prototyping previously discussed. Finally, the summary of the literature review will be introduced.

Throughout chapter three, the methodology based on the triangulation of quantitative and qualitative methods is proposed. These mixed methods will be used for instrument and model validation. An immersive service prototyping guideline will be proposed for service innovation in accordance with the impacts previously highlighted by our research. The validation experiment will be conducted in a learning academic environment. The chapter also covers the experiments, describing the protocol, parameters, and all the descriptive and statistical data concerning the experiments and the participants. The model and instrument will be also included in this chapter as well the stakeholders' feedback, and the observations and metrics selected for the experiment.

Chapter four is describing the research findings from the empirical study, after analyzing the data from the experiment. This chapter contains the statistical analysis and validation of the research model and instrument. This chapter includes the qualitative and quantitative findings from the instrument, as well as the impacts observed through the experiment. After the confirmation and validation of our model and instrument; an industrial workshop and focus group discussion is conducted to benchmark the research results.

Chapter five will include discussions on the perceived and implicit impacts of immersive technologies on service prototyping and the immersive service prototyping recommendations. This will conclude the dissertation results by answering the research questions, describing the contribution of this investigation to the existing state of the art, outlining the lessons learned and giving recommendations for future application in an industrial setting.

Finally, chapter 6 will cover the main conclusions and limitations of the model, instrument, and immersive service prototyping from a general point of view and thus outlining the prerequisites for future work. The chapter will also include a proposed plan for future research in an industrial setting.

1.5. Summary

Prototyping is frequently used in the industrial developmental stages for products; especially for products like machinery, automobiles or complex tools. Yet, there was no best practice for the immersive prototyping of services found in the literature. As the service technologies evolve the service complexity and intricacy increase as well, which increases the need for a better service representation and visualization. The current approaches used or developed typically focused on the development process; which doesn't integrate the service prototyping experience in the development process. Service prototyping is an agile co-creative development process that allows an enhanced service maturity to emerge through iterations. Service prototypes aims to transform intangible service ideas into real experiences. Immersive technologies might enable the stakeholders of a service prototyping process to have a more comprehensive experience due to immersion. The academic motivation here is to gauge the impacts of these immersive technologies utilized in the service prototyping process. To be able to understand these impacts, an investigation is needed to understand the stakeholders' reflection and evaluation of the service prototype experience with the use of immersive technologies. This investigation is focusing on the performances, experience and adoption degree of both immersive and conventional service prototypes. The motivation behind this empirical industrial study is helping organizations to be able to understand service prototyping forms and tools; without the need of an initial investment or extensive research. The hope is that this research is used as a basis for future academic research and industrial application.

Figure 1.6 Overview of the Research

2. Literature Review

2.1. Introduction

The literature review is a continuous process throughout the thesis period. It starts by looking at the amount of publications related to the different concepts that are part of this study. Secondly, relevant previous work, especially empirical studies, were identified and filtered according to related to factors impacting a service prototype's effectiveness, efficiency, and experience. Thirdly, existing gaps are identified, where a list of the researched definitions is constructed. Finally, the existing definitions from the relevant domains are extended up and updated to adapt for service prototyping in order to answer the research questions, and investigate the concepts of Immersive Service eXperience (IX) and Service Prototyping eXperience (SPX). The dissertation research scope "Service Prototyping in Maintenance Assembly" appears at the intersection of several research domains, such as: Service Innovation, Service Design, User eXperience, XR Industrial Assembly and Service Prototyping, as presented in the Fig. (2.1) below.

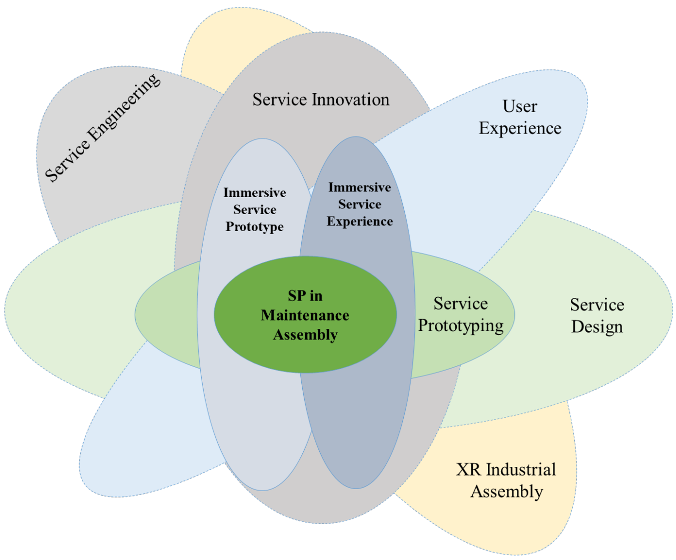

Figure 2.1 Thesis Research Scope

The focus of this study is on service prototypes in industrial maintenance assembly as shown in Fig. (2.1) above. There is a current transition happening in the industry pushed by different trends, such as: digitalization, industry 4.0, artificial intelligence and servitization. Assembly is a task that is found in most of the industrial and manufacturing processes. Baines et al. (2009) defines servitization as the organization's innovation abilities to increase the added value transitioning from selling products to selling product service systems. This transformation is also visible in the amount of research investments in regards to digitalization and servitization. The relevant research publication streams for our investigation are: (1) service research studies; (2) XR studies; (3) service prototyping; (4) immersive service experience; (5) XR in industrial training; and (6) XR in maintenance assembly.

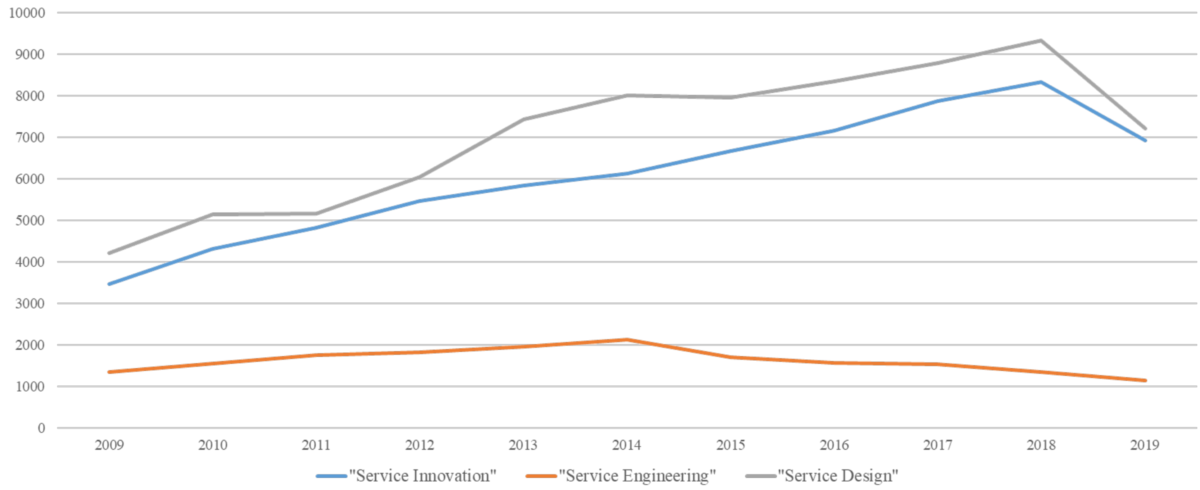

Figure 2.2 Service Innovation, Design, and Engineering amount of publication from 2009 up-to 2019

Fig. (2.2) highlights the level of interest, characterized by the amount of published papers during the last decade, among three main service research domains (a) "Service Innovation" (SI), (b) "Service Engineering" (SE), and (c) "Service Design" (SD). Regarding SI, it was on a continuous rise in the past 10 years, until slowly declining in 2018. This could be due to the fact that some of the publications might have still not been registered, as the decline is only by 11%. In 2019, it has about doubling from 2009. This shows a growing interest in both academic and industrial SI research. Looking at SD, it has a pretty similar curve compare to SI. It also has a similar decline of 10% in the number of papers from 2018 to 2019. This could be attributed to the researching interest reaching a peak and receding as we can see with many other literature streams. As for SD, in 2019, it has about doubling from 2009. This confirms the great interest in SD research, especially in the fields of user design and application development. Concerning SE, it has a much lower amount of publications than SI and SD: SE publications for 2019 were 1140, comparatively to 6920 for SI and 7270 for SD. In 2019, SE is lower than in 2009, by more than 15%. This decline confirms that there is less interest in researching SE, which might also suggest less applied research.

Some decades ago, there was a trend in the Industry involving immersive technologies for product prototyping; nowadays this trend appears in prototyping services, especially for industrial applications. Product prototyping is pretty common in the manufacturing industry while service prototyping does not yet have the same industrial interest because it remains a novel concept. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) were in the Gartner's top 10 strategic technology trends in 2016, 2017 and 2018. Gartner researchers predicted that by 2019, immersive technologies solutions would be adopted by 20% of large enterprise businesses (Forni, 2017). One thing to notice is that all immersive technologies are not anymore in the Gartner hype cycle, which might suggest that they turned to be more established technologies rather than emerging technologies.

XR immersive technologies and devices allow users to see into other environments, and immerse user by using digital information. In today's global market a competitive advantage can be achieved by effectively apply new technologies and processes. VR, AR, and MR technologies have advanced into a higher level of sophistication in the past 20 years. There were several mainstream immersive applications in the past several years, which introduced the technology to the masses, allowing more people to think of more ways for adoption and integration into their daily life. According to Seth et al. (2011) immersive technologies have also changed the way researcher look at training and learning processes like performing a real-time simulation of a specific service, or enabling users to become immersed in a virtual environment and interact as if they were in the real world.

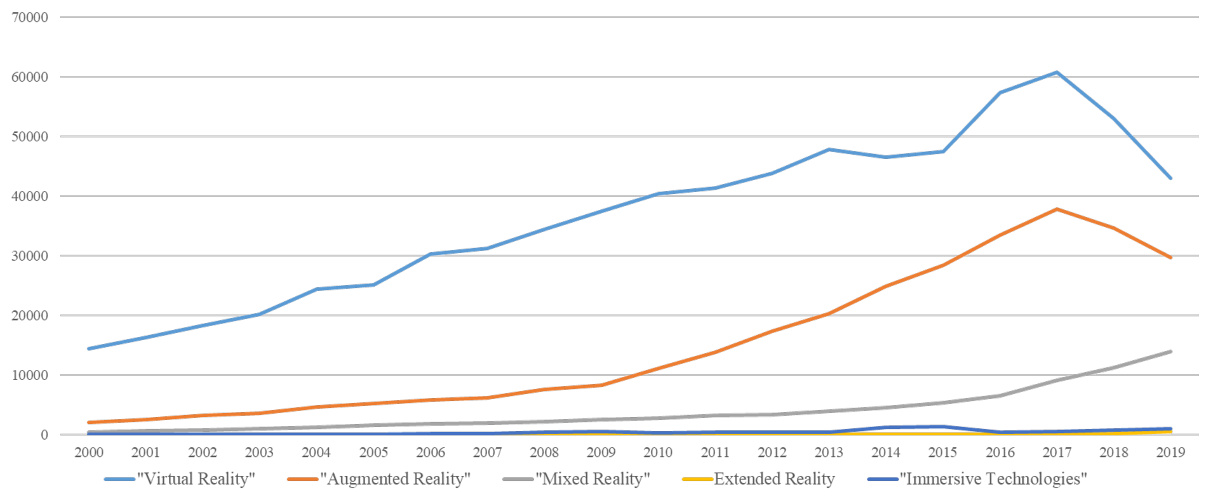

Figure 2.3 VR, AR and MR amount of publication from 2000 up-to 2019

A literature review on the existing state of art of immersive technologies literature was carried out, and the numbers of publications done in the past 20 years is shown in Fig. (2.3). This search was conducted by using Google scholar with three different keywords that best represent the immersive technologies literature. These keywords used were (a) "Virtual Reality", (b) "Augmented Reality", and (c) "Mixed Reality". As shown in the figure above that XR amount of published papers has been on a rise and as the applications and use-cases are numerous and the actual acceptance and adoption is increasing daily as seen from the integrated AR apps and VR arcades becoming mainstream. To date there were only 3,930 publications related to the search term "eXtended Reality" (XR), this shows that it is the term is used but not as much as VR, AR or even MR. Immersive technologies as a keyword is not used often in research, as an example in 2019 there was 2,210 publications with the key word “eXtended Reality” compared to 44,700 publications with “Virtual Reality” in them.

The search shows that VR were on a steady rise until it peaked in 2017 and is on a steep decline ever since. This decline could be interpreted to the increase in the amount of publications in both MR and XR, which are doubled every year since 2017. Considering AR were also on a steady rise till the peak at 2017 and then is on a steady decline ever since. This could be also being attributed to the increase in the number of publications in both MR and XR. There is a steady increase in MR and it is continuing rising. The increase could be attributed to the release of the Microsoft Hololens, which was in late 2016, which might have been the catalyst for such increase. The decline in both VR and AR might also be due a slowdown in researching concerning the technology, due to saturation or organizational competition challenges, another factor of this decline might be that the technology innovations are now in the application phase, and after several years there will be more innovation related to MR and XR rather than VR and AR, even though the research in the industrial application is still in its early stages. There is an abundance of publications that cover the definitions, characterization, and aspects of each of these technologies. These definitions are summarized in the literature summary tables later in the sub section of eXtended Reality. To start discussing service prototyping and prototypes, we have to first look back at the “prototyping” and “prototype” literature to see the interest and amount of research done.

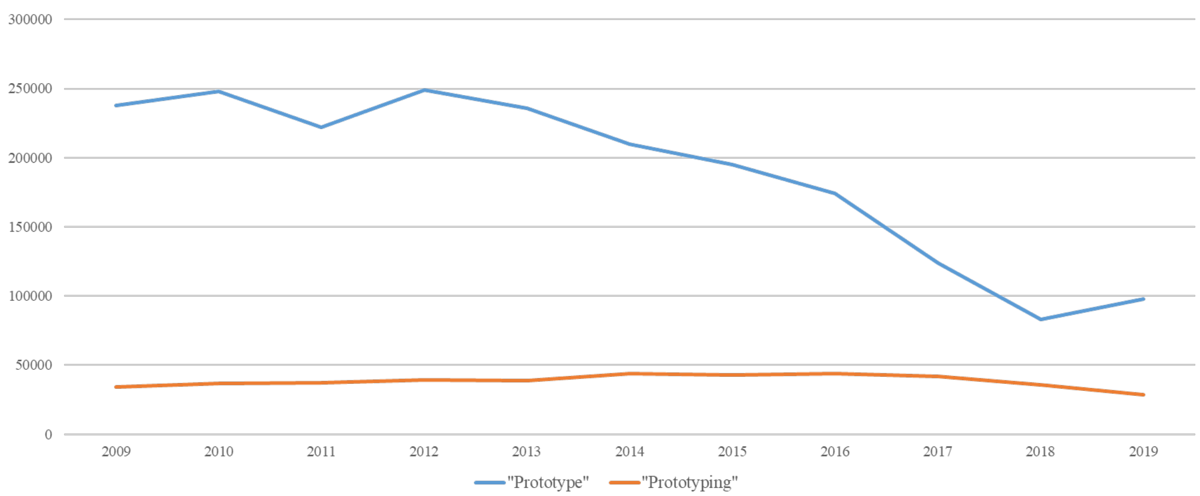

Figure 2.4 Prototyping and prototype amount of publication from 2000 up-to 2019

The literature search was done on the past 10 years, as it is the most relevant timeframe for such a novel topic. The keywords used in the search were (a) “prototyping” and (b) “prototype”. The literature search included every domain that uses prototyping and prototypes, the amount of publications is presented in Fig. (2.4). There is a bigger research interest for prototype as shown from the published papers. The number of published papers on prototype in 2019 were 98,000, while on prototyping were only 28,600, which represents almost 30%. Looking back at 2009, the research interest in "prototype" was much higher with 238,000, while "prototyping" was only 34,400, which is 15% of number in that same year.

Many companies fail when introducing the new services, due to their complexity and intangible nature, as such prototyping supports the involvement stakeholders in the service development (Simo et al., 2012). Prototyping should reveal complications, and issues so that service designers can modify the prototype until the desired design is reached. The industrial applications and interest in service prototyping and prototypes is high, and active. Project dimenSion was one of the academic and industrial service prototyping governmental funded research projects that spanned from the end of 2015 till start of 2019 to research service development advancement. The project consisted of two research institutes and seven industrial partners, ranging from small to large organizations. This project gauged the industrial interest for service prototyping in the industrial service sector in Germany, through industrial surveys, workshops and use-case implementations. The results of the project illustrated that there is an increasing industrial high interest and need for service prototyping and service prototypes, especially immersive service prototypes (van Husen et al., 2016; Sämann et al., 2016).

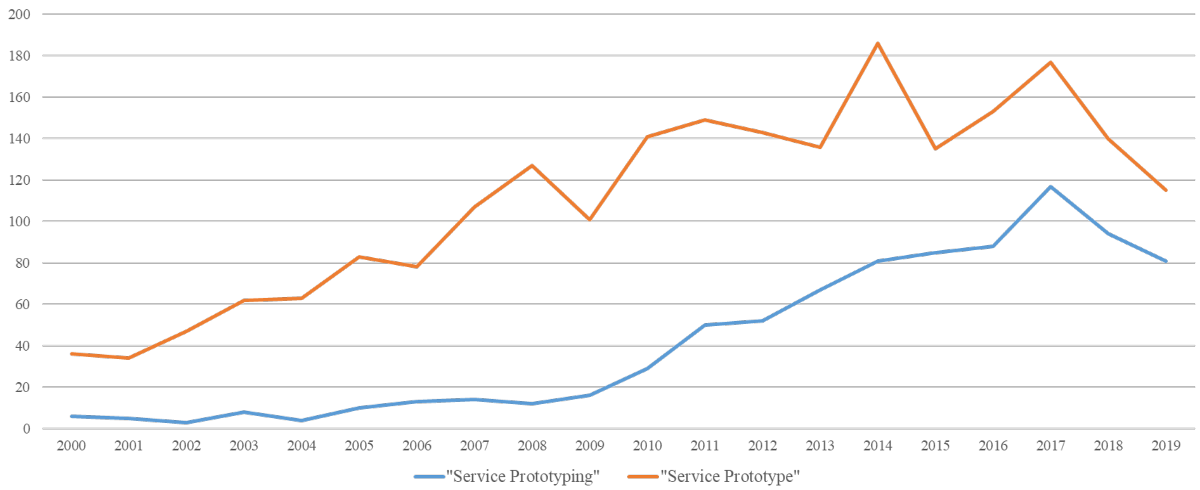

Figure 2.5 Service Prototyping and Prototype amount of publication from 2000 up-to 2019

Illustrated in Fig. (2.5) is a graph representing the amount of publications discussing service prototyping and service prototype from 2000 up-to 2019. The search was conducted by using Google scholar with the two terms: (a) "service prototyping" and (b) "service prototypes" because they are already widely used by scholars and allow to gauge the academic interest in service prototyping and service prototype. As "service prototyping" and "service prototype" terms were emerging research topics in the year 2000; the amount of published papers was 941 for service prototyping, and 2,520 in the case of service prototype, which is about 250% more. The number of publication was growing-up until the year 2017, and then is now declining ever since. This might be attributed to the increase in industrial applications, so the publications might come later on after the testing of these implementations and applications. "service prototype" publication numbers were going up and down while regularly growing.

According to Gavish et al. (2015) industrial training is one of the most widely accepted and adopted applications of immersive technologies. Immersive technologies and XR applications are being widely used in various industrial sectors like industrial education (Gavish et al., 2015) and construction training (Hilfert and König, 2016). Sportillo et al. (2015) reveals some insights regarding experience of assembly tasks by using immersive technologies. The practicality and effectiveness of the immersive experience are improved, when the users are completely suspending their sense of doubt during a virtual experience (Apostolopoulos et al., 2012). Hassan et al. (2019) identified independent UX and performance attributes in relevance to immersive industrial training; (1) physical constraints; (2) visual quality, (3) tracking quality and space, (4) safety, (5) presence, energy and immersion, (6) communication, (7) tool usage.

The seemingly real user interaction with tools is vital for the experience in VR industrial training applications (Gavish et al., 2015). The more the sense of reality is preserved the more realistic and engaging will the VR experience be (Ries et al., 2008). There are several researchers that discuss conventional manual training (Webster et al., 2013) and VR based simulation training (Schuemie et al., 2000). Others assert that mobile AR has many applications in maintenance assistance (Rankohi and Waugh, 2013). However, there are benefits and limitations to the application of MR in manual task training in manufacturing (Juang et al., 2013) and in construction (Khuong at al., 2014).

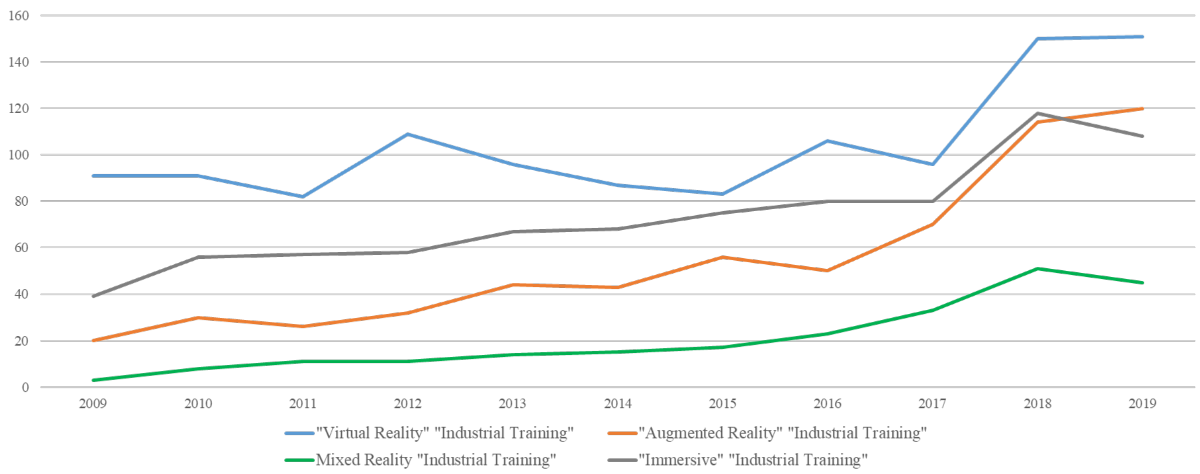

Figure 2.6 Immersive (XR) Industrial Training amount of publication from 2000 up-to 2019

It can be observed that there is steady increase in the amount of published papers regarding immersive technologies and training as shown in Fig. (2.6). Training is one of the most important services in any industry, especially industrial manufacturing industry (Fernandes et al., 2003). The terms used in the Google scholar search were: (a) “virtual reality” with "industrial training”, (b) “augmented reality” with "industrial training", (c) “mixed reality” with “industrial training” and (d) "immersive" with "industrial training". This literature search was done to illustrate the interest of immersive industrial training in the past ten years, which constitutes more than 10% of the number of publications on industrial training. Regarding VR industrial training as it was steadily rising throughout the years until 2017 where there was a jump in the amount of publications then a continuation afterwards. Considering AR industrial training had an upward increase throughout the years until 2017 then another increase into 2018. Considering MR industrial training was on a steady increase through the years then it had a slight increase in 2017, then corrected to the norm afterwards. The sudden increase in publication numbers in 2017 might be attributed to the release of devices like the Hololens, and the start of a race of creating more affordable or more use-case centric MR solutions that lead to more research. The decline might be attributed to the fact that a lot of companies wait several years to publish the results of their successful products to prevent the copying and reverse engineering of their products or devices.

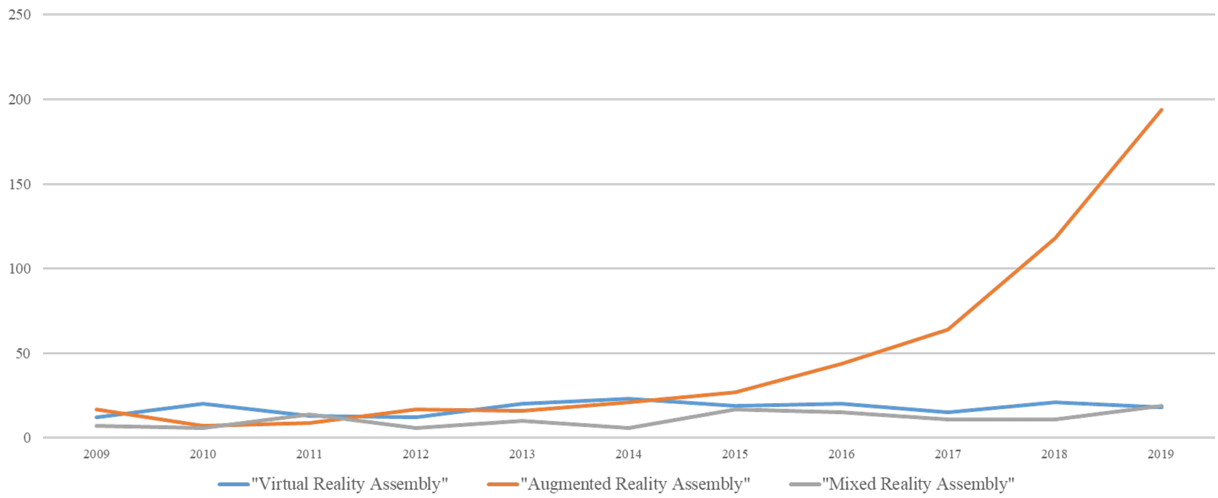

Figure 2.7 XR Assembly amount of published papers from 2000 up-to 2019

The amount of published papers covering both terms of XR and assembly is growing; as shown in the Fig (2.7). The number of AR assembly is exponentially growing, and the number of VR or MR assembly is on a pretty linear trend. The number of AR assembly is more than 11 times the amount of VR assembly or MR assembly published papers. This shows that there is an exponential increase of studies in AR assembly. This rise in AR assembly could be attributed to the digitalization movement and the introduction of Industry 4.0 systems that are being pushed everywhere in the world.

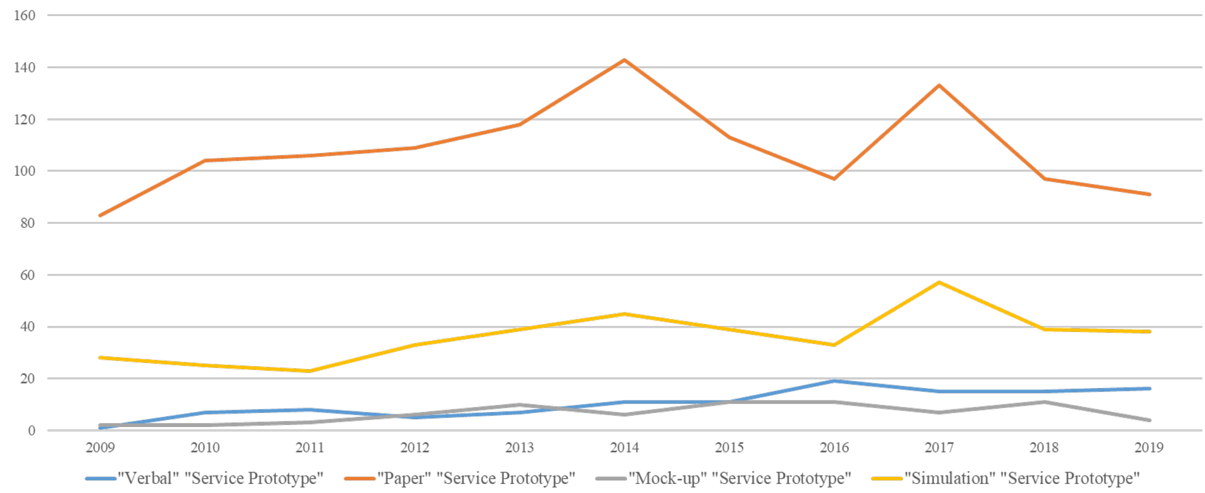

Figure 2.8 Conventional Service Prototypes amount of publication in the past 10 years

As shown in Fig. (2.8), the amount of publication on Conventional SP (CSP) are represented in these prototype forms, namely: (a) "verbal", (b) "paper", (c) "mockup", and (d) "simulation"; each of them is then combined with the term "service prototype". For example, if we prototype an instructional manual with conventional service prototype forms, it could be a "verbal prototype" (instruction guide), or a "paper prototype", or a "mock-up prototype", or even a "simulation prototype". Many scholars have already studied conventional form of service prototypes. Regarding PSP, which has much higher amount than all the other SP forms as it the most established tool. The amount of publications for all SP forms seems to be static, which might be due to the increase in the research on immersive prototypes. Looking at the immersive service prototypes literature, according to a Google scholar search, it appears that the combined term "immersive service prototyping" or "immersive service prototype" is brand new. The only times it was mentioned before was in our prior publications (Abdel Razek et al. 2017, 2018, 2019).

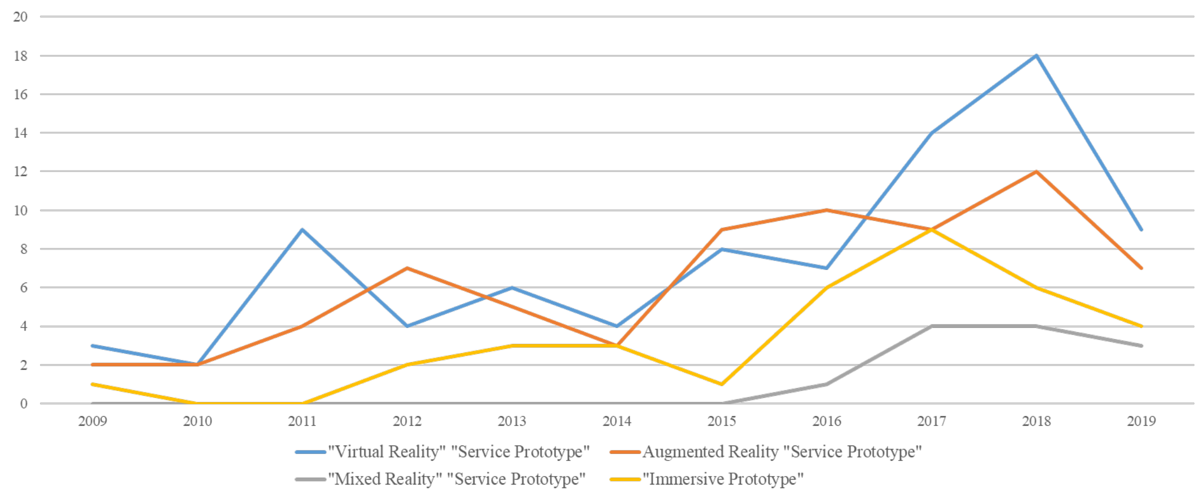

Figure 2.9 Immersive Service Prototype amount of publication from 2009 up-to 2019

The amount of publication in the past 10 years regarding Immersive SPs is shown in Fig. (2.9). ISP can be summarized in four searches; (1) “virtual reality”, (2) “augmented reality”, (3) “mixed reality” that are combined with “service prototype” and then, (4) “immersive prototype”. As observed there is an overall upward trajectory in discussing immersive technologies application in service prototyping. This resurgence might be attribute to the introduction of new affordable immersive technologies equipment, like HMDs, AR glasses, and MR devices. The level in innovation in software, programming and coding could be also a factor in that resurgence. The figure shows that this is under-researched novel topic, which needs more research and investigation to increase the knowledge base and to clarify its aspects. Research conducted on VR service prototypes was more than that of the other XR technologies, this might be due to the fact that VR is the most established of the three, and also the first one to be created and utilized.

VRSP publication was on a steady rise until 2018 then saw a decline. This could be due to papers that were not published yet in 2019. Regarding ARSP there is an unsteady progress, but it is showing a positive progress throughout the years. This progress might be attributed to the increase of mainstream applications like Pokémon Go AR app that increased research interest and the mass acceptance and adoption. MRSP was actually non-existent until 2016 afterwards it was on a steady progress upwards. This steady progress might be attributed to the release of MR devices like Microsoft ‘s Hololens, which was released in 2016. Considering immersive prototype research, which has a similar trend to that of ARSP except that in 2017 it declined, this might be due to the divergent of the research to MR or XR. The overall decline, observed in 2019 might be due to different reasons such as late publication date, NDAs, or several other unknown factors. The term CSP is novel and not used in the literature.

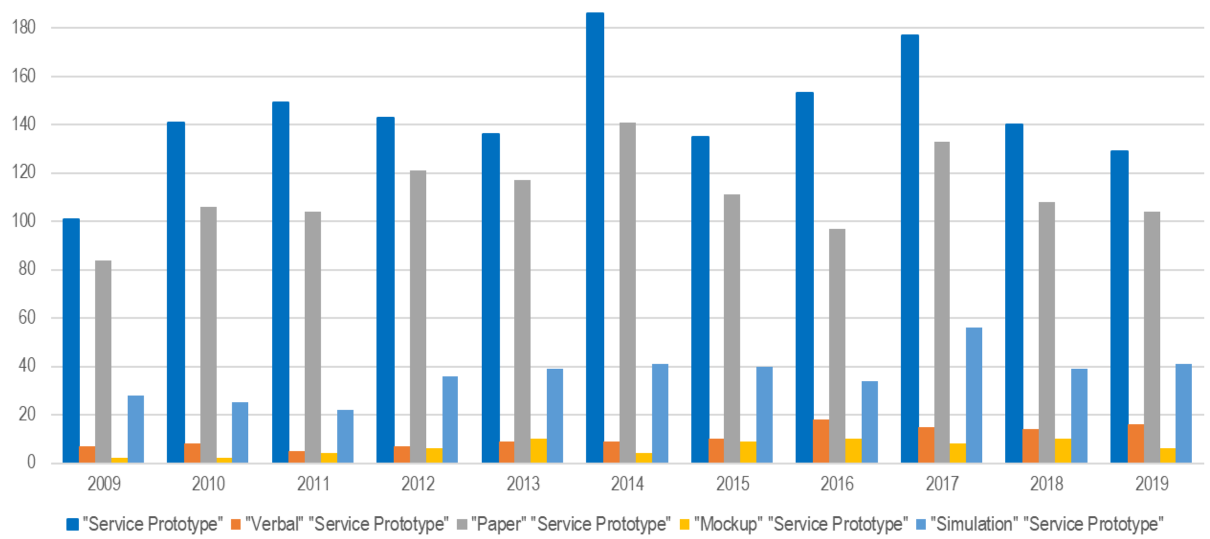

Figure 2.10 Service Prototype and different forms of Service Prototype amount of publication from 2009 up-to 2019

As presented in Fig. (2.10), paper SP has the highest amount of publication in comparison to the other SP forms. While the number of publications concerning simulation SP is about 30% that of the paper SP, while verbal and mock-up SPs publications numbers were pretty low. The graphs show that paper SP research is the most research and used conventional service prototyping form.

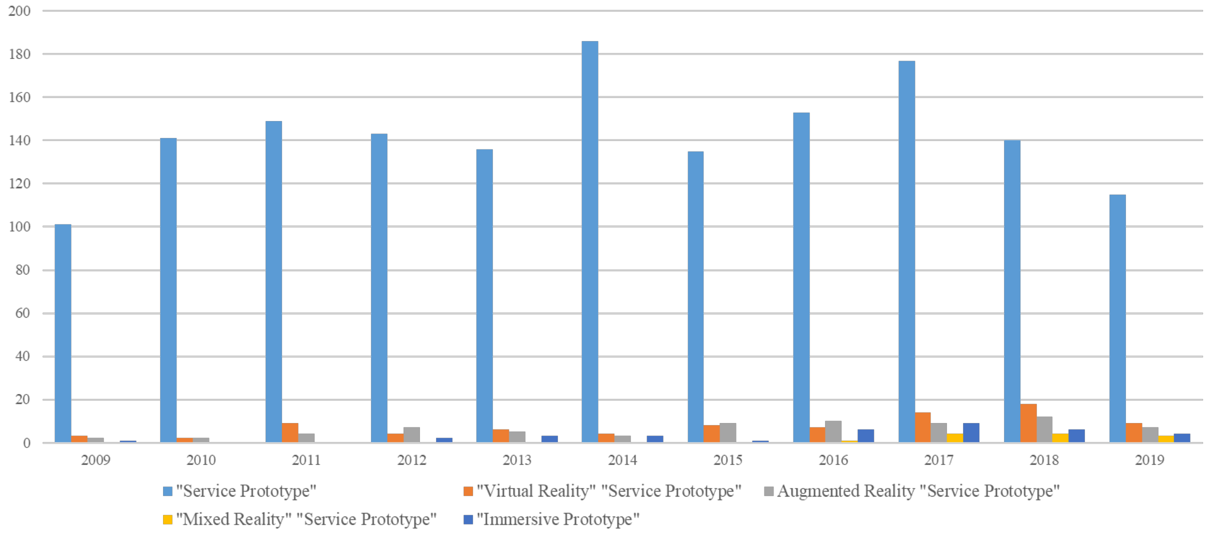

Figure 2.11 Service Prototype and Immersive Service Prototype amount of publication from 2009 up-to 2019

Fig. (2.11) illustrates the amount of publication papers of SP research compared to the ISP research. The immersive service prototypes that were selected were the extended reality (VR, AR, MR). Comparing Figure 2.10 and 2.11 shows that CSP forms have much higher number of publications than ISP forms. This shows that there is significant difference between the research done on CSP and ISP. The amount of the publications that were found by using the term "service prototype" were much higher than all the ISP literature. In 2019, ISP publications formed 25% of the total number of SP found literature. The interest in ISP is growing yearly, as in 2009 it only represented 6%, which compared to the current 25% ratio in 2019 showing increased interest in research and a steady growth in the amount of publications.

2.2. Service

Service is a broad term that might be interpreted from getting a meal in a restaurant to maintenance or training. The selected industrial service sector relevant for this study is restricted to the industrial manufacturing service sector. As such there was also a literature review done to extract the most relevant definitions of service in that sector. In ISO (2015) service is defined as "*the means or methods that organizations use to deliver, usually intangible although they may also include tangible elements, results that customers value and wish to achieve*". Shostack (1977) was one of the first to describe a service by characterizing it into four elements (IHIP) *Intangibility*, *Heterogeneity*, *Inseparability*, and *Perishability*. Bitner (1992) coined the term "*Servicescape*" by compounding three dimensions of the service physical environment. Sakao and Shimomura (2007) defined a service as an activity of a provider and a customer to change the state to the desired level by means of artifacts. Several researchers characterized a service by using three elements, Andrade (2001) with objects, procedures, and people, Brezet et al. (2001) with device, infrastructure, and user practice, Bullinger et al. (2003) with the structure, process, and outcome dimensions, Edvardsson et al. (2015) with activities, interactions, and solutions, Papazoglou et al. (2006) with coupling, cohesion, and granularity, lastly Calieri and Pezzotta (2012) with entities, life-cycle, and actors. Several other researchers define a service by four dimensions, Grönroos (2000) with processes, activities, resources, and customer, Tomiyama (2001) with artifacts, provider, receiver, and environment, Shimomura and Tomiyama (2005) with provider, receiver, contents, and channel, and lastly Lusch and Vargo (2006) with competences, deeds, processes, and performance.

Table 2.1 Service Existing Definitions

Service Definitions	**References**
Characterized a service with four elements: "*intangibility, heterogeneity, inseparability, and perishability*"	Shostack 1977
Characterized "*Servicescape*" by three compound dimensions of the service physical surroundings: *"ambient conditions, spatial layout and functionality, signs, symbols, and artifacts"*	Bitner 1992
Characterized service into four elements: "*processes, activities, resources, and customers*"	Grönroos 2000
Characterized service into three elements: "*objects, procedures, and people*"	Andrade 2001
Characterized service by three elements: *"device, infrastructure, and user practice"*	Brezet et al. 2001
Characterized a service by defining four aspects: "*artifacts, service provider, service receiver, and environment*" within a service framework	Tomiyama 2001
Characterized service into three dimensions: "*structure dimension, process dimension, and outcome dimension*"	Bullinger et. al 2003
Characterizes services with three core dimensions: "*activities, interactions, and solutions*"	Edvardsson et al. 2005
Characterizes a service within a framework with four elements: "*provider, receiver, contents, and channel*"	Shimomura and Tomiyama 2005
Characterized a service with four dimensions: "*competences, deeds, processes, and performance*"	Lusch and Vargo 2006
Characterized a service along these dimensions in the context of service-oriented design: "*coupling, cohesion, and granularity*"	Papazoglou et al. 2006
Service can be defined as an activity that provider offers customers to change from an existing state to the new desired state by means of artifacts	Sakao and Shimomura 2007
Characterizing a service by using the anatomy of prototypes as the two dimensions: "*metaphor of filter and manifestation of design ideas*"	Lim et al 2008
Characterizing a service in context of product-service systems: *"real or abstract entities, life-cycle, and actors"*	Cavalieri and Pezzotta 2012
Characterized a service as an organizational process to add value to their customers	Patrício et al. 2018

Tab. (2.1) lists the most relevant definitions of service from previous publications. According to Teixeira et al. (2012), the focus of service innovation should be on the customer and the co-created value. Patricio et al. (2018) concluded that service is a process that organizations use to deliver, intangible and tangible elements, resulting in customers' added value. According to Simo et al. (2012) any companies flop after introducing new services, due to their complexity and intangible nature, prototyping then supports the involvement stakeholders in the service development. This might be due to the lack of use of new technologies, like immersive technologies. To determine the best possible technological solution in for added value in services; immersive technologies were selected as it satisfies those requirements for a more comprehensive representational solution for service prototyping. All the definitions that used in the dissertation are displayed in Tab. (2.15) and are based on the definitions found the literature as presented in the following subsections.

2.3. Immersion and XR

Oxford dictionary defines immersion as "*deep mental and social involvement in something*". Witmer and Singer (1998) describe it as a subjective experience within an interactive environment. Slater (2003) simply explains immersion as the degree of technology delivery in all sensory modalities and tracking capabilities to their equivalent in the real world. McMahan (2003) adds that immersion results from the user's cognitive captivation in the virtual world, while Brown and Cairns (2004) add that total immersion means a total loss of awareness of the real world. Jennett et al. (2008) clarifies that the involvement in the task, which causes a lack of attentiveness for time and space as well as of a sense of being in the task environment. There is a huge potential for immersive technologies in the digitalization age, especially in the services sector. According to Pallot et al. (2013a) the immersion concept can take physical, cognitive or collective form according to the purpose and feature. Immersive prototyping is an innovative prototyping process that utilizes technologies to immerse the stakeholders for a specific purpose. Conferring to Dupont et al. (2016) where it immersion is considered as the perception of being physically there while in immersive reality providing the ability to interact and communicate with immersive environments, where one or more of the five senses are engaged.. Moreira et al. (2013) explained that immersive prototyping requires an accurate configuration of targeted immersive environment as such that it is both technically and functionally similar to the real one, with strong focus on specific stakeholders' needs and objectives.

According to Pallot et al. (2013a) immersive technology forms vary from VR, AR, and MR. Dupont et al. (2016) add that these immersive technologies could be utilized to fool the eyesight, hearing and haptic; where a total immersion is when the five senses are observing the immersive reality as actual including the natural intuitive interactions. Barnes (2017) explains that by moving around or using an immersive device equipped with the sensors and trackers to gather information to be able to alter and adjust the immersion. Cummings and Bailenson (2015) state that immersive technologies are becoming more affordable. Sutherland (1968) was the first to define a graphics-driven Head Mounted Display (HMD), as his idea was to combine it with tracking devices. information. Rolland and Hua (2005) distinguished HMDs by their user perspective, either by being monocular, bicular, or binocular. Powerwall is considered as a large high resolution display screen, so users can move, navigate and view freely an immersive environment (Ball et al. 2007). The first powerwall was built in 1994 in the University of Minnesota, USA. The first Cave Automatic Virtual Environment (CAVE), which is typically a spatial display within a larger space, was invented (Cruz-Neira et al., 2012). Cruz-Neira et al. (2012) established the distinction between passive immersion, as a user is seated and having a 360° scene and wearing a HMD and active immersion, where the user is freely moving in 360° in a scene in a CAVE. Fast-Berglund et al. (2018) defines eXtended Reality (XR) as a term that contains all real-and-virtual combined environments, including user interactions with wearables like VR, AR, and MR.

According to Thon (2008) the idea of attention alteration is vital to the concept of immersion. Lombard et al. (2009) states that immersion is understood as a user's mental state when they are involved, or engaged. Nechvatal (2009) suggests that the more the technology is pushed forward the more the immersive the experience will be better. Per Pallot et al. (2013), an immersive platform is an assembly of both hardware and software with a specific 3D content application, where VR, AR and MR technologies are established as different immersive platforms. Immersion is the main concept that is responsible for the added value of immersive technologies. Nordin et al. (2014) describes immersion as "*real-world dissociation*". Agarwal et al. (2019) defines immersion as the state of deep mental engrossment, usually experiencing awareness and surrounding. Pallot and Richir (2016) defined "*immersiveness*" as "*the state of being deeply engaged, recognized as a tactical and sensory-motoric immersion; or fully absorbed in solving a problem, seen as a strategic and cognitive immersion; or reading a captivating story or watching an exciting movie, considered as a narrative or emotional immersion*". Immersion concept can take physical, mental or social form depending on the purpose and attributes (Pallot et al. 2013). Conferring to Pallot and Richir (2016) on existing immersive platforms used in various applications address senses by immersing one or more of the five human senses, this is represented in form of an immersive User eXperience (Pallot and Richir, 2016, Dupont et al., 2017, Pallot et al., 2017). Pallot et al. (2016; 2017) and Dupont et al. (2016; 2017) also add that immersive technologies are used to fool the human senses; whereas total immersion constitutes the five senses to perceive the immersive reality as real, while allowing natural intuitive interactions.

Table 2.2 Immersion Existing Definitions

Immersion Definition	**References**
"*Deep mental and social involvement in something*"	Oxford dictionary
Subjective experience of being enveloped in an interactive environment	Witmer and Singer 1998
"*The more the system delivers displays and tracking that preserves fidelity in relation to their equivalent real-world sensory modalities, the more that it is immersive*"	Slater 2003
"*Immersion means the player is caught up in the world of the game's story" "results from the user's mental absorption in the world*"	McMahan 2003
"*Total immersion results in a loss of awareness of the physical world*"	Brown and Cairns 2004

"*An overpowering of the sensory information, from the real environment through large screens and powerful sounds to focus the user entirely on the stimulus*"	Ermi and Mäyrä 2005
"*The involvement in the play, which causes lack of awareness of time and of the real world, as well as a sense of "being" in the task environment*"	Jennett et al. 2008
"*Is understood as a user's psychological state when they are involved, absorbed, engaged, or engrossed*"	Lombard et al. 2009
"*Real world dissociation measures the sense of time, awareness of surroundings and mental responsiveness*"	Jennett 2009
"*Immersion means the extent to which high fidelity physical inputs are provided to the different sensory modalities in order to create strong illusions of reality in each*"	Mandal 2013
"*Immersion is real-world dissociation*"	Nordin et al. 2014
"*The state of being deeply engaged, recognized as a tactical/sensory-motoric immersion; or fully absorbed in solving a problem, seen as a strategic/cognitive immersion; or reading a captivating story or watching an exciting movie, considered as a narrative or emotional immersion*"	Pallot and Richir 2016
"*The sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus*"	Murray 2017
"*Immersion is a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive processes cause a shift in their attentional state such that one may experience dissociation from the awareness of the physical world*"	Agarwal et al. 2019

The most relevant definitions and characterizations of immersion are presented.in Tab. (2.2). Bjork and Holopainen (2004) suggest that there are four experience categories of immersion, namely the sensory-motoric, cognitive, emotional and spatial experiences. There are several other important immersion factors like presence which is mentioned by Slater (2003) as "*the psychological sense of being in a virtual environment*", which is also the extent of each user's cognitive and perceptual systems are tricked into believing they are somewhere else as mentioned by Weiber et al. (2010). Csikszentmihalyi (1990) characterizes flow as an important immersion factor, which is considered the user's physiological state when they are involved in action where nothing else seem to matter. Nordin et al. (2013; 2014) mentioned that concepts such as real world dissociation, fun, flow, presence and immersion have been widely used to describe the digital games user's experience. Pallot et al. (2013) describes the flow as the totally engaged user's feelings while attaining perception of enjoyment and control. Eynard et al. (2015) adds that he time of usage, and the willingness to re-use can be considered as a good indicator of the experience degree of enjoyment. Dupont et al. (2017) adds that a good way to measure the user's engagement degree; is by observing whether their sense of time is distorted and whether external surroundings cease to exist for the user.

2.3.1. Immersion and Cybersickness

Many researchers theorize that the immersive experience be contingent to the user engagement degree (Agarwal and Karahanna, 2000; Brown and Cairns, 2004). Pallot et al. (2013) suggests that an immersive experience hinges on the degree of the user's immersion and presence, engagement and enjoyment. Jannett (2009) suggests that Real World Dissociation (RWD) measures the sense of time, awareness of surroundings and mental responsiveness, and Nordin et al. (2014) proposed that immersion is RWD, while Dupont et al. (2017) add that the three RWD properties depend on the extent to which one or more persons are absorbed by a common task. Pallot et al. (2013) argue that it depends on the feeling when equipment, time and surrounding disappear from the user's mind. Dupont et al. (2016) suggest that immersive technologies usually fool three senses through visual, auditory and tactile channels. There are demonstrated benefits in using immersive services prototypes, like exploring and learning with a VR prototype, which is learning by doing without any risk (Pallot and Richir, 2015). Krueger (2011) and Rizzo et al. (2015) have demonstrated that Immersive Virtual Environment (IVE) can be utilized for therapy or other post-traumatic rehabilitation. Cummings and Bailenson (2015) claim that the higher the quality of immersion, the higher the sense of presence in the IVE. According to Wirth et al. (2007) and Cummings and Bailenson (2015), presence comprises of user sense of self-location and interaction potential with the IVE. However, there are also drawbacks to using immersive virtual environments; according to Lawson (2014), it can induce motion sickness, vertigo, dizziness, visual tiredness and nausea. According to Pallot and Richir (2015), the three key challenges for realizing IVEs are: (a) improving immersion quality; (b) increasing easiness of immersion creation; (c) reducing the risk of the forms of sickness in immersive environments. Furthermore, when using HMDs instead of a costly power-wall or CAVE, the resulting immersive experience and side effects might not necessarily be the same due to the blindness of the physical environment (Pallot and Richir, 2015). Dupont et al. (2016) mentions that full immersion occurs when the five human senses observe the computer-generated reality as physical reality.

Davis et al. (2012) mention that cybersickness, motion sickness, and simulator sickness have comparable indicators; however, they are instigated by different experiences. Kennedy et al. (1993) argue that there is an association between cybersickness, motion sickness, and simulator sickness in their primary physiological causes and symptoms forms, which might seem to be related yet dissimilar. Stanney et al. (1997) described the difference between cybersickness and simulator sickness, where cybersickness is described as a constellation of indications of uneasiness and sickness induced after a VR experience. LaViola (2000) suggests that cybersickness can result in multiple symptoms, such as: nausea, disorientation, headaches, and eyestrain. Cobb et al (1999) added that 80% of participants that experienced a VR system had some form of cybersickness in the first ten minutes. Chen et al. (2011) suggest that the likelihood of cybersickness in VR systems are around 30%, while Kim et al. (2005) argue that it could be over 80%. Rebenitsch and Owen (2016) mention that while cybersickness has been a recognized issue in VR and AR systems for years, much of the nature of cybersickness as an ailment is still vague. Weech et al. (2019) propose that presence and cybersickness are negatively related. Dennison et al (2016) recommend neurophysiological and non-physiological measures to estimate the change in cybersickness during immersion. Davis et al. (2012) believe that understanding the causes of cybersickness is a necessary step in making virtual environment more useable. According to Richir and Pallot (2017), the main implication of immersion due to the phenomenon of illusion (false 3D) is that it provokes brain and visual tiredness that cause uncomfortable immersive experience.

2.3.2. Virtual Reality

According to the American Heritage Dictionary (2005) "*virtual*" is defined as the "*existing or resulting in essence or effect though not in actual fact, form, or name*", which is "*created, simulated, or carried on by means of a computer or computer network*". VR classically refers to the application and use of interactive computer generated simulations created to allow users with to engage in environments that appear and feel similar to real world objects and events (Sheridan, 1992; Weiss and Jessel, 1998). VR is composed of interactive computer simulations (Sherman and Craig, 2018) capable of three-dimensional replications that have seemingly tangible bodily user interactions (Dioniso et al., 2013). This transfers the sensory information to a user (Abari et al., 2017) to induce a behavior by using artificial sensory stimulation with little or no consciousness of this interfering (LaValle, 2017). The obvious strength of the VR approach is the method it assimilates users with the virtual environment allowing also the manipulation of virtual objects, and the performing of other actions in a manner that tries to immerse the user completely within the virtual environment. The progression in VR technology has provided the motivation for adopting and applying it efficiently in various different industrial applications such as design, modelling, process simulation, manufacturing planning, training, and testing. (Mujber et al., 2019). Ermi and Mäyrä (2007) suggest that the potential of VR in learning is frequently linked with its power to offer users with the immersion and presences feelings. Hwang and Hu (2013) mentioned that the main VR benefit is its utilization as a tool to improve the understanding of intangible or intricate concepts. Narraro-Haro et al. (2016) reported that VR captures the attention in a manner that improves interference outcomes in experimental contexts. In an experimental learning context, VR emotional component is thought to create a greater impact compared to traditional training (Faria et al., 2016).

Schwald and De Laval (2003) advocated that even though AR is a novel technology than VR, it has been considered and used in several service sectors such as, training and maintenance. Grenfell and Warren (2010) added that immersion is frequently quoted as one of the motivations for using virtual reality for learning. Huang et al. (2010) suggest that immersive experience becomes vital to comprehend unknown concepts of the target user. Vince (2004) mentions that designers could design concepts and explore them at a virtual level long before they were created and that the applications are limitless when we reach the desired technological level. As VR is a well-established technology, there are numerous definitions from diverse research domains. As such a definition list was created to display the main VR characterization and definitions as shown in Table (2.3).

Table 2.3 Virtual Reality Existing Definitions

Virtual Reality Definitions	Reference
"*A computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment*"	Online Oxford Dictionary
"*VR is electronic simulations of environments experienced via head-mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations.*"	Coates 1992
"*VR is an alternate world, filled with computer-generated images that respond to human movements*."	Greenbaum 1992
"*Real-time interactive graphics with three-dimensional models, combined with a display technology that gives the user the immersion in the model world and direct manipulation, we call virtual environments*."	Fuchs and Bishop 1992
"*The illusion of participation in a synthetic environment rather than external observation of such an environment. VR relies on a three-dimensional, stereoscopic head-tracker displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience*."	Gigante 1993
"*An immersive, interactive experience generated by a computer*"	Pimentel and Teixeira 1993
"*VR refers to immersive, interactive, multisensory, viewer-centered, three dimensional computer generated environments and the combination of technologies required to build these environments.*"	Cruz-Neira 1993
"*VR lets you navigate and view a world of three dimensions in real time, with six degrees of freedom. In essence, virtual reality is clone of physical reality*."	Steur 1995
"*VR is when the user is effectively immersed in a responsive virtual world. This implies user dynamic control of viewpoint*"	Brooks 1999
"*VR is a closed computer system that consists of a virtual environment, a physical environment, as well as a software and hardware interface, which allows interaction between a human and a computer.*"	Zaho 2002
"*VR offers something new, it does allow the user to reach out and move objects about, as if they existed.*" "*VR is much more than immersive systems working with an HMD*"	Vince 2004
"*A technology to create an environment through the simulation of computer equipment and add real or virtual pictures in the simulated situations to comprehend the situation.*"	Wan et al. 2012
"*VR technologies completely immerse a user inside a synthetic environment and while immersed, the user cannot see the real world around him*."	Kipper and Rampolla 2012
"*VR is popular name for an absorbing, interactive, Computer-mediated experience in which person perceives a synthetic environment by means of special human-computer interface Equipment*."	Mandal 2013
"*VR is computer-generated simulations of three-dimensional objects or environments with seemingly real, direct, or physical user interaction.*"	Dioniso et al. 2013
"*VR is an interactive computer simulation which transfers sensory information to a user who perceives it as substituted or augmented*."	Abari et al. 2017
"*VR is the action to induce a targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference*."	LaValle 2017
" *Medium composed of interactive computer simulations*."	Sherman and Craig 2018
"*Alternate reality technology that is characterized by generating real-time, immersive and interactive multi-sensory experiences situated in, and artificially induced by, a responsive three-dimensional computer-generated virtual environment usually paired with advanced input and output devices*."	Jung 2019

2.3.3. Augmented Reality

Merriam Webster Dictionary defines augmented as the act to make "*greater, larger, or more complete*" (Merriam Webster Dictionary "*augmented*"). Azuma (1997) first defined AR as a variation of VR, where the users view the real environment while synchronously viewing the virtual augmented information seeming to the user as if the virtual and real objects coexisted in the same space. AR was categorized as the technology that enables computer-generated virtual information to be superimposed onto a real-world environment in real time (Azuma 1997; Zhou et al. 2008). Azuma et al. (2001) characterized that AR adds virtual objects in a real environment, interacting in real-time and in three-dimensions. Dubois et al. (2003) added that AR improves the user interactions by providing additional information. Chi-Fu Lin et al. (2014) argued that AR augments the real environment rather than replacing it. Curcio (2016) mentioned that AR increases the volume of information that a user can extract from the environment. A number of potential AR applications have been reconnoitered, such as: visualization, maintenance and repair, and entertainment, and targeting (Azuma 1997). AR can guide users by using virtual objects, lately made mainstream by the Pokémon Go mobile game. The objective of this virtual information is to convey the most relevant information to the user giving a new sense to the surrounding environment. The sense given will depend on the anticipated application, whether for communication, maintenance, game, training, or education (Van Krevelen and Poelman 2010). As AR is a developed emerging technology, which is reflected in the amount of publications compared to VR, and MR. There are numerous definitions from diverse research fields, as such a list of the most relevant definitions was created in Table (2.4).

Table 2.4 Augmented Reality Existing Definitions

Augmented Reality Definitions	**Reference**
"AR refer to overlaying computer-presented material on top of the real world."	Caudell and Mizell 1992
"AR is a variant of virtual reality that uses semi-transparent head-up headsets to superimpose computer-generated images to the actual view of the user."	Rekimoto and Nagato 1995
"AR is a specific example intelligence amplification: using the computer as a tool to make a task easier for a human to perform."	Brooks 1996
"AR supplements the real world by superimposing virtual objects onto it and improving its users' perceptions and interactions between the real environment and the virtual objects."	Azuma 1997
"An AR system should: combine real and virtual objects in a real environment, run interactively and in real-time, and register real and virtual objects with each other."	Azuma et al. 2001
"AR refers to display devices that add 'virtual' information to a user's sensory perception."	Feiner 2002
"AR improves interactions between the user and their real environment by providing additional capabilities or information."	Dubois et al 2003
"AR systems offer precise and intuitive depictions of virtual objects and real environments."	Narzt et al. 2006
"AR is taking digital or computer generated information, whether it is images, audio, video, and touch or haptic sensations and overlaying them over in a real-time environment."	Kipper and Rampolla 2012
"The combination of virtual and real objects in a real environment; a system that aligns/registers virtual and real objects with each other; and that runs interactively in real time."	FitzGerald et al. 2013
"AR allows the user to see the reality of the environment, as well as the synthesis of virtual objects in the real environment superimposed or contrasted with virtual reality. Therefore, AR augments real environment rather than completely replaces real environment."	Chi-Fu Lin et al. 2014
"AR Smart Glasses are defined as wearable AR devices that are worn like regular glasses and merge virtual information with physical information in a user's view field."	Rauschnabel et al. 2015
"AR increases the amount of information that a human can take from the environment."	Curcio 2016

2.3.4. Mixed Reality

MR is not a well-established technology yet, especially that there is still a division in different definitions used by researchers. The basis for MR is the virtuality continuum formulated by Milgram and Kishino (1994) a concept to describe the immersion range from real environments to virtual environments including all the possible mixed forms. They also state that MR covers the area between the two extremes of reality and virtuality by merging the real with virtual worlds. In this current age, the technological advancement in MR is increasing, as such a simple classification that was presented by Milgram and Colquhoun (1999) is no longer adequate. It is necessary to include finer divisions of the different MR (Schnabel et al. 2007). Schnabel (2009) defines a mixed environment as the intersection of real and virtual environments where physical and digital elements co-exist, and interact and amalgamate. Schnabel (2009) also explains that MR integrates digital information seamlessly in the user's environment allowing the user to interact with these digital objects and information while presenting it together in a single experience unlocking new boundaries of engagement in collaboration. Dunleavy and Dede (2013) clarified that MR interfaces combine real and virtual environments to enable mental immersion in an environment that combines physical artefacts and digital information. Schart and Tschanz (2017) described MR as the hybrid or merged reality, lying between VR and AR, where virtual objects expand the environment as if they were one recognizing the surroundings and displaying digital objects in the area. The effectiveness of MR as a tools for training, especially in manufacturing and maintenance activities is a continuing debate including experts from different fields to attempt to define a mutual framework for designing and assessing MR tools for the industrial applications. On the other hand, what is apparent from the success of the Microsoft Hololens, and the Hololens II in the market and the numerous applications using MR technologies, especially if looking at the project from the past three Laval Virtual Conference, are increasing every year as industrial acceptance and adoption was apparent. There were several definitions for MR, the most relevant are shown in Tab. (2.5).

Table 2.5 Mixed Reality Existing Definitions

Mixed Reality Definitions	Reference
"MR refers to the merging of real and virtual worlds to create new environments and visualizations, where physical and digital objects co-exist and interact in real time."	Milgram and Kishino 1994
"In treating immersive technologies as occurring along a continuum, where there is no clear distinction between 'augmented reality (AR)' and 'augmented virtuality (AV)', but instead having a continuum with AR closer to the real world and AV closer to a virtual environment."	Milgram and Colquhoun 1999
"The intersection of real and virtual environments is defined as a Mixed Environment (ME), within which physical and digital elements co-exist, and interact and intermingle in a more expansive form."	Schnabel 2009
"MR interfaces combine real and virtual environments to enable mental immersion in an environment that combines physical artefacts and digital information."	Dunleavy and Dede 2013

"MR is a type of hybrid system that involves both physical and virtual elements. Many experts describe mixed reality as the sliding scale between a fully physical environment with no virtual elements, and a completely virtual environment."	Technopedia Web Dictionary
"MR is the result of blending the physical world with the digital world. Mixed reality is the next evolution in human, computer, and environment interaction and unlocks possibilities that before now were restricted to our imaginations."	Microsoft's Definition of MR

2.4. Prototyping

The word "*prototype*" originated from the French word "*prototype*" from circa 1600, which directly comes from the medieval Latin word "*prototypus*", meaning original or primitive, which also comes from Greek "*prototypon*", meaning the first form (Online Etymology Dictionary). The word was first used in the English language from 1590s as "*prototypon*" (Online Etymology Dictionary). Prototyping is a common process before having a market ready product especially for products, like cars or hardware. Prototyping is a well-established process that is utilized in various industries (Doke, 1990). According to Budde et al. (1992) "*Prototyping is not a game, nevertheless a systematic technique for directly translating ideas, drafts and concepts into software, and for their simulation and utilization in the system development process*". There are several forms of prototyping; ranging from simple paper prototypes (Snyder, 2003) to complex immersive prototypes (Kim et al., 2008). Booth and Kurpis (1993) referred to prototyping as the "*use of representations*", while Blomkvist and Holmlid (2010) state that prototyping is the "*use of prototypes to explore, evaluate or communicate in design*". According to Ries (2011) prototyping allows for an accelerated learning effect through the increased speed of implementation in contrast to lengthy analysis and development cycles. According to Brown (2008) the objective of prototyping is to learn about an idea's advantages and disadvantages and to recognize next steps in the development process. Rhinow et al. (2012) identifies three main roles for product prototypes, exploration, evaluation, and communication. Blomkvist and Holmlid (2011) suggest also that service prototypes can be used for exploration, evaluation and communication. Sämann et al. (2016) identified three purposes for using prototyping in service development comprising of (1) monetary requirements, (2) non-monetary requirements, and (3) technical implementation. Diefenbach et al. (2019) identified barriers to using prototyping in product development to its full potential, including; (1) organizational integration, (2) business impact, (3) tools, and (4) skills and knowledge.

2.4.1. Service Prototyping

Conventionally a service designer starts the development process with an initial ideas brainstorming although there are always indefinite aspects of a new design, particularly if it is connected some new technology or in a Product-Service-System (PSS). Service are considered to be challenging to test as they are intangible, often the only way to see if a concept actually works is to create a prototype of it and try it out. Still there is neither collective nor a scientifically proven system for service prototyping development. Hippel (1989) was the first to mention the term "*service prototyping*" in the publication "*Shifting product and service prototyping to users: an innovation process advantage?*". Although service prototyping has different definitions from diverse perspectives, the key is to study the characteristics and functions of the service to be developed and to refine its prototype until the desired concept reached. Beyer and Kochen (2013) describe service prototyping as to be a variety of approaches and activities due to the complexity nature of services. Miettinen (2009) characterized service prototyping with three aspects, the environment, process, and meaning, while Blomkvist and Holmlid (2011) characterized the service prototyping framework with seven aspects, the process position, purpose, audience, fidelity, techniques, validity, and author. Blomkvist (2014) describes it as use of prototypes to explore, evaluate or communicate in design.

Table 2.6 Service Prototyping Existing Definitions

Service Prototyping Definitions	References
Characterized service prototyping as: real-life environment, process, and meaning	Miettinen 2009
Characterized a service prototyping as a framework consisting of: position in process, purpose, audience, fidelity, technique, validity, and author.	Blomkvist and Holmlid 2011
Service prototyping cannot be said to be one thing but rather a variety of approaches and activities, because of the complex character of services	Beyer and Kochan 2013
"*Service prototyping is described as a type of development for exploration, evaluation and communication*"	Blomkvist 2014
An iterative process that uses representations of a complete service or parts of it, before it really exists, in order to allow stakeholders, especially users, exploring, evaluating and communicating a service idea	van Husen et al. 2016

The most relevant definitions and characterizations of service prototyping in the literature are shown in Tab. (2.6). The published papers of Blomkvist were a major inspiration to our research in service prototyping, and we used his research as starting point for our study on service prototyping and prototypes. According to Blomkvist (2014) service prototyping is being embraced and applied by more researchers, service stakeholders like designers and managers in more industries. Blomkvist and Holmlid (2011) added that service prototyping process includes the service stakeholders in the service development process. This inclusion enables defining a service prototyping framework (Passera et al., 2012) that enables utilizing service prototyping for exploring, evaluating and communicating service ideas co-creatively (Blomkvist, 2014; van Husen et al., 2016). There are several limitations in the previous conventional service prototyping approaches found in the literature. Some of the approaches focus on the service development process, while other approaches display certain aspects of a service; yet most, neglect to integrate the experience of all design dimensions. Some of the proposed approaches were more sectors specific; other methods have singular approaches that can neither be adjusted to the complex nature of service, nor for integrating a service prototyping experience. Some of the SP approaches found in the literature only emphasized on physical artifacts, making it challenging to differentiate from product prototyping. Additionally, other SP approaches created prototypes in the later stages of development, which means that if they want to make major changes they would have wasted resources as it is more useful to create prototypes at the earlier stages of the development.

Most of the definitions are somewhat lacking as most represent a static mono-dimensional version of service prototyping, where the focus is only on physical artifacts and relatively unspecific future situations leading to an abstract reflection on the developed service. Then to be able to create an inclusive service prototyping definition that is more dimensional and broad, we needed to consider other prototyping definitions from previous publications. Service prototyping is described as a type of development (Blomkvist, 2014) or a use of representations (Booth and Kurpis, 1993) or a representation of parts or a whole system (Coughlan et al. 2007) characterized by four dimensions (van Husen et al., 2016); and that a prototype should make a service evident (Beaudouin-Lafon and Mackay, 2007) and not an abstract nor a verbal description that needs further explanations (Coughlan et al., 2007); yet, including a concrete (Booth and Kurpis, 1993), tangible and experiential demonstration before the final service exists (Balzert, 1989; Blomkvist and Holmlid, 2010).

2.4.2. Service Prototype

Mogensen (1994) adds that prototypes are aimed towards the future in the sense that they suggest what the future could be like. Gedenyrd (1998) referred to these aforementioned futures as future service situations. However, the first mention of the term "*service prototype*" (SP) was from Schon and Helferich in 1989. Service prototypes have been characterized and defined by several authors: two of them characterized a SP with four main dimensions; Houde and Hill (1997) characterized it as the look, feel, role, and implementation; Beaudouin-Lafon and Mackay (2007) characterized it with representation, precision, interactivity, and evolution. Diana et al. (2009) characterized a SP with three elements: place, situation and condition. Blomkvist and Holmlid (2010) defines it as "*Any shared physical manifestation externalizing an otherwise internal or unavailable vision of a future situation*". The most recent and multidimensional characterization of a SP was from van Husen et al. (2016), which characterizes a SP with four design dimensions: *actors*, *artefacts*, *processes*, and *environment*.

Table 2.7 Service Prototype Existing Definitions

Service Prototype Definitions	References
Characterized a service prototype with four main dimensions: look, feel, role, and implementation	Houde and Hill 1997
Characterized service prototypes with four dimensions: representation, precision, interactivity, and evolution	Beaudouin-Lafon and Mackay 2007
A prototype ought to make a service not an abstract or only a verbal description that requires further clarifications	Coughlan et al. 2007
Characterized service prototypes with three dimensions: place, situation, and condition	Diana et al. 2009

"A prototype ought to make a service visible"	Beaudouin-Lafon and Mackay 2009
"Any shared physical manifestation externalizing an otherwise internal or unavailable vision of a future situation."	Blomkvist and Holmlid 2010
Characterizes a service prototype with four design dimension: *actors*, *artifacts*, *processes*, and *environment*	Van Husen et al. 2016

The relevant SP characterizations and definition found in the literature are shown in Tab. (2.7). Some researchers tried to categorize and differentiate prototyping techniques with prototype's fidelity level (McCrudy et al., 2006); however, it is lacking an all-inclusive outlook because it only focuses on one attribute of a prototype. It might be also problematic to divide service prototypes into vertical and horizontal prototypes (Floyd, 1984) or even by categorizing prototypes into horizontal, vertical, task-oriented, and scenario-based service prototypes (Beaudouin-Lafon and Mackay, 2003), which might not be sufficient to evaluate due to the diverse kind of generated feedback (Blomkvist and Holmlid, 2011). Most of the service prototyping publications found in the literature address prototyping techniques for systems, products, products service systems or software. The use of prototyping in services is relatively new, and the understanding of which SP form to use is not well addressed in the literature. There is a lack of knowledge in the ability to select the most appropriate service prototyping form for each prototyping purpose and for each specific service process to reach the desired objective. A list of SP attributes are shown in Tab. (2.8) with their definition or characterization from the literature.

Table 2.8 Service Prototype Attributes (Abdel Razek et al. 2018a)

Attribute	Definition	Reference
Fidelity	Level of detail and functionality built into a service prototype	Rudd et al. 1996; Beaudouin-Lafon and Mackay 2003
Resolution	Degree of resemblance of the service prototype to the final service design	Blomkvist and Holmlid 2011; Passera et al. 2012
Effort	Organizational resources that are being used or needed to complete a service prototype	Abdel Razek et al. 2017
Interactivity	Degree to which the user can interact with the prototype	Beaudouin-Lafon and Mackay 2003
User Experience	Perceptions and responses from the use or anticipated use of a service prototype	ISO 9241-210 2009
Usage	Defines the conventional life cycle of a service prototype	Beaudouin-Lafon and Mackay 2003
Communication	Transferring information and knowledge	Preim and Dachselt 2015
Feedback	Generating reliable and detailed stakeholder's ideas from using a service prototype to optimize it	Blomkvist 2014
Visualization	Transforming intangible service ideas and concepts into a live static visible service prototype	Blomkvist and Holmlid 2011; Moritz 2005
Simulation	Transforming complex intangible service designs into a simulated interactive service prototype	Floyd 1984; Blomkvist and Holmlid 2011

These definitions were extracted and refined to be used and to avoid confusion with other contradicting definitions from the literature, as these definitions are most relevant to this dissertation with reference to the researchers that offered that definition or partial definition. Service prototypes should be constructed according to their purposes, activities and tasks, as depending on what the objective of service is, the service prototypes will look different. Prototypes are intended for a specific prototyping activity and task, which can be then linked to their matching service prototyping purpose.

Table 2.9 Service Prototyping Purpose, Activity, and Objective (Abdel Razek et al., 2018a)

SP Purpose	SP Activity	Description	References
Explore	Experimenting	Done when there is no current information, knowledge, and experience to collect Idea	Passera et al. 2012
Evaluate	Testing	Done when aspects of the functionality is known, and to analyse these aspects' quality for decision making	Ganz and Meiren 2010, Miettinen et al. 2012
	Demonstrating	Done when there is doubt about viability, where can be demonstrated with evidence, can be used as a feasibility analysis	Blomkvist and Holmlid 2011, Jung and Seong 2014
Communicate	Learning	Done where there is information available, but no current knowledge, so more knowledge can be created from the communication of known information for training and learning	Houde and Hill 1996, Buchenau and Suri 2000, Passera et al. 2012
	Interacting	Done when there is no decision made yet, and through exchange between several stakeholders a basis for decision-making can be provided	Blomkvist and Holmlid 2011, Jung and Seong 2014, Zaninelli 2013
	Integrating	Done when there is no overview of the service and to create an inclusive concept for decision making	Blomkvist 2014
	Planning	Done when the time plan is unknown, and by using various prototypes as a step in the timeline diagram it can be used for time management	Moritz 2005

Service prototyping different purposes broken down into seven activities and tasks are represented in Tab. (2.9), which were extracted from the literature, as it was discussed in a previous publication (Abdel Razek et al., 2018a). The purpose is dictating the conditions of how a service prototype is made (Blomkvist and Holmlid, 2011). The three service prototyping purposes are exploration, evaluation, and communication (Blomkvist and Holmlid, 2011). The SP form has to produce a representation sufficient enough for the user to perceive it and react to it; causing feedback which used to improve the process for further iterations until purpose fulfilled. The objective of a SP is to give stakeholders the most comprehensive and rich service experience even before it exists; that produces more observations and better feedback. The SP forms and selection factors were also discussed in one of our previous publications (Abdel Razek et al., 2018a, 2018b). The collected activities from the literature were listed to the corresponding service prototyping purpose; service stakeholders can use this list as a help to better understand service prototyping purposes and activities.

2.4.2.1. Conventional Service Prototypes

We consider conventional service prototypes are the prototyping forms that use conventional methods for representing and displaying the prototype. As the CSP as a keyword were not explicitly mentioned in the literature, a search was done on alternative search terms for the literature review. Stark et al. (2009) developed a smart hybrid prototyping approach, which includes different technologies and tools to create prototypes like VR, AR, MR, mockups, sketches and simulation. Exner et al. (2014) compared prototyping methods according to their fidelity levels, differentiating between physical (i.e. paper, physical mockups, sketches), virtual (simulations, digital mockups, MR), and both (i.e. AR, functional mockup, rapid prototyping). Several researchers attempted to differentiate and categorize service prototyping forms; (a) Rudd et al. (1996) with implementation, (b) Walker et al. (2002) with application, (c) Holmquist (2005) differentiated them into low and high fidelity, (d) Kim et al. (2006) with usability, (e) Blackler (2009) with type of interaction, and (f) Blomkvist and Holmlid (2010) suggests that is a variety of approaches and activities. To make it easier to understand the concept of conventional service prototyping, a classification for the forms was established in our previous publication (Abdel Razek et al., 2018a).

These different SP forms are differentiated by their method of application and representation. The conventional SPs are categorized into four forms, (1) Verbal Service Prototypes (VSP), (2) Paper Service Prototypes (PSP), (3) Mock-Up Service Prototypes (MSP), and (4) Simulation Service Prototypes (SSP). All these keywords that represent CSPs didn't exist in the literature in these forms, still through the literature review we found similar definitions and characterizations that helped in defining these terms in a later sub-section.

2.4.2.1.1. Verbal Service Prototypes

Verbal Service Prototypes (VSP) are based on engaging stakeholders by increasing their understanding of a new service idea verbally, there was no definite definition for VSP found in the literature. Bill Moggridge explains in his keynote speech at the Danish Service Design Symposium "*when you put all these things together, with elements from architecture, physical design, electronic technology from software, how do you actually prototype an idea for a service, and it seems that really, it's about storytelling, it's about narrative*" (Moggridge 2008). The verbal communication is key for stakeholders to understand and give feedback. Blomkvist and Holmlid (2011a) explain that VSP aims to uncover the real add value of storytelling when releasing the needs of stakeholders as well as help them realize new opportunities, this all while deepening provider's understanding of service hotspots. From our understanding of the literature we will consider the VSP definition from our previous publication, as relies on verbal communication to create a cognitive stimulus to engage stakeholders in a narrative or story (Abdel Razek et al., 2018a). VSP could be used with conjunction with other prototyping forms. It could be done as an introductory prototyping process, to start a brainstorming session or to deduce stakeholder's requirements for example. VSP creation requires little effort, nevertheless a skilled narrator is vital to effectively engage and influence stakeholders. The main indicator of success is the stakeholders' engagement, acceptance level, and their amount of feedback.

2.4.2.1.2. Paper Service Prototypes

According to Ehn and Kyng (1992) paper prototyping is considered as one of the most utilized prototyping form in service design, particularly when aiming on involving stakeholders. Brandt and Grunnet (2000) clarify that paper service prototyping makes the stakeholder's involvement in the service development process feasible. Synder (2003) considers Paper Service Prototypes (PSP) as a representative variation of user's usability testing by performing tasks while using paper. Kangas and Kinnuen (2005) suggest that PSP can be used to get key insights on stakeholders' requirements, and identify stakeholders' gains and pains without any technological investment. Paper prototyping emphases on co-creation, by gathering information from stakeholders in form of fuzzy paper mock-ups; where several iterations could be used, to improve the prototype. Paper service prototyping could be used as a preliminary prototyping process when prototyping a service. Paper service prototyping involves little to no effort, and its main success indicator is stakeholders' engagement and the quality of feedback. Paper is a practical prototype form as it is readily available virtually everywhere, and its shelf life is very long if stored properly; on the other hand, it is not the most sustainable material. PSP enables creating a rapid service prototypes by using handwritten notes, and drawings, as it is a skill that virtually every stakeholder masters and can do in a short period of time.

2.4.2.1.3. Mock-Up Service Prototypes

The word "*mockup*" stems from Circa 1915–1920, from the verb mock up by imitation which comes from the French word "*maquette*" which translates roughly in a prototype (Webster's New World College Dictionary "*mockup*"). In an industrial context, a mock-up could be anything from a scale or a regular size depiction to representation of a design, equipment, machine. Mock-ups are also widely accepted as tools for teaching, demonstrating, designing, evaluating, and testing in various industries. Papantoniou et al. (2016) considered a mock-up also as a prototype if it delivers some design functionality for testing. Mock-ups are often used by designers to acquire feedback from stakeholders about design ideas early in the design process. Mockups could be constructed in a physical or a digital form as discussed by Exner et al. (2014). Morris (1992) describes a physical prototype as an early form model used in assessing design, fit, form and performance. Antionino and Zachmann (1998) characterized a digital Mock-up as a realistic computer simulation of a product with the capability of all required functionality covering every process from design, manufacturing, and service. Greasley (2004) adds that mock-ups could be also used to communicate a new service idea. Moritz (2005) explains that rough mock-ups can help stakeholders understand the service idea quickly, while perfect mock-ups help in evaluating and explaining it. Mock-ups can be used to assess the limits and possibilities of service aspects. Fontaine et al. (2009) indicated that a mock-up could communicate the service idea before its creation. According to Miettinen et al. (2012), a mock-up can be realized in using various methods and material, which can be iteratively enhanced to introduce more detailed prototype as the need arises for evaluating more precisely. Blomkvist and Holmlid (2012) add that mock-ups comprise either one physical element or a combination of them that can be made from different materials and by different methods. Physical mock-ups are routinely used for assembly tests (Bernard, 2005).

Digital Mock-ups are usually in the form of images, videos, three-dimensional models, or figures that illustrate or explain an idea (Halskov and Nielsen, 2006). Miettinen et al. (2012) refers to digital mock-ups as concept mock-ups with digital user interface with both physical and digital interactions. The selection of the tech, form, method and material of mock-ups depends on the stakeholder's needs for interactivity, engagement, and conception factors. Mock-ups service prototypes can be intricate and complex (Moritz, 2005), as such there is no commonly used definition for Mock-Up Service Prototypes (MSP) in the literature. MSP improves the comprehension of a service artifact to simulate elements from real service situations. MSP can be used as part of an early service experience for to envision service scenarios and artifacts, or be used as an evaluation prototyping tool, or even to communicate a SP to stakeholders. Mock-ups can be also in form of video or animation that allows the stakeholder to evaluate or communicate the prototype in form of creating one.

2.4.2.1.4. Simulation Service Prototypes

According to the Cambridge Dictionary "*simulation*" means "*a model of a set of problems or events that can be used to teach someone how to do something, or the process of making such a model*" (Cambridge English Dictionary "*simulate*"). Merriam Webster defines it as "*the imitative representation of the functioning of one system or process by means of the functioning of another*" (Merriam Webster Dictionary "*simulate*"). Gaba (1999) describes simulation as a technique that replaces and enhances the real experiences with guided ones replicating a significant aspect of the real world in a fully interactive manner. According to Gladwin and Tumay (1994) simulations can be done for almost all service processes. Conferring to Shostack (1982) whom included that real service scenarios are getting more complex every day, while Smith (1999) added that rarely does a simulation cover all the design dimensions; still, it proposes a quicker, more pragmatic and cost-effective method to evaluate a service system. Leonard and Rayport (1997) explains that physical simulation, with artefacts, might be supportive for stakeholders to test the service beyond their physical limitations, and include that computer-based simulation prototyping can be useful in simulating multi-dimensional service situations. Smith (1999) also clarifies that the process is more than conducting examinations to get a better understanding of the service system, or to evaluate a service design. Eriksson (2005) illuminates that simulations can help in anticipating various service variables reactions at different service stages, coming in many forms ranging from simple paper simulation to computer-generated simulation. Exner et al. (2014) describe a simulation as the design and replication process of a service process.

However, Blomkvist and Holmlid (2012) mention that simulation based prototypes can be mostly useful for fast primary service idea evaluation. According to Lateef (2010) simulation-based learning can be the answer to developing professionals' skills, and attitudes, whilst not taking any unnecessary risks. Then simulation can be considered as a process that can be used to practice, learn and demonstrate that can be implemented in many different fields. The basic initial cost of simulation is relatively low; but, depending on the resolution and fidelity levels; the costs can be considerably higher. Nonetheless, still could be considered a worthwhile investment. Agreeing with Blomkvist and Holmlid (2012) in that simulation of SP is lacking a real-time representation affecting the user experience; often by giving a predetermined reaction to every interaction, contradicting with the random nature of service interactions.

2.4.2.2. Immersive Service Prototypes

Immersive service experience is an expression or describe the state of immersion of stakeholders while in action in an IVE (Sayers et al., 2014); co-creative virtual environments (Ciasullo et al., 2018) or service learning environments (Hullender et al., 2015); or for in the development of students' skills and knowledge (Barton, 2015). Sarkar (2016) also mentions immersive service experience in regards to the aim of internet of things application to provide a real-time interaction. Dupont et al. (2016) explain that immersive devices can come in many shapes and forms, as the Head-Mounted Display (HMD), where stakeholders can be visually immersed, and the addition of tactile and haptic devices can improve the immersive experience. According to Pallot et al. (2013a) the degree of immersion is the key to engage the stakeholders along the design process, depending on the number of stakeholders' fooled senses including how the feeling of time, effort and technology dissolve. Immersive prototyping is a novel research field, and until the writing of this dissertation there were only 46 published papers in total when searching for the term "*immersive prototyping*" on the Google scholar database. This is one of the motivations that derived the search for the definitions and characterizations on that topic, which was done throughout the literature review. This was to set some standard of definitions to be further researched, which could be discussed and even reused by other researchers in the future research. Further characterization of immersive technologies service prototyping applications is needed. This is needed to differentiate between the conventional, and immersive service prototypes, as a book could be immersive even though it is paper based. Conferring with previous published papers from Pallot and Dupont, we could consider immersion in ISP as digital immersion based on the use of immersive technologies, making the degree of immersion considerably higher than the conventional SP forms. To figure out this degree of immersion, the term Immersiveness was used to describe the digital immersion degree of a prototype based on immersive technologies (Pallot et al. 2013).

According to Kohler et al. (2011) immersive technologies could be used to offer stakeholders information and training about the service that will be offered. Services are tangible concepts that need to be experienced to be truly understood. In the context of service prototyping, the potential of innovative representational technologies that allows users to learn, understand and follow instructions when handling an unknown task in a risk free environment, is quite huge. Immersive technologies are said to enable the simulation of various service tasks that require numerous and native interactions. According to the published papers found, organizations are starting to make use of innovative technology in industrial application, especially in prototyping. This might be a critical advantage for every organization for keeping a competitive edge because the level of service is the differentiator in many cases in the industrial service sector. Therefore, any advantage that can be achieved by efficiently and effectively implementing immersive technologies to face the modern challenges confronted in the current industrial service practices is definitely welcomed. ISP is a novel approach to the service sector, which explains why there is a scarcity of published studies.

The published papers explicitly discussing the impacts of immersive service prototyping or, immersive service prototyping experience were found to be lacking, as there is very little information about the topic. Several new conventions and conferences have been created to research immersive technologies, and a large number of facilitators and consultancies are using service prototyping in their initiatives and workshops. Immersive Service Prototypes was not mentioned as a term in the literature before our previous publication (Abdel Razek et al., 2018a) concerning the exploration and definition of immersive service prototypes, so some keywords were chosen to best represent the key terms used. Immersive service prototypes literature was first cited starting from the year 2009, before that there were no publications mentioning the keywords. As such we choose the keywords (a) "virtual reality", (b) "augmented reality", (c) "mixed reality", all three of them combined with "service prototype", and then "immersive prototype" as these keywords might best represent ISP literature. XR service prototyping implementations may seem to be compatible, as SP aims to visualize a tangible idea and turn it into an experience, and immersive technologies (XR) aim to visualize simulations into an experience as well.

2.4.2.2.1. Virtual Reality Service Prototype

As seen from the figures of Virtual Reality based Service Prototypes (VRSP) publication numbers, there is an increase in the number of publication throughout the years. Many researchers used virtual service prototyping process, and used virtual service prototypes. Nevertheless, there is a lack of definition and description about VRSP. Brooks (1999) clarifies that it is VR when the user is successfully engrossed in an interactive virtual environment. Kipper and Rampolla (2012) explained that VR immerses the user completely inside a computer-generated environment. Gowda et al. (1999) added that VR involves using computers and other technologies to create digital prototypes. Song et al. (1999) referred to virtual product prototyping as the simulation of the user and product with their interactions throughout the design stages to analyze the performance of the product; the same could be then interpreted then for services and service interactions. Kohler et al. (2011) explained that VR then could deliver a variety of possibilities to dynamically assimilate users into the service development process, like by co-creative object creation and distribution. Rau et al. (2016) used VR prototypes as a term to differentiate between prototyping forms in a service innovation context, where it is a computer-based environment as users can interact via digital representations of themselves. The main advantage for VR is being able to training of risky tasks without any risk, like sky training (Pallot and Richir, 2015). Jung et al. (2019) concluded that alternative reality technologies are characterized by means of creating an instantaneous, immersive and interactive experience, where the user is in a three-dimensional computer-generated virtual environment.

2.4.2.2.2. Augmented Reality Service Prototype

As seen from the figure of the Augmented Reality based service prototyping published papers, it is not well researched as well. There are many applications that mainly use AR to test the prototypes with stakeholders, or to guide stakeholders through a prototyping process. The literature still lacks definition for Augmented Reality Service Prototype (ARSP), and the characterization of what kind of impacts does AR have on the prototypes and stakeholders. Caudell and Mizell (1992) referred to AR as the overlapping of computer generated information on top of the real world. Narzt et al. (2006) stated that AR systems allow intuitive representations of virtual information in real environment, while permitting natural interactions. Feiner (2002) mentions AR as the ability to display the added virtual information onto a user's cognitive perception.

2.4.2.2.3. Mixed Reality Service Prototype

The Mixed Reality based service prototyping literature is definitely lacking behind the other two immersive forms, but for that reason until 2016 there was hardly any research done in the field. This scarcity of published papers shows that this field is novel, and is definitely lacking the definition, and even in the number of applications and use-cases. MR integrates digital information with the user's environment allowing user interactions (Schnabel, 2009), while combining both environments to mentally immerse the user (Dunleavy and Dede, 2013). MR expands the reality by virtual objects and information, which is displayed on the surrounding area (Schart and Tschanz, 2017).

2.5. Experience

Experience is a broad term that is widely used in research and practice as well. There are abundance of literature discussing experience, its facets, aspects, and definitions. Carbone and Haeckel (1994) defined an experience as the impression formed by stakeholder's encounters with products, and services.

Bergmann (1999) refers to experience as the stored knowledge attained during previous issue resolving. Pine and Gilmore (1999) mentioned that experiences are individual events that affect each in a personal manner, stemming from the individual's previous mental and physical state. Schmitt (2003) explains that experiences result from underlying a situation that triggers the senses, heart and mind. While Collins (2007) argues that experience is the summation of skills and information resulting from participating or observing an activity or event. Berry and Carbone (2007) clarified that an experience can be a positive or a negative experience, depending on the user's impressions, which can be anything that is perceived or sensed. According to Sanders (2008) customers are the true experts in domains of experience such as living, learning, or working and bring them to actively participate in the design decisions. A list of the most relevant experience definitions from the literature is shown in Tab. (2.10).

Table 2.10 Experience Existing Definitions

Experience Definitions	**References**
"*Take-away impression form by people's encounters with products, services, and businesses – a perception produced when humans consolidate sensory information.*"	Carbone and Haeckel 1994
"Experience is specific knowledge that has been acquired by and agent during past problem solving;" therefore "experiences are stored knowledge."	Bergmann 1999
"Experiences are events that engage individuals in a personal way and derive from the individual's prior state of mind and being."	Pine and Gilmore 1999
"Result of encountering, undergoing, or living through situations. They are triggered stimulations to the senses, the heart, and the mind."	Schmitt 2003
"The accumulation of knowledge or skill that results from direct participation in events or activities" and "the content of direct observation or participation in an event."	Collins 2007
"An experience is inherent; a positive experience is not. Customers consciously and unconsciously filter a baggage of clues, in the form of experiences, and organize them into sets of impressions –. Anything perceived or sensed – or conspicuous in its absence – is an experience clue."	Berry and Carbone 2007

The agreed standard definition of UX as the International Standard Organization (ISO FDIS 9241-210): "*User Experience is a person's perceptions and responses that result from the use or anticipated use of a product, system or service*". In a service context, McCrudy (2006) describes UX as the interactions between the service stakeholders and the service, organization, creating a reaction. According to Wu et al. (2009) UX is categorized into two constructs, namely: *Quality of Service* (QoS) and *Quality of Experience* (QoE), they also modeled QoE as multi-dimensional construct of user perceptions and behaviors. Wu et al. (2015) adds that the presence depends on QoS factors, such as: latency, frame-rate or optical calibration. In the case of an immersive experience, Pallot et al. (2013) suggests an extension on Wu's models, to take account of social interaction in immersive environment context. We will consider the UX ISO definition as the standard definition, as such no definition table of UX definitions was created.

The customer experience is a term widely used by researchers, according to Brakus et al. (2009) there is a customer experience for every service exchange. While Pine and Gilmore (1999) describe this experience as a series of memorable events. Grewal et al. (2003) characterize the customer experience in regards to two experiences, price and promotion. Verhoef et al. (2009) define it as a multidimensional construct that illustrates the customers' holistic state in the nature, involving their cognition, affection, emotions, social and physical responses to the provider or seller. As our research encompasses all stakeholders of the service in the prototyping process, we can use the customer experience as a basis for the stakeholder's experience. The relevant definitions of customer experience are listed in Tab. (2.11).

Table 2.11 Customer Experience Existing Definitions

Customer Experience Definitions	**References**
"By 'total experience' we mean the feelings customers take away from their interaction with a firm's goods, services, and 'atmospheric' stimuli."	Haeckel et al. 2003
"A personalized experience is unique to each individual consumer. Co-creation experience takes place in individual-centric experience networks. Linked to learning process and change."	Prahalad and Ramaswamy 2004
"Customer service experience is a holistic, perceived phenomenon that is always subjective, case specific and personal."	Schembri 2006
"The internal and subjective response customers have to any direct or indirect contact with a company" even the *"unplanned encounters with representatives of a company's products, services, or brands" as well as "word-of-mouth recommendations or criticism, advertising, news reports, reviews, and so forth."*	Meyer and Schwager 2007
"An experience is also built up through a collection of these touch points in multiple phases of a customer's decision process or purchase journey ."	Puccinelli et al. 2009
"The total customer experience is a multidimensional construct that involves cognitive, emotional, behavioral, sensorial, and social components.	Schmitt et al. 2010
"The customer's subjective response to the holistic direct and indirect encounter with the firm."	Lemke et al. 2011
"Cognitive, emotional, physical, sensorial, spiritual, and social elements that mark the customer's direct or indirect interaction with other market actors."	De Keyser et al. 2015
"Customer experience is a multidimensional construct focusing on a customer's cognitive, emotional, behavioral, sensorial, and social responses to a firm's offerings during the customer's entire purchase journey."	Lemon and Verhoef 2016
"An experience can be thought of as the result of a process or a customer journey that builds on multiple encounters at different touchpoints. The experience is formed by what happens during the journey and different stages of the process may have a stronger impact on the overall evaluation."	Patrício et al. 2018

An extensive literature review was done on all the relevant and most referenced publications concerning Service eXperience (SX) definitions. Tseng et al. (1999) proposed that it could come in form of a sensation or information that creates perceptive, emotive, and interactive responses; resulting in a memory (Edvardsson et al., 2005), which according to Patrício et al. (2011) spans all possible encounters with diverse actors in different situations. Chandler et al. (2015) considered SX as an ongoing dynamic engagement of actors, while Jaakkola et al. (2015) defined it as subjective, and individual depending on the stakeholder's expressions and interpretations. Bell (2005) argues that SX can be affected through varying the pleasure constructs, while Flanagan et al. (2005) add that it is affected by the service quality.

Galetzka et al. (2006) argue that SX is most affected by the service validity and reliability, however Aurier et al. (2007) claim that service value, and customer relationship quality affect SX. Most of the relevant definitions and characterizations for the term "*service experience*" were collected in table form, which was also discussed in one of our previous publications. A list of the most relevant SX definitions and characterizations are displayed in Tab. (2.11).

Table 2.12 Service Experience Existing Definitions

Service Experience Definition	Reference
"The outcomes of interactions between organizations, related systems/processes, service employees and customers."	Bitner et al. 1997
"Experience of service in its totality, a sensation, or knowledge acquisition that emerges from being engaged with many actors at different times and places."	Tseng et al. 1999
"A service process that creates the customer's cognitive, emotional, and behavioral responses, resulting in a mental mark, a memory."	Edvardsson et al. 2005
"Hedonic impression" "Practical contact" "Individual experiences"	Helkkula 2011
"A service experience spans all potential service encounters with different potential partners" "is a process that happens over multiple channels within one focal organization" "encompassing the interactions between the customer and all organizations in the value network needed to perform a given customer activity."	Patrício et al. 2011
"Service experience is an actor's subjective response to or interpretation of the elements of the service, emerging during the process of purchase and/or use, or through imagination or memory."	Jaakkola et al. 2015
"The overall customer experience that is borne out of all forms of customer interactions, communications, and transactions regarding the service offerings, over time."	Kumar et al. 2019

There are several models discussing the occurrence of technology user adoption, which identified different technological impacts affecting the adoption potential. These adoption impacts are mentioned in the literature from several researchers; (1) Fishbein and Ajzen (1977) proposed the theory of reasoned action; (2) Ajzen and Kuhl (1985) proposed the theory of planned behavior; (3) Davis (1985) proposed the technology acceptance model, (4) Bandura (1986) proposed the social cognitive theory, (5) Davis et al. (1992) proposed the motivational model, (6) Thompson et al. (2001) proposed the model of PC utilization, (7) Venkatesh et al. (2003) proposed the unified theory of acceptance and use of technology, (8) Robinson (2010) offered the theory of interpersonal behavior, (9) Rogers (2010) suggested the diffusion of innovation theory. (10) Taherdoost (2018) compared these aforementioned theories to better understand their application. The measurement model from Topolewski et al. (2019) was applied in order to figure out the causal effect of the SP eXperience (SPX) on acceptance and adoption.

There were several identified aspects from these aforementioned theories that would be used in developing the Service Prototype Acceptance Model based on UX (SPAMUX); most of them are subjective like usefulness, attitude towards use, and actual user's expectation. Davis (1985) proposed the Technology Acceptance Model (TAM) to model the user's technology use acceptance; Vankatesh and Davis (2000) extended the TAM model to include the adoption's perceived usefulness, social influence, cognitive instruments, and demonstrability. Venkatesh and Bala (2008) proposed an additional extension on the TAM model including the effects of the perceived ease of use, which impacts the behavioral intensions negatively and the perceived usefulness positively due to the increased technological experience. The experience of a prototype could represent a part of the final service experience, as such it is vital to create an experience that represents the actual situation and shows the attitude towards using and the intention of using a prototype. The SPAMUX is based on the external variables that affect the acceptance of a service prototype, where these variables are divided upon (1) monetary usefulness, (2) non-monetary usefulness, and (3) technical usefulness. The non-monetary and technical usefulness are directly affecting the attitude of the user towards using the service prototype, while the monetary usefulness directly affects the intention of using the service prototype. The actual use is then aggregated from the attitude towards using and the intention to use. The SPAM model will be further explored in future publications.

2.6. Immersive Technologies (XR) in Assembly

The SP used in the experiment is an instructional guide prototype created to represent the actions of service technician servicing machinery. This is a widely used method in the industrial services (maintenance, remote service, etc..), and there were several published papers found that investigate the use of different immersive technologies to assist in similar industrial tasks, most notably for assembly, and training. We identified several studies reporting some form of SP applications or case studies; however, most are lacking the inclusive analysis or validity. These reported experiments applied mainly qualitative methods, only few used quantitative methods, and none used mixed methods. They were typically based on a case study within an actual or virtual service scenario. Most of these selected current publications investigated a service for which they utilized SP for exploring, designing, evaluating and communicating a service idea. Tab. (2.13) represents a list of the relevant previous SP studies.

Table 2.13 SP Studies in The Literature

Studies	Industry	SP	Research	Description	Reference
Service Prototyping Definition	Service Prototyping	***SP***	Qualitative study composed of six expert interviews	Studying how experts work with prototypes and the different meanings of prototyping in practice	Blomkvist and Holmlid 2010
Service Walkthrough	Tourism Service Design	***AR***	Qualitative research by using case study	Using props and mobile AR for a service walkthrough to test the development of augmented tourism services	Arvola et al. 2012
Car self-sales service	Automotive retail	***VR***	Qualitative research by using usability use case to test a model through service prototyping	Simulating customer activities in a 3D service VR environment aims to suggest a service model of self-service car sales environments	Oh et al. 2013

S-Scape Service Prototyping	Retail	***VR***	Qualitative research by using case Study in a shop floor environment	Doing a Hybrid of theatre style storytelling and VR to improve a service design for brand guidance structures for the convenience of customers	Jung Bae 2014
SINCO Methods	Service Prototyping	***SP***	Qualitative research by using interviews, and use case data	Learning if their service prototyping methods can induce transformational change, if it can prompt learning processes, and to deconstruct the service design process	Kuure et al. 2014
PSS Lifecycle Testing	Manufacturing Industry	***VR***	Qualitative research by using case study of testing the smart hybrid prototyping of PSS lifecycle	Analyzing prototyping methods and tools to foresee their potential and determine how existing methods can be used for PSS-Prototyping	Exner et al. 2014
Service Processes Optimization	Hospitality	***MR***	Qualitative research by using a case study of real life experiment with real physical sensors in a restaurant	Improving service process based on visualization of human-behavior and point-of-sales visualized data to improve service processes	Fukuhara et al. 2014
Evaluating Servicescape Designs	Retail	***VR***	Qualitative research by using case study, and user feedback	Simulating a VR experience for the customer in a Duty-free shop to gauge their buying patterns	Kwon et al. 2015
3D Multiple Medical Imaging System	Healthcare Consultation	***VR***	Quantitative research by using a survey 30 participants in a scenario of a doctors' consultation	Using a mobile App for VR medical imaging to evaluate the appropriateness of a 3D VR service app for further utilization	Peng et al 2017
Virtual Body-storming Cognitive Walkthrough	Service Prototyping	***VR***	Qualitative research by using case study with three experts to evaluate a VR service prototyping method	Evaluating the virtual body storming methods with experts regarding the user immersion and engagement	Boletsis et al. 2017
Prototyping Service Journey	Service Prototyping	***VR***	Quantitative research by using a two group of 21 participants each fill a survey after using it	Evaluating VR service walkthrough method based on the user experience and the subjective significance and quality of feedback they produced afterwards	Boletsis 2018
Mobile AR App Evaluation	UX Evaluation	***AR***	Mixed methods approach with questionnaires, physiological sensors, and performance evaluation	Evaluating a mobile AR prototype App by using various methods and sensors. This multi-method approach can capture the holistic UX of any service, system or product.	Satti et al. 2019
Evaluation of an AR Assembly Guidance	Assisted Manufacturing	***AR***	Quantitative research by using a comparative experiment of comparing two guidance systems in an industrial setting	Comparing an AR guidance with a conventional guidance in an industrial environment based on the user experience and feedback to implement the better solution in the organization	Bode 2019

Only three quantitative studies were found; however, none had reached anywhere near 100 participants. Swedish, Korean and Japanese scholars were pioneers in applying immersive technologies on service prototypes. Attention to immersive technologies and their applications, especially in service prototyping, is on the rise since 2014; this could be also observed from the strong servitization and digitalization mind-set of the EU, especially in France and Germany. Immersive service prototypes were used to visualize human behavior through avatars. Others explore the user experience, or service experience or service environment. Immersive service prototypes were also intended to optimize service processes, and to improve service design. Other studies showed the use of ISP to train employees (Kuure et al. 2014) or even to simulate self-services (Oh et al. 2013). Several studies also compared conventional SP forms with each other, to find out which one has a better performance and experience (Bode 2019), and almost in all of them ISP performed better and gave a better experience (see a presentation of those studies in the chapter Discussion). ISPs were especially utilized in stakeholders' centered service situations with complex interactions. ISPs are used in various industries like manufacturing (Bode 2019), automotive (Oh et al. 2013), retail (Kwon et al. 2015), healthcare (Peng et al 2017), hospitality (Fukuhara et al. 2014), and customer services (Jung Bae 2014). Mixed methods evaluation is used in similar studies that include an evaluation of multiple prototypes, in both conventional and immersive forms (Satti et al. 2019).

We research several published papers that compare or investigate the use of immersive technologies in the field of assembly and instruction guidance; to be able to have a better understanding of the impacts of immersive technologies on the service prototype used in the experiment. The most relevant publications were selected and presented in Tab. (2.14) to illustrate the differences and similarities between them and our research.

Table 2.14 XR Assembly Relevant Publications

Publication Title	Field	Tech	Description	Reference
Virtual prototyping for customized product development	Product Development	VR	Explained their virtual prototyping design approach for manufacturing simulation techniques; to support the implementation of concurrent engineering.	Tseng et al. 1998
VR and AR as a training tool for assembly tasks	Assembly	VR AR	Experimentation of compare assembly completion times of VR, AR, engineering drawing, and assembly plan. The results showed that VR and AR were found to out-perform the 2D engineering drawing.	Boud et al. 1999
Assembly planning effectiveness using VR	Assembly	VR	Experimentation of comparing blueprints, non-immersive desktop, and an immersive VR environment to examine the effectiveness of the skills learned. The results showed that on average the participants using immersive and non-immersive VR outperformed the ones using blueprints by 50% of assembly completion time.	Banerjee et al. 1999
VR as a tool for assembly	Assembly	VR	Investigated the usability of VR for manufacturing assembly. The results highlight several limitations of VR application, like the lack of haptic feedback.	Boud et al. 2000
Physically based modeling in virtual assembly	Assembly	VR	Studied the characteristics and requirements of virtual assembly versus traditional computer graphic based assembly. Results	Wang et al. 2001

			showed that the virtual assembly provides an intuitive method of assembly evaluation.	
VR and its usefulness for ergonomic analysis	Ergonomic Analysis	VR	Experimentation of a task completion in a VR environment and a real environment. The results showed that VR can be compared to a similar experimental task in real environment if it involves only measuring movement ranges.	Whitman et al. 2004
VR and AR support for discrete manufacturing system simulation	Simulation	VR AR	Described the architecture of a AR and VR systems in the supporting of the manufacturing planning process.	Dangelmaier et al. 2005
Effectiveness of paper, VR and stereo-VR in the delivery of instructions for assembly tasks	Assembly	VR	Compared between desktop VR, desktop stereo VR and a paper-based approaches in regards to performance, completion times, and accuracy. The results showed that the complexity significantly impacts the performance in regards to the completion time, and that the representation benefits the accuracy.	Strobel and Zimmerman 2011
Virtual training and learning transfer of assembly tasks	Assembly	VR	Compared VR training and traditional physical training on the effectiveness for learning transfer. Results showed that the physical training outperformed virtual training; however, after two weeks the VR trained participant improved their assembly times.	Carlson et al. 2015
Comparison of virtual and physical training transfer of bimanual assembly tasks	Assembly	VR	Experimentation of solving 3D burr puzzles comprised of virtual and physical training elements, with VR, paper and video based instructions. The results showed that the performance of VR trained participants was promising; however, there were no significant differences between VR training and the best performing physical training.	Murcia-Lopez and Steed 2018
Manual assembly training in virtual environments	Assembly	VR	Investigated the role of different visual cues while performing manual assembly in an immersive VR setting and a non-immersive environment in regards to user's performance. The results showed that for specific tasks immersive VR training might be faster and more accurate than training on a 2D screen.	Dwivedi et al. 2018
Application of VR in task training in the construction manufacturing industry	Maintenance	VR	Experimentation where the participants either used a VR training or a traditional paper instructional manual. Where VR users were on average slower and less successful at completing the task.	Barkokebas et al. 2019
Integrating AR in the assembly domain-fundamentals	Assembly	AR	Details an introduction to AR systems, and described the abilities and the added value of AR in assembly.	Reinhart and Patron 2003
Performance evaluation of AR for direct assembly	Assembly	AR	Compared AR assembly guiding system with a printed manual, computer assisted instructions using a monitor and using a HMD. The results showed that AR reduced the assembly task error rate by 82%.	Tang et al. 2004
AR for assembly guidance using a virtual interactive tool	Assembly	AR	Experiments to validate the performance of an AR-based method using a monitor and a HMD, which showed that the AR-based method can provide an efficient way for assembly guidance.	Yuan et al. 2008
AR for assembly processes design and experimental evaluation	Assembly	AR	Experiment to compare AR assembly guidance with a paper manual and a verbal expert tutorial. The results showed that AR	Wiedenmaier et al. 2009

			is more suitable for complex tasks, where in simple task the performance didn't differ significantly.	
Using Animated AR to cognitively guide assembly	Assembly	AR	Experimentation with AR prototype guiding system against a paper based. The AR system yielded a shorter duration to the task completion, while, having less assembly errors, and even lowered the task total load. The learning curve of beginner assemblers was reduced and task performance relevant to working memory was increased.	Hou et al. 2013
Evaluation of an AR assisted manufacturing system for assembly guidance	Assembly	AR	Compared and evaluated an AR assembly guidance system with a traditional paper instructions system in terms of effectiveness and usability. The results showed that the AR guidance is a far better choice than the traditional one, and it had also a high user acceptance	Bode 2019
Assembly guidance information representation assisting user cognition	Assembly	AR	Studying the impact of AR assembly guidance on four visualization technologies. The results showed that AR instructions have a strong visual stimulation, that it enables users to have a longer task related attention span, and increased the information effectiveness and quality	Wang et al. 2020
A framework of marker-less assembly guidance system with Hololens glass	Assembly	MR	Proposed a marker-less MR guidance system for manufacturing assembly in order to display virtual information onto the real world. The results showed that the guidance system performs well in a real manufacturing scene.	Teng et al. 2017
Evaluating the Microsoft HoloLens through an augmented reality assembly application	Assembly	MR	Evaluating MR potential for delivering assembly instructions, by using a proof of concept prototype. The results showed that while the Hololens is a promising, there are still areas that require improvement before it is ready for factory assembly application.	Evans et al. 2017
A MR approach for virtual assembly	Assembly	MR	Presented a MR system that integrates virtual assembly environment. The results showed that the MR had a statistically significant improvement in the user's performance in the assembly task execution, compared to the virtual environment.	Zaldívar-Colado et al. 2017
Measuring the performance impact of using a MR device to provide guided assembly work instructions	Assembly	MR	Compared MR Hololens assembly guide with desktop, tablet and tablet AR instructions in regards to completion time, error count, and score. The use of MR led to a time saving of 16% over the tablet AR, and had lower error rate as well.	Hoover et al. 2020

De Sa and Zachmann (1999) investigated the necessary steps to apply VR in virtual prototyping to verify assembly and maintenance processes, where the results showed that VR will play a vital role in virtual prototyping of maintenance processes. Bullinger et al. (2000) suggested that virtual assembly planning makes interacting with the assembling and disassembling components possible, and based on the user interactions the assembly time and cost can be determined beforehand. Kibira and McLean (2002) demonstrated the challenges of using simulation modeling for assembly operations and production process in the same model, and then established a method for designing a manufacturing process from a product prototype by using VR simulation modeling. Schenk et al. (2005) suggested that combining VR and assembly simulation allows stakeholders to train assembly tasks with a fully interactive immersive visualization of the assembly line. Pingjun et al. (2006) demonstrated the elementary advantages of a VR system for assembly planning and training. Li (2009) reviews the potential of using VR to support the assembly process, while identifying and investigating VR benefits in the optimization of assembly processes. Sung et al. (2009) demonstrated an immersive VR method for representing the design and assembly processes to improve the system's efficiency. Gutierrez et al. (2010) presented a controlled VR training system to improve the skills needed for industrial maintenance and assembly, as the added value here is the flexibility of the system to adapt to the task demands and requirements. Marcinčin et al. (2011) described AR applications with regards to their execution in assembling processes. Bordegoni and Ferrise (2013) showed how virtual prototypes are utilized as a substitute for physical mock-ups or artifacts as a communication tool for product design and usage. Winkes and Aurich (2015) proposed an approach to enhance assembly planning by using VR assistance for the detection of planning failure. Barkokebas et al. (2019) assessed the effectiveness of maintenance assembly and disassembly task training by using VR.

Wiedenmaier et al. (2003) suggested that AR is more suitable for complex assembly tasks. According to Tang et al. (2004) overlaying 3D AR instructions on the actual work reduced the error rate for an assembly task by 82% in comparison to printed manuals or computer instruction. Yuan et al. (2008) suggested that the main characteristic of using a virtual interactive AR system is the intuitive manner in which a technician can immerse themselves in a pre-determined assembly sequence without the need of any sensors. Billinghurst et al. (2008) presented a mobile-based AR assembly system that allows the user to view complex models on the handheld device. Stork and Schubö (2010) investigated the benefits of AR and spatial prompting in assembly, where AR demonstrated an improvement in the performance times and an increased speed of assembling movements. Wang et al. (2013) suggested that an AR hybrid approach to assembly enhances the user experience and reduce the task time. Hou et al. (2013) added that by using an AR guiding system instead of a paper based one, the performance of the task is improved, the duration of the task completion is shortened and the learning curve of beginners is reduced. Radkowski (2015) investigated AR assembly assistance effectiveness in regards to the difficulty of an assembly task to identify advantages such as time and error reduction.

Zauner et al. (2003) provided an intuitive method for researcher to generate a MR-based assembly instruction system. Nilsson and Johansson (2006) investigated the application of MR to give instructions to start a health-care process in regards to user experience and acceptance. Liverani et al. (2006) presented a system that combines CAD and MR wearables to reduce the communication gap between engineers and operators in order to improve personnel training with regards to assembly and part seeking processes. Wang et al. (2020) tested the performance of four different assembly interfaces paper drawings, electronic handbooks, 3D design software and AR prototype system for assembly, in terms of assembly time, and operational experience. Hoover et al. (2020) compared the MR instructional guide to a computer, tablet, and AR tablet instructional guides in regards to the completion time, errors, and user's score, as the MR guided assembly saved 16% of the time in comparison to the AR tablet, and users made fewer errors as well. De Souza Cardoso et al. (2020) investigated the applicability of AR and MR in various industries, including manufacturing, production, and assembly. The study suggests that AR applications in an industrial environment are directly related to the complexity of the process, to improve process flexibility to provide a more efficient process (de Souza Cardoso et al., 2020).

2.7. Identified Gaps

An extensive search was done on the definitions and characterization of service prototyping and service prototypes throughout the literature review. In one of our previous comparative study (Abdel Razek et al., 2018), we characterized what constitutes a CSP and an ISP forms and we also proposed a respective definition due to the absence of any available definition. Several scholars have previously stated that there is a lack of empirical studies on service prototypes (Blomkvist and Holmlid, 2010; Exner et al., 2014). This matches with the results of this literature review undertaken on the service prototyping and prototypes publications, which confirms this lack of empirical investigations. This lack of empirical investigations was in fact one of the motivations to carry out a comparative study between CSPs and ISPs.

In the current body of knowledge, immersive service prototyping was mostly used in user oriented service scenarios with complex interactions in diverse industries like manufacturing, healthcare, automotive, catering, and sales. We have also identified up-to-now only 75 published papers via a Google scholar search that combines the words "*immersive*" and "*service prototype*". There were only 5 remaining published papers after filtering them in searching with "*immersive service prototype*" expression. Most of those published papers were mainly theoretical and lacked a quantitative validation. There were no studies found that investigated the impacts of immersive technologies on service prototypes. Some published papers included a comparison between two use-cases or prototype solutions in different or similar forms (see Table 2.13); yet most were qualitative studies and they were not covering the SPX aspect as well. In summary, we have identified that there are no available definitions for both ISP (including VRSP, ARSP, and MRSP) and SPX, and a lack of SP empirical quantitative studies in the literature. There was also a lack on research on the impacts of XR on service prototyping in the literature. Furthermore, there is a lack of empirical studies addressing ISP forms.

2.8. Proposed Research Framework

Researchers attempted in differentiating between different SP forms in several forms, (1) Floyd (1984) divided them into vertical and horizontal; (2) Rudd et al. (1996) differentiated them by their implementation; (3) Walker et al. (2002) differentiated them by their application; (4) Beaudouin-Lafon and Mackay (2003) categorized them into horizontal, vertical, task-oriented, and scenario-based; (5) Kim et al. (2006) differentiated them by their usability; (6) Holmquist (2005) and McCrudy et al. (2006) differentiated them with their fidelity level; (7) Stark et al. (2009) proposed a smart hybrid prototyping approach combining different forms and technologies; (8) Blackler (2009) differentiated them by their type of interaction; (9) Exner et al. (2014) differentiated them according to their fidelity level, and form (i.e. physical, virtual, and both); (10) Blomkvist and Holmlid (2011) differentiated them by their different activities and contexts. In summary, some of these above-mentioned studies only focused on one attribute of a prototype, or lacked an all-inclusive outlook. To make it easier to understand the concept of service prototyping forms, a classification for these forms were established in one of our previous publications (Abdel Razek et al., 2018a). To better understand the impacts of these immersive technologies (XR), differentiating SP forms into two main categories, Conventional Service Prototypes (CSP), and Immersive Service Prototypes (ISP) is helpful for this study.

There were several published papers done in the last three years (Abdel Razek et al., 2017; 2018, 2019) concerning service prototyping forms, and a comparative study between immersive and conventional service prototypes. The initial results show that there is a significant difference between some of the immersive service prototyping forms compared to conventional ones. The differences are measured in regards to the performance, experience and level of acceptance. Combining all these aforementioned points with the knowledge found on the Immersiveness and User eXperience (Pallot et al., 2013, Pallot et al., 2017, Eynard et al., 2016, Dupont et al., 2017), we can suggest that service prototypes are intended to help service stakeholders in the complex service processes from development to testing and launching. ISP is also intended to explore, evaluate and communicate service processes and stakeholder's behaviors through user experience, and more particularly immersive experience. The Service Prototype eXperience (SPX) is latent experience generated through the usage of a service prototype. There was no mention of the expression "s*ervice prototype experience*" in any published paper. There were only two mentions of the term "*service prototyping experience*" found in two different published papers, which showed both the term "*service prototyping experience*" to describe the design experience of either a transportation buddy service (Leber, 2014), or a future space traveling (Lee, 2018). Unfortunately, none of the above-mentioned published papers defined or characterized the concept of service prototyping experience, as the term was only used to describe the construct of user experience in a prototyping process.

We also had to create the term "*conventional form of service prototypes*" (CSP); it means that this is a conventional form of service prototypes, such as: verbal, paper, or mock-up based. CSP could come in various forms, as they are based on the use of technique or some form of tool to represent the prototyping process. The convention here comes from the use of these conventional tools like by using speech, a piece of paper, a mock-up or a simulation, these tools could be also immersive but won't have any digital immersive output. ISP is also mentioned in recent papers and means immersive forms of service prototyping that use XR (VR, AR and MR) technologies, which uses a digital output for the immersion (HMDs, AR App, Hololens). The CSP and ISP terms were coined to differentiate the different forms of service prototypes in one of our previous publications (Abdel Razek et al., 2017). CSP are extensively studied and applied by many researchers as observed in the literature (see Figure 2.10). Our empirical study puts us in an ideal position to be at the frontier of exploring characterization and definition of service prototyping specifically in regards to service innovation. By analyzing these research focal points, a literature gap arises; in which there is a lacking literature that discusses ISP, and absence of quantitative empirical studies on immersive service prototyping or the impacts of using immersive technologies on service prototyping. There is no previous mention of conventional SP definition, but we based our definitions on the existing SP forms definitions in the literature. VSP is a prototype that uses speech representation of a new service idea to increase the understanding of the stakeholders through a narrative, especially storytelling. Inferring from the literature and using our own definition, PSP is then a paper-based prototype in form of depictions, drawing, and description of a new service idea. We refer to our definition of mock-up service prototyping from our previous publication (Abdel Razek et al., 2018a). MSP can be considered as a physical or digital representation of a service idea, or design to enable stakeholders to experience, evaluate or communicate a service design. Because there was no common definition found in the literature for Simulation Service Prototypes (SSP), as such we refer to our early publication that defined simulation service prototyping (Abdel Razek et al., 2018a). SSP can be considered as the set of replication processes of a real or imaginary service situation or activity. SSP can be used as a part of virtually all the service prototyping forms, especially mock-up, and virtual reality, service prototyping processes.

To bridge the literature gap, a research model and instrument were constructed and applied in experimentation on immersive and conventional service prototypes. This experimentation was designed to explore and characterize the impacts of XR on service prototypes, by comparing different SP forms. The comparison then shows if there is a significant difference between the SP forms, and will reveal the impacts of using XR on SP. The participants in the experiment have used each of the different SP forms, then, filled a survey after each use. This survey is a bipolar questionnaire that allows the users to express their rating on specific properties while providing their feedback on each of their given rating. The experience and acceptance are also subjective of each user, as they are covered in the bipolar survey. Each participant's performance was measured in recording the duration to complete the task, amount of errors, and explanation requests. To investigate the impacts of using XR on service prototypes, we had to consider the different SP forms. This study is an explorative research to investigate the impacts of the use of XR on SPs, as the literature available are limited, and information from industrial case studies are constrained. This research strives to be the base for future research on conventional and immersive service prototypes, especially in industrial services setting.

Due to the actual lack of empirically validated SP research framework and model in the current literature, we decided to design our own, based on previous work from Pallot et al. (2013; 2017), which will be duly experimented and validated. By using the same properties and constructs that were validated by Pallot et al. (2017), we assume that perceptual, emotional and cognitive forms of immersion directly affect the degree of immersiveness. The Perceptual eXperience (PX) is gaged with the intuitively of the prototype which constitute as user sensorial engagement, and the interactivity of the prototype which represents the user behavioral engagement. The Emotional eXperience (EX) is assessed based on the degree of attractiveness of the prototype to the user, which depends on multiple pictorial factors, and the degree of user emotional engagement with the prototype. The Cognitive eXperience (CX) is evaluated on the user's interestedness level in the prototype, and the user's cognitive engagement with the prototype. The Immersive eXperience (IX) is then summarized in perceptual, emotional and cognitive experiences; this experience might have several impacts on the prototype use and application. The SP Effectiveness (SPE) is gauged from the friendliness of the prototype that exemplifies the user presence, the pleasantness level of the prototype to the user, and the user perceived usefulness of the prototype. The impacts could be due to the user immersion, cyber sickness or other effects due to the immersion physical and physiological effects. The impacts also could be due to the quality of the prototype, or due to the performance of the prototype.

2.8.1. Research Questions and Hypothesis

The main research question is about investigating the potential impacts of using immersive technologies in a service prototyping process within a service innovation setting.

RQ: What are the impacts of using immersive technologies in service prototyping? The objectives are to firstly identify and select impact factors, through the literature review and secondly assess each impact factor through experiments that will compare CSP and ISP outcomes.

Q1: **What are the impacts of immersiveness on SP stakeholders' perception of time, attentiveness to their surroundings and responsiveness to external events (Real-World Dissociation effect)?** The first sub-question is about investigating the impacts of immersive technologies on the users, and how are they affected by immersion in comparison to the real world, like perception of time, attention to their surroundings, and responsiveness to external events. **H1**: The deeper the degree of immersiveness, the more effective the real world dissociation. When users will be immersed, their perception of time, surroundings and external events will decrease while immersiveness increases.

Q2: **What are the impacts of immersiveness on the user experience of SP stakeholders (Service Prototyping eXperience)?** The second sub-question discusses the impacts of immersiveness on the stakeholders' service prototyping experience, and how will it affect their user experience. **H2**: The deeper the degree of immersiveness, the more satisfying the SPX. When users will be immersed, their perception of getting a satisfying SPX increases while immersiveness increases.

Q3: **What are the impacts of immersiveness on the Ergonomic quality and Hedonic quality of the Service Prototype Effectiveness?** The third sub-question discusses the impacts of immersive technologies on the service prototyping effectiveness. **H3**: The deeper the degree of immersiveness, the higher the degree of effectiveness. When users will be immersed, their ability to carry out effectively a specific task increases while immersiveness increases.

Q4: **What are the impacts of service prototype effectiveness on the Service Prototype eXperience?** The fourth sub-question is about investigating the impacts of service prototype effectiveness on the stakeholders' SPX. **H4**: The higher the service prototype effectiveness, the more satisfying the Service Prototype eXperience. When users are more effective on a specific task, it increases the satisfaction of stakeholders' SPX. While immersiveness increases, stakeholders are more effective, hence, making fewer errors.

Q5: **What are the impacts of Service Prototype eXperience on the intention to adopt?** The fifth sub-question is investigating the impacts of SPX on the stakeholders' intention to adopt the prototyped service. **H5**: The more satisfying the Service Prototype eXperience, the higher the degree of stakeholders' adoption of the prototyped service. When users get a more satisfying SPX, it increases stakeholders' intention to adopt the prototyped service.

2.8.2. Proposed Service Prototype eXperience Definition

One of the objectives was to find a way to have the most comprehensive SPX definition. There is a lack of definition for SPX in the literature. The only mention of the term SPX was found in a thesis work, which describes an SPX for the design of a transportation buddy service (Leber 2014) and also in another publication exploring the ground experience for space tourism (Lee 2018). In both papers there was no mention of a definition or a characterization of the SPX, but more of a description of the experience that the user has during the process. We defined immersive service prototyping as a process that uses a real or fictional service idea, to allow service stakeholders to anticipate the service experience with an immersive service prototyping experience for exploration, evaluation, and communication (Abdel Razek et al., 2017; Abdel Razek et al., 2018a, b).

Figure 2.12 Experiences Relationships Graphical Representation (Extended on Abdel Razek et al. 2018a)

Fig. (2.12) shows our proposed visual depiction of the overall relationship between the overall stakeholder experience, User eXperience (UX), Service eXperience (SX) and Service Prototype eXperience (SPX) as well. This proposed representation is inspired by similar experience depictions in the literature (Garrett, 2010; Pallot and Pawar, 2012; Dupont et al., 2016). This representation helps understanding the importance of the experience construct; and how it plays a main part in the service development processes; especially for the co-creative service prototyping processes. We propose to substitute the customer experience with that stakeholder experience as it encompasses all the relevant actors in the service. This stakeholder's experience includes user experience among other experiences. According to this representation, the user experience is comprised of product and service experience aspects. Both product and service experiences have a different but connected instantiation relationship; if it is not a product or a product-service-system then the service experience will replace the product experience and reversely with a product. SPX is a part of the service experience, and the summation of all the service prototypes experiences can be summed to represent the future service experience. The SPX relation to the UX and the SX can be seen in Fig. (2.12), where the user product and service experience are combined to create the stakeholder's experience.

Then, we can consider immersive service prototyping as the use of a real or fictional service idea to allow stakeholders to anticipate the experience within an immersive environment. ISP may appear as VR simulation training, or an AR instructional guide or a MR hologram for guidance system. Immersive service prototypes forms can be categorized into three SP forms. Other than that the term virtual reality service prototyping and prototypes are novel and were not used before in the literature, as such we refer to our previous publication where we defined virtual reality service prototyping (Abdel Razek et al., 2018a). VRSP is a prototype that uses VR to explore, evaluate and communicate a service idea, design or concept. As mentioned before that there was no definition or even a mention of ARSP before our research started; so, we refer to our previous publication for the augmented reality service prototyping definition (Abdel Razek et al., 2018a). ARSP is a prototype that uses AR to explore, evaluate and communicate a service idea, design or concept. As the term mixed reality service prototyping is novel and was never mentioned before our previous publications, we therefore refer to it for inspiration to attempt to define MSRP (Abdel Razek et al., 2018a). MRSP is a prototype that uses MR to explore, evaluate and communicate a service idea, design or concept. As there were several “experience” definitions that are valid and widely used, a definition is generated from the most relevant definitions to best represent the experience that results from service innovation, and especially through service prototyping. The following definitions, presented in Tab. (2.15), are constructed based on the definitions found in the literature review and the research work done on service prototyping in the past four years.

Table 2.15 Extended Definitions used in the Dissertation

Concept	Definition	References
Service eXperience (SX)	A continuing dynamic subjective, and individual engagement of stakeholders, which depends on their expressions and interpretations covering all possible encounters with diverse stakeholders in different service situations.	Tseng et al. 1999, Edvardsson et al. 2005, Patricio et al. 2011 ; Chandler and Lusch 2015, Jaakkola et al. 2015
Service Prototyping	A process for service development that uses service representations, or parts of it, in order to explore, evaluate and communicate a service idea, design or concept even before the service exists.	Abdel Razek et al. 2017
Service Prototype (SP)	Service prototype can be considered as an experimental version of the service idea, which allows evaluating the service performance and experience, even before the service exists, in order to co-create the service in an agile iterative manner.	Abdel Razek et al. 2018a
Service Prototype Experience (SPX)	The user’s retained knowledge and individual experience, impressions and observations from a service prototyping process, which includes what is perceived or sensed The specific moments that leads to creating a complete service experience. $\sum_{n=1}^{\infty}(SPX1 + SPX2 + \cdots + SPXn) = SPX, \quad Optimally \sum_{n=1}^{\infty}(SPX) \cong SX$	Non existing definition (Extended on Abdel Razek et al. 2018a)
Conventional Service Prototype Experience (CSPX)	Service prototypes that are initiated by using conventional methods as verbal-, paper-, mockup-, and simulation- based used to engage stakeholders to explore, evaluate, and communicate service ideas or parts of it.	Non existing definition
Immersive Service Prototype Experience (ISPX)	Immersive based service prototypes that immerse stakeholders by using VR, AR, or MR to engage stakeholders in exploring, evaluating and co-creating a service idea.	Non existing definition
Immersive Service Prototyping	The use of a real or fictional service idea to allow stakeholders to anticipate the experience within an immersive environment.	Non existing definition (Extended on Abdel Razek et al. 2018a)
Virtual Reality Service Prototype (VRSP)	VR based SP illustrating a virtual replication of a service idea or parts of it enabling stakeholders to be immersed in an interactive virtual environment by using a VR HMD.	Non existing definition (Extended on Abdel Razek et al. 2018a)

Augmented Reality Service Prototype (ARSP)	AR based SP overlaying a service idea, representation, or parts of it, to augment the stakeholder's real environment with virtual information by using a mobile device.	Non existing definition (Extended on Abdel Razek et al. 2018a)
Mixed Reality Service Prototype (MRSP)	MR based SP that reflects a service idea or parts of it, to engage stakeholders by interacting with holograms (virtual objects representation) and information in their real surroundings by using a Hololens MR device.	Non existing definition (Extended on Abdel Razek et al. 2018a)

2.8.3. Proposed SP research Model

The SP research model includes the immersion part of the Immersive and Collaborative Environment (ICE) User eXperience model and factors from Pallot et al. (2017) and Dupont et al. (2018) that was developed to extend more traditional Immersive Virtual Environments (IVE). This model was devised to be able to address the research questions, and attempt to validate the hypothesis while avoiding the situation of having too many questions overwhelming the willingness of respondents (see Table 16). The SP research model includes the IX and SPE impacting the SPX, and its causal effect on the intention to adopt the proposed service. The Immersive eXperience (IX) could be described as the combination of the perceptual, emotional, and cognitive immersions (Pallot et al., 2017) of a user (See Figure 13).

The social immersion (Pallot et al., 2017) is neglected because the experiment is individually based; there isn't any collaborative activity among several users. Furthermore, including social immersion would require a broader investigation due to the diverse effects of the social interactions, which are not necessary to add at this explorative stage. The efficiency and effectiveness of each SP form (SPE) is also related to the SP effectiveness and efficiency that impact the SPX as well. The SPE, as perceived by users, is convey via usefulness, which is the degree to which users perceive the capacity to complete their goal, and Friendliness, which is the degree to which users perceive the amount of effort for completing their tasks. Nonetheless, there were observations made by the researcher when participants were experimenting the different forms of prototype. Observation metrics, such as: the duration to complete the task, number of errors made, and the number of further explanations requested, were recorded and noted. Other aspects have been included during the observation like the feeling of sickness (cybersickness) when participants were wearing a HMD and their mood or attitude at the end of their experiment session.

Table 2.16 UX Properties included in the Bipolar Survey instrument

Survey	UX Property	Description
Q1	Intuitiveness	Degree to which users perceive the instinctive use of the prototype
Q2	Interactiveness	Degree to which users perceive the capacity to interact with the prototype
Q3	Friendliness	Degree to which users perceive the amount of effort completing tasks
Q4	Attractiveness	Degree to which users perceive emotionally the prototype
Q5	Pleasantness	Degree to which users perceive the hedonic aspect of the prototype
Q6	Emotionally engaging	Degree to which users perceive themselves engaged emotionally

Q7	Excitement	Degree to which users feel interest and excited in the task
Q8	Cognitively engaging	Degree to which users perceive themselves engaged cognitively
Q9	Usefulness	Degree to which users perceive the capacity to complete their goal
Q10	Timelessness	Degree to which users perceive the disappearing notion of time
Q11	Attentiveness	Degree to which users perceive their attention capacity to external events
Q12	Responsiveness	Degree to which users perceive their responsive capacity to solicitations
Q13	Convincingness to adopt	Degree to which users are convinced to adopt this prototype
Q14	Willingness to re-use	Degree to which users wish to re-use this prototype
Q15	Readiness to recommend	Degree to which users are ready to recommend this prototype

These 15 UX properties, which are later included in the bipolar survey, are shown in Tab. (2.16). They are turned into bipolar rating questions based on a semantic scale with two antonyms, like '*Unattractive*' and '*Attractive*' or '*Useless*' and '*Useful*'. Every bipolar rating question (quantitative) embeds an open-ended question (qualitative) where respondent can provide their motivation and/or reasons justifying the given level of rating.

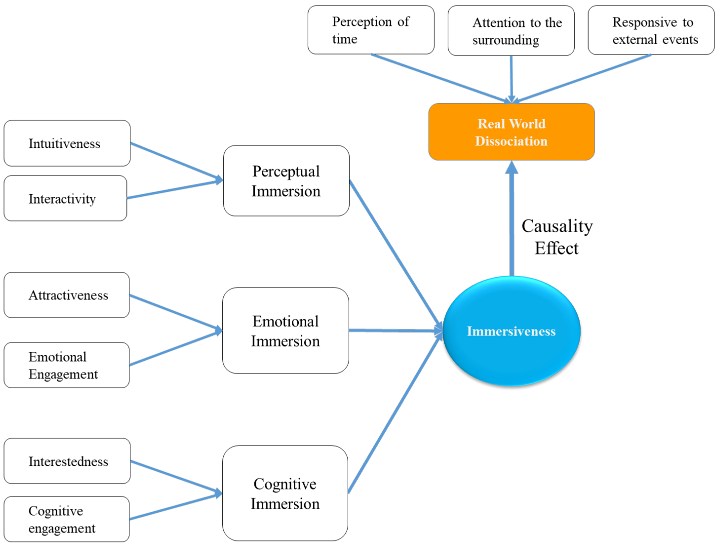

Figure 2.13 Immersive Experience Research Model Constructs (Extended from Pallot, et al. 2017)

Biocca and Delaney (1995) explained that the perceptual immersion is the degree of submersion of the user's perceptual senses in an environment. The well-known causal effect of immersiveness, often named Real World Dissociation (RWD), is characterized by phenomena like how much the time seems to disappear as opposed to in a normal state, and how much users are inattentive to their surroundings, and whether they are irresponsive to external events as shown in Fig. (2.13). In this study, the Immersive eXperience (IX) represents the degree to which users feel immersed in a particular context. IX is a combination of the three facets, of immersiveness or types of experience (Pallot et al., 2017), namely: (1) Perceptual Immersion or Perceptual eXperience (PX); (2) Emotional Immersion or Emotional eXperience (EX); (3) Cognitive Immersion or Cognitive eXperience (CX). Then, Immersiveness or IX has a causal effect on RWD (Figure 2.13) with the hypothesis that the deeper the immersiveness, the more effective the real world dissociation.

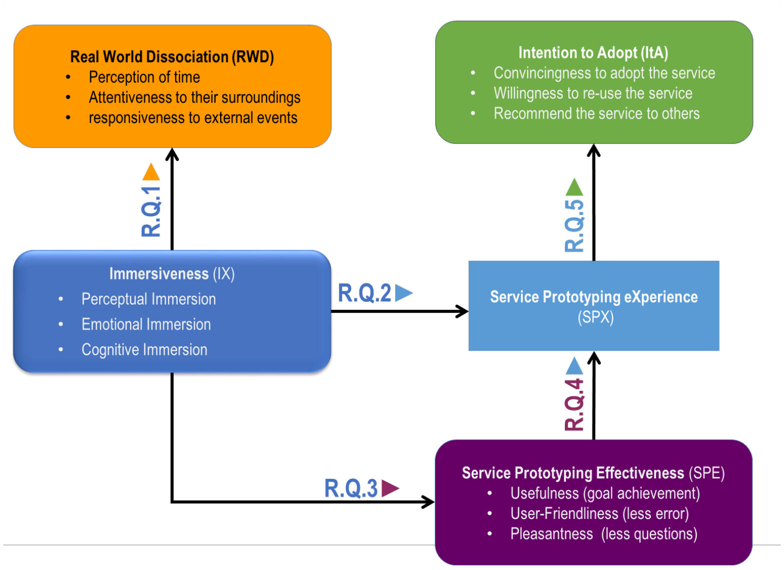

Figure 2.14 Simplified view of the SP Research Model

Biocca and Delaney (1995) explained that the perceptual immersion is the degree of submersion of the user's perceptual senses in an environment. The first causal effects might arise due to the use of immersive technologies, as how the time feels immersed as opposed to in a normal state, and if the user was aware of their surroundings, and if the user is responsive to external factors or events. The service prototyping causal effects that might occur on how the user learns from the prototype exploration, how the prototype is ability to communicate to the user, and how the user is able to measure or decide by the prototype evaluation.

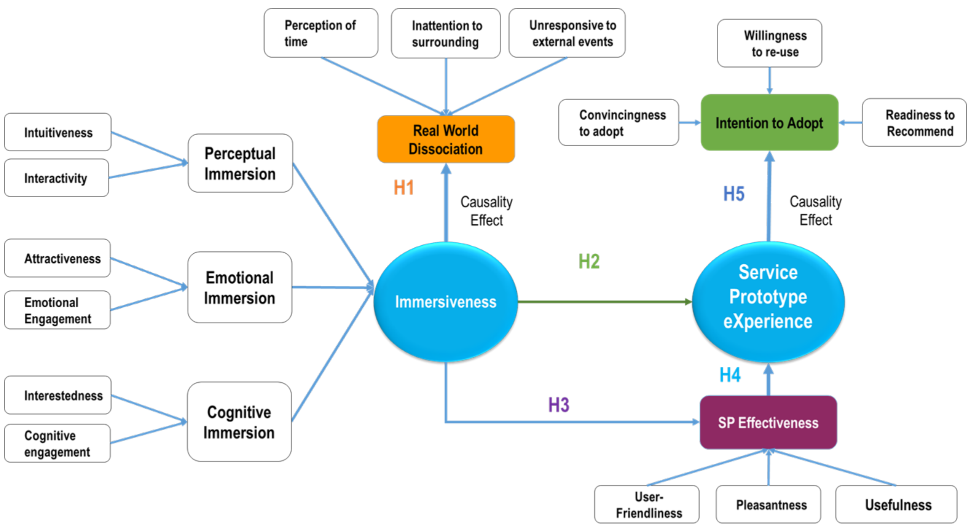

Figure 2.15 Detailed view of the SP Research Model

A detailed view of the proposed SP research model is shown in Fig. (2.15). The user immersion while using a SP effects could be observed and assessed by seeing if the user is convinced to adopt the ISP, or is willing to re-use in another context, or even to recommend it to others for further use. The causality factors can be summarized into three constructs Service Prototyping eXperience (SPX), Service Prototyping Effectiveness (SPE), and Real World Dissociation (RWD). SPE will affect the ability to achieve the objective, to have less errors, and less inquiries. RWD affects the time-feeling distortion, the degree of attention to surroundings and to external factors. SPX will be affected by immersiveness and SPE.

2.9. Summary

This chapter aims to give a higher understanding of SP related research domains, and to interconnect these research domains in a cohesive form. However, the literature review is a continuous process that spans throughout the entire cycle of the dissertation in order to identify more recent publications that are relevant and even allow making comparison with recent studies. The most significant research publication streams for this dissertation include 'services', 'immersion', 'prototyping', 'acceptance or adoption' and 'experience'. XR assembly in the industrial maintenance service sector has appeared as the main focal application of this study. The lack of empirical studies dedicated to the comparison of different forms of SP constitutes a clear gap in the literature despite the fact that 2 empirical studies were lately identified (one published in 2019 and one in 2020). It was shown that there is the lack of viable cross-intersectional empirical studies done on immersive service prototyping that is currently limited to AR. Identified relevant theories and existing models constituted the basis for elaborating a research framework dedicated to increase the understanding of the impacts of these immersive technologies (XR) on service prototyping. The research questions guided the literature review towards the elaboration of a proper model on SP and to find out the XR impacts on SP forms. There is also a lack of characterization of the service prototyping experience in the body of knowledge; therefore, a SPX definition is proposed for explaining stakeholders' experience happening in a service prototyping process. A SP research model is proposed based upon the causal effect of IX on the user's RWD and of SPX on adoption intention.

3. Methods

3.1. Introduction

This chapter presents the research context, approach, methods and experiment design. The main research investigation is to study the impacts of using immersive technologies on the service prototyping process. The objectives are to firstly identify impact factors through the literature review; secondly, to create a research model with the proper constructs in order to validate the hypotheses; thirdly, to prepare the necessary experiments for collecting data; and select the proper analysis methods for evaluating all impact factors allowing to compare CSP and ISP performances. Overall, the investigation is composed of a baseline experiment in which participants have no support for disassembling and re-assembling elements of a physical part (mechanical assembly), followed by an experiment operated through several sessions within different sites where participants have been using different forms of prototype. The SP experiment needed to have a room with high processing computer, equipped with XR devices, assembly tools, place for observations and mobile devices. The SP experiment has been designed to participants engage perceptually, emotionally and cognitively so, there is a need of a wide base of participants with different levels of knowledge and experience. The wide base of participants at the three campuses of Arts et Métiers ENSAM and Furtwangen University ranging from students to professors was the most appropriate for conducting the experimentations.

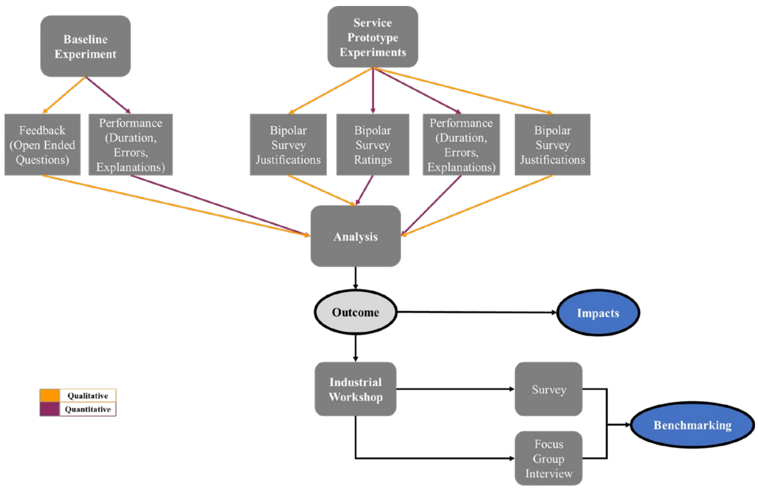

Figure 3.1 Simplified Overview of the investigation

The investigation starts with creating a baseline for the performance, as it is vital to find out the difference in performance when using or not using service prototypes. The SP experiment was conducted with the five different SP forms, where the participant's experience, acceptance and performance are measured (bipolar survey, task completion duration, errors calculations, explanations requests calculations) and evaluated (survey questions justifications, facial expression in the attitude). Due to the unavailability of MR technology (Microsoft Hololens), this part of the experiment was not executed concurrently with the other 4 SP forms.

3.2. Context

In order to explore the impacts of the immersive technologies (XR) on service prototyping, three approaches will be used to collect data: (1) explorative bipolar survey with rating justifications done after the completion of each task; (2) the performance of the participants throughout the experiments; and (3) the feedback and ratings justifications from the participants. The validation experiment aims to validate the research model and instrument, through the comparison of immersive and conventional service prototypes in an experiment and then evaluate it in an industrial setting. Overall, the experiments were conducted in three different locations: Furtwangen, Laval and Angers. The main goal is to reach different academic target groups in order to achieve a higher level of participants' diversity: (1) IT & Engineering (Furtwangen); (2) Software Engineering (Laval); and (3) Mechanical Engineering (Angers). The test, baseline and MRSP experiments were all done at the Furtwangen University Campus in Germany.

The validation SP experiment has been designed to engage participants perceptually, emotionally and cognitively. Paper-based instruction leaflets are quite common in the industry for servicing machinery or even for more personal uses like assembling Ikea furniture. This kind of drawing-based instructions can be considered as a part of the service process. The instruction leaflet presents to the participants, for example, the necessary steps and elements for assembling or disassembling specific furniture. Therefore, for designing our experiment, we have imagined a service to support people needed to assemble or disassemble a mechanical element constituted of several parts in the most comfortable, efficient and reliable way. In this case, service stakeholders would explore, along the service prototyping process, different service alternatives through the use of different forms (PSP, MSP, VRSP, ARSP, MRSP) of service prototype that the participants will experience and provide feedback on the above-mentioned aspects (immersiveness, real world dissociation, efficiency, experience and intention to accept and adopt). The participants had to fill out four bipolar surveys throughout each individual experiment session. Each bipolar question presents a semantic scale with rating values ranging from -2 to 2. The questionnaire starts with the selection of the SP form that was completed. A table of the English, French and German surveys can be seen in the Appendix. The tasks were clocked from the moment that participant starts the disassembly or assembly task till the end of each of these tasks. The participants were all assigned different SP cycles, as to eliminate biasing from doing the task with the same SP form at the start or end of a cycle. The experiment cycle consists of the combination of the SP forms used in a specific order. The SP cycle that the participant starts with changes every set of participants to eliminate biasing as well.

The labs were the experiment took place were well equipped with state-of-the-art VR systems, HTC Vive at VR Lab in Laval and HTC Vive Pro at VR Lab in Angers and at the Services Competence Center in Furtwangen. Colleagues, students and also faculty members have participated to experiment sessions. The experiment took place in a span of one and half year, and it required a lot effort to recruit participants for the experiments as the experiment duration is one hour and requires extensive physical and mental work. The experiment design was also very demanding as the experiment includes different SP forms with different technologies and by using several devices, where participant have to use to complete the task and also give their feedback, and I used other devices to observe the participants' performance, attitude and capture their verbal feedback as well. The colleagues at all the labs were more than helpful in facilitating the recruitment of the participants and for using the devices and rooms necessary for the experiments. I am thankful to all the colleges in Arts et Métiers labs in both Angers and Laval for enabling me to finish 48 participants in less than two weeks, which was crucial for the study.

Figure 3.2 VR Lab at the Presence & Innovation Lab in Laval

The experiment in Laval was conducted at the Laval Virtual Centre VR lab of the Presence & Innovation Team as shown in Fig. (3.2) above. The experiment session in the VR lab in Laval was done in one week, where every day 8 participants were engaged. The conducting of the experiment was extensive due to the time constraint and due to coinciding of the experiment with examination time of the students as well. However, the colleagues at the lab supported the experiment process so that everything went smoothly.

Figure 3.3 VR Lab at the Laval Virtual Center, Laval

The experiment in Angers was conducted at the VR Lab at École Nationale Supérieure des Arts et Métiers (ENSAM) in Angers as shown in Fig. (3.3) above. The experiment session in the VR lab in Angers was also done in the span of one week, where every day more than 8 participants were engaged. The experiment also was challenging to conduct as the students were in the examination period, but the staff and the colleagues at Angers were more than helpful in making the experiment sessions went exactly as planned.

Figure 3.4 Service Lab at the Furtwangen University

The experiment in Furtwangen was done in the service competence center at the Furtwangen university as shown in Fig. (3.4) above. The experiment session at Furtwangen spanned over one year, as it was extremely challenging to recruit volunteers that are willing to do the experiment and was demanding to have experiment appointments to suit the timetable of the center, volunteers and myself along with all the devices needed to complete the experiment. The colleagues at Furtwangen supported the study with everything from help in the recruitment process, to facilitating the devices and rooms needed for the experiment, which I am very thankful for as well.

3.3. Research Approach

This study investigates immersive technologies impact on service prototypes but on one had an only quantitative study will not give the complete picture as it might show the statistics but not the reasoning On the other hand, an only qualitative study might be beneficial to find the reasons of the impact, but that would also be lacking as it will be on a limited base of participant and can't be interpreted on a larger scale. Mixed methods seem to be the most suitable research method to challenge such multidimensional explorative study (Johnson and Onwuegbuzie, 2014). To validate the model an experiment is needed to test out hypothesis. According to Creswell et al. (2013) Mixed methods tries to interpret the findings by merging the qualitative and quantitative data; using the qualitative data to explore and interpret the quantitative findings. Pallot and Pawar (2012) used mixed methods to investigate immersive experience study, and was also used by Krawczyk et al. (2017) and Topolewski et al. (2019) for a similar immersive experience investigation. Mixed methods technique will allow findings validation by using triangulation of qualitative and quantitative data, by using the qualitative data to explore and interpret the quantitative findings through the feedback collected and the stakeholders from the planned quantitative and qualitative embedded questionnaire (Greene et al., 1989; Morse, 1991; Morgan, 1998; Tashakkori and Teddlie, 1998; Creswell et al., 2003).

There are several forms of mixed methods, like (a) concurrent, (b) sequential, and (c) transformative approaches (Creswell et al., 2003). The concurrent approach has different forms as well, which qualitative and quantitative data congregate to provide a more inclusive analysis (Creswell et al. 2003). The data is then collected and integrated for interpretation concurrently, as such one form of data is nested within the other form for further analysis. The research method of a quantitative qualitative embedded survey, where the quantitative and qualitative data will be collected and analyzed at the same time; as the observations will elaborate on both the quantitative and qualitative results. The quantitative data offer a statistical overview on the service prototypes performances, while the qualitative data provide explanation on their performances, experience and acceptance. The rationale for this approach is that the quantitative results will provide a statistical overview on the use of immersive service prototyping and the potential impacts of using immersive technologies on service prototyping process, while the qualitative results will explain those statistical results and explore in depth the impacts of immersive technologies on the service prototyping experience, but both findings, combined with the interpretations, will validate our hypothesis. To be able to have both sides of the data, it was decided to adopt the mixed methods methodology, to be more confident that different methods lead to the same findings. by using a combination of concurrent triangulation strategy; the data results are compared as one of the data results complements the other one (Creswell et al. 2003).

The bipolar questionnaire consists of 15 quantitative sematic scale rating questions; each rating question includes a qualitative justification element in order to better understand the motivation explaining the level of submitted rating. These justification elements embedded in the bipolar questionnaire allow participants to freely express their feedback about their rating. This questionnaire was written firstly in English and then was translated into German (used at The Furtwangen University) and into French (used at ENSAM Laval and Angers Campuses). All questions were carefully selected to cover the SP experience facets, SP efficiency facets, and the real world dissociation factors as discussed in previous publication (Abdel Razek et al., 2018). The Service Prototype eXperience (SPX) stems from the participants' rating and feedback during the experiment. The SPX is reflected from the rating questions that shows if participants were convinced of that SP form; if they are willing to re-use the SP form in another context, and if they would recommend this SP form to others; the SPX is an extension on the Immersive eXperience model from Pallot (Pallot et al., 2017) built on the baseline of the holistic view of UX (Pallot and Pawar, 2012). The real world dissociation factors are also extracted from the responses of the participants on the questions that revolve around the feeling of the notion of time disappearing during the experiment; the ability to be attentive to outside factors, and the responsiveness to external influences as it was previously used by (Pallot et al., 2017). The service prototyping efficiency is then measured by the clocking of disassembly and assembly tasks for each SP form as well as the number of explanations asked and errors made by the participants while doing it.

A comparison of this research approach with similar immersive technologies related studies in the service prototyping domain was done to foresee what kind of approaches other studies used to explore service prototyping forms. The research approach to define service prototyping forms took a different way than the other researchers and studies. Blomkvist and Holmlid (2010), defined service prototyping by interviewing six experts in a qualitative study. Arvola et al. (2012) used a service design case study with AR walkthrough prototype. Hou et al. (2013) experimented with AR prototype guiding system against a paper based. Oh et al. (2013) used a qualitative research by using usability use case to test a model through service prototyping. Jung Bae (2014) used a qualitative research approach to test a prototyping method by using case study. Kuure et al. (2014) used qualitative research by using interviews, and use case data to test service prototyping methods. Exner et al. (2014) used a qualitative research approach to test hybrid prototyping of PSS lifecycle by using a case study of testing. Fukuhara et al. (2014) used a qualitative research for optimizing service processes by using a real life case study. Peng et al. (2017) evaluated a service design by using a quantitative research approach by using a survey with 30 participants. Boletsis et al. (2017) evaluated a VR service prototyping method by using qualitative research through a case study with three experts. Boletsis (2018) also evaluated service prototyping methods by using a survey quantitative research with two groups of 21 participants. Satti et al. (2019) evaluated a mobile AR app by using a mixed methods approach. Bode (2019) compared two guidance systems (AR, paper) in an industrial setting by using quantitative research with a comparative experiment.

There were several studies that are similar from the industrial assembly research domain, as studies that compared between different forms of assembly guidance or assembly training. Boud et al. (1999) compared assembly completion times of immersive (VR, AR) and conventional (drawing, plan) assembly methods. Banerjee et al. (1999) compared effectiveness of the skills learned by using blueprints, non-immersive desktop and immersive environment. Tang et al. (2004) compared assembly guiding systems by using AR, printed manual and computer assisted instructions in an experiment. Wiedenmaier et al. (2009) compared assembly guidance with a AR, paper manual and a verbal expert tutorial with an experiment. Strobel and Zimmerman (2011) compared between desktop VR, desktop stereo VR and a paper-based approaches in regards to performance, completion times, and accuracy. Murcia-Lopez and Steed (2018) compared VR, paper and video based instructions in an experiment setting. Barkokebas et al. (2019) compared performances of a VR training or a traditional paper instructional manual in an experiment. Bode (2019) compared AR with paper instructions systems in terms of effectiveness and usability in an industrial setting. Hoover et al. (2020) compared completion time, error count, and score of MR Hololens assembly guide with desktop, tablet and tablet AR instructions in an experiment setting.

3.4. Research Methods

By using the triangulation design validating data model where both sets of data are collected at the same time from the survey by using a quantitative qualitative embedded questionnaire. The survey was conducted on Jaxber app as it offers an easy way to collect the data from the participants on their digital devices or on our own supplied tablets. The observations and attitude data was also directly captured and typed in an excel file. The data collected is then correlated with the observations observed during the experiments in order to validate the model.

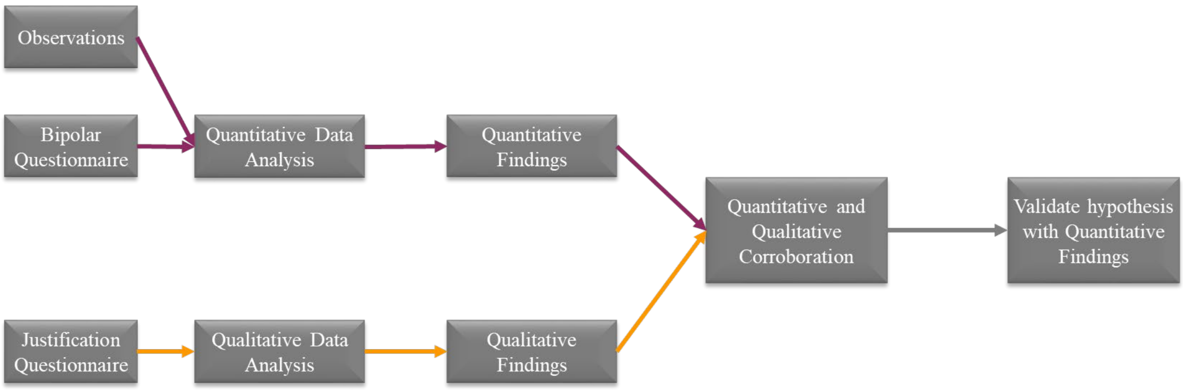

Figure 3.5 Mixed Methods Triangulation: Validating Data Model

The mixed methods triangulation approach used can be seen in Fig. (3.5) above. The research model, which is an adapted from the Immersion User eXperience model from Pallot et al. (2013; 2017) and Dupont et al. (2017). This model was devised after reviewing the literature, and adapting on these models to address the research questions for attempting the hypothesis validation. The research model includes the developing of an immersive experience, its immersiveness factors and causality factors. Immersive eXperience could be described as perceptual, emotional, and cognitive immersions (Pallot et al., 2017). The Immersive eXperience is then summarized in three UX properties perceptual, emotional and cognitive immersion experience, these UX properties could impact the experience in several ways. There is no social immersion at this stage, as the experiment will be done individually. These impacts could be divided into the user immersion, service prototyping process, assembly process, and experimental process.

As per Pallot et al. (2017) we can consider that; (1) the perceptual Immersion (PX) is measured by assessing the intuitively of the prototype, which is established as user sensorial engagement and the interactivity of the prototype, which signifies the user interactive engagement. (2) the emotional Immersion (EX) is assessed based on the degree of prototype attractiveness to the user, which depends on various aspects: the perceived and the user's level of emotional engagement with the prototype; (3) the cognitive Immersion (CX) is gauged based on the level interestingness of the prototype, and the cognitive engagement of the user from the prototype, and (4) Service Prototyping Effectiveness (SPE) is represented by the user friendliness of the prototype exemplifying the user presence, pleasantness level of the prototype, and the perceived usefulness of the prototype to the user. The causality effects then are measured by three separate UX factors. The first casual effect could be due to the use of the XR devices, as the immersed time feels different to in a normal state. This is represented in the sense of user awareness of their surroundings, and responsiveness to external factors or events. The service prototyping causal effects depends on the purposes of service prototype, on how the learning of the user is affected. The user should have the ability to complete the task after using the prototype. The immersion of the user while using an immersive service prototype could affect the user as they will observe and asses the prototype by experiencing it instead of just seeing it. The user then could conclude if they are convinced to adopt the immersive service prototype, or is willing to re-use in another context, or even to recommend it to others for further use. The causality factors can be summarized into two constructs; (a) Real World Dissociation (RWD) which is based on the sense of time, sense of presence, and responsiveness to the surrounding; (b) Intention to Adopt (ItA) represented in the convincingness to adopt it, willingness to re-use it, and degree on which to recommend it to others. To be able to have an inclusive description of the impact of immersion, we need to have several questions in the research instrument for each high construct, and for each UX property one question.

Figure 3.6 Research Model Factors and Constructs (Extension on Pallot et al. 2017)

As shown in Fig. (3.6) above, Immersiveness (IX) allows users to perceive, and react, and from their reactions, feedback, and own observations will establish the causality effects. IX could be described as perceptual, emotional, and cognitive immersion, while neglecting the social immersion as the experiment will be done individually. To include the social immersion and other immersion types a much bigger investigation is needed due to the diverse effects of the social and diverse other interactions, which are not necessary to add in this explorative stage. The first casual effect is due to the use of immersive technologies, (a) as the user will feel time differently when immersed as opposed to in a normal state, (b) if the user was aware of their surroundings during the task, and (c) if the user is responsive to external variables. The service prototyping efficiency causal effects differs for each SP purpose and in each SP form, it is based on the prototype's ability to communicate the interned information to the user. The immersion of the participants will also allow them to assess service prototype experience and if they are convinced to adopt it, willing to re-use, or even to recommend it to others. SPX rating can be considered as the participants' rating of the experience during the experiment; the SPX factor is an adapted from the Immersive eXperience model from Pallot and Pawar (2012). The real world dissociation factors are also extracted from the responses of the participants on the questions that revolve around the feeling of the notion of time disappearing during the experiment; the ability to be attentive to outside factors, and the responsiveness to external influences as it was previously used by Pallot et al. (2017). The service prototyping observed performance is then measured by the timing of disassembly and assembly tasks for each SP form; as well as the number of errors made and of questions asked by the participants.

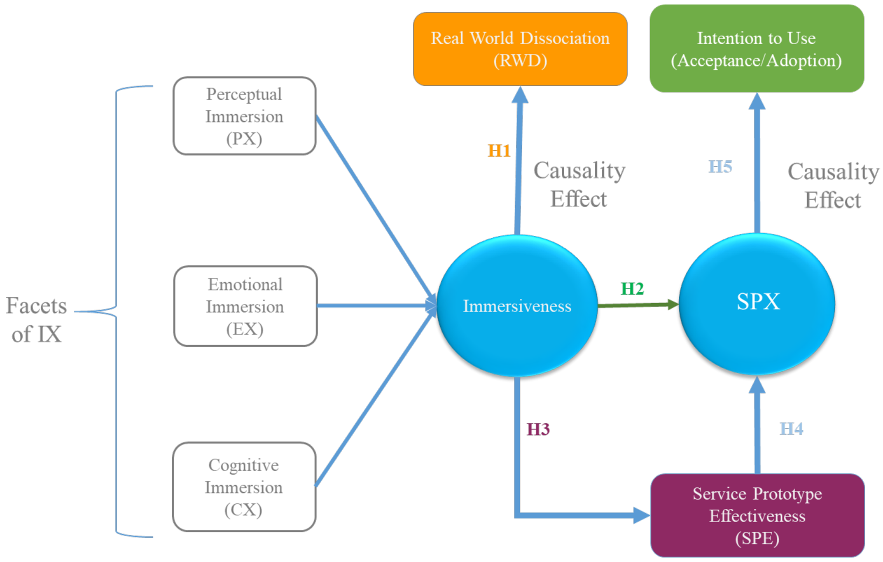

Figure 3.7 SP Research Model

The research instrument consists of 15 bipolar rating questions in a survey with a semantic scale to attempt to verify the model shown in Fig. (3.7), where the user has to justify that rating in the justification space in order to understand the motivation behind the submitted rating. These justification elements embedded in the bipolar questionnaire allow participants to freely express their feedback about their submitted ratings in text form. This survey was created in English, as to be used in published studies, and then was translated into German, which was used in the experiments done at the Furtwangen University, and into French which was used at ENSAM Laval and Angers Campuses. These questions were carefully selected to cover the SP experience facets, SP efficiency facets, and the real world dissociation factors as discussed in previous publication (Abdel Razek et al., 2018b).

Table 3.1 Research Instrument Questionnaire

Q	SPX Survey	R1	R2	R3	R4	R5	Justify
	Rating Scale	***(-2)***	***(-1)***	***0***	***(+1)***	***(+2)***	
Perceptual eXperience (PX)							
1	How intuitive is the prototype?	[-2] Unintuitive	[-1] Mostly Unintuitive	[0] Almost Intuitive	[1] Mostly Intuitive	[2] Intuitive	
2	How interactive is the prototype?	[-2] Passive	[-1] Mostly Passive	[0] Almost Interactive	[1] Mostly Interactive	[2] Interactive	
Emotional eXperience (EX)							
4	How attractive is the prototype?	[-2] Unattractive	[-1] Mostly Unattractive	[0] Almost Attractive	[1] Mostly Attractive	[2] Attractive	
6	How emotionally engaging were you with the prototype?	[-2] Uncommitted	[-1] Mostly Uncommitted	[0] Almost Committed	[1] Mostly Committed	[2] Committed	
Cognitive eXperience (CX)							
7	How interesting is the prototype?	[-2] Unexciting	[-1] Mostly Unexciting	[0] Almost Exciting	[1] Mostly Exciting	[2] Exciting	
8	How cognitively engaging was the prototype?	[-2] Unthinking	[-1] Mostly Unthinking	[0] Almost Thinking	[1] Mostly Thinking	[2] Thinking	
Real World Dissociation (RWD)							
10	Please rate the feeling of time while using the prototype	[-2] Timely	[-1] Mostly Timely	[0] Almost Timeless	[1] Mostly Timeless	[2] Timeless	
11	How attentive were you of your surroundings?	[-2] Attentive	[-1] Mostly Attentive	[Almost Inattentive	[1] Mostly Inattentive	[2] Inattentive	
12	How responsive were you to external factors, during the prototype use?	[-2] Responsive	[-1] Mostly Responsive	[0] Almost Unresponsive	[1] Mostly Unresponsive	[2] Unresponsive	
Service Prototype Effectiveness (SPE)							
3	How friendly is the prototype?	[-2] Unfriendly	[-1] Mostly Unfriendly	[0] Almost Friendly	[1] Mostly Friendly	[2] Friendly	
5	How pleasant is the prototype?	[-2] Unpleasant	[-1] Mostly Unpleasant	[0] Almost Pleasant	[1] Mostly Pleasant	[2] Pleasant	
9	How useful is the prototype?	[-2] Useless	[-1] Mostly Useless	[0] Almost Useful	[1] Mostly Useful	[2] Useful	
Intention to Accept and Adopt (ItA)							
13	Please rate the degree of convincingness to adopt	[-2] Unconvinced	[-1] Mostly Unconvinced	[0] Almost Convinced	[1] Mostly Convinced	[2] Convinced	
14	How willing are you to re-use this prototype?	[-2] Unwilling	[-1] Mostly Unwilling	[0] Almost Willing	[1] Mostly Willing	[2] Willing	

15	Please rate the level of recommendation of the prototype	[-2] Dissuade	[-1] Mostly Dissuade	[0] Almost Recommend	[1] Mostly Recommend	[2] Recommend	

After the formulation of the significant factors for each experience, a list of the questions with their corresponding constructs have been articulated as shown in Table (3.1) above. Each of these rating questions has semantic scale of [-2] for the lowest rating grade, to [+2] for the highest one, where [0] is for neutral rating, and with two quartiles with [-1] and [+1]. The word to best describe the factor and its antonym is used for the [+2] and [-2] accordingly, and for [-1] and [+1] the term "mostly" was added next to the word or the antonym, and for the neutral the term "almost" added to the word. These questions could lead to understanding the degree of acceptance and the user friendliness. Each lower construct will be measured by asking three questions on each property, this is in addition to the task completion durations, and the justifications on the during the experiment will represent the most comprehensive representation of the impacts of immersive technologies on service prototypes.

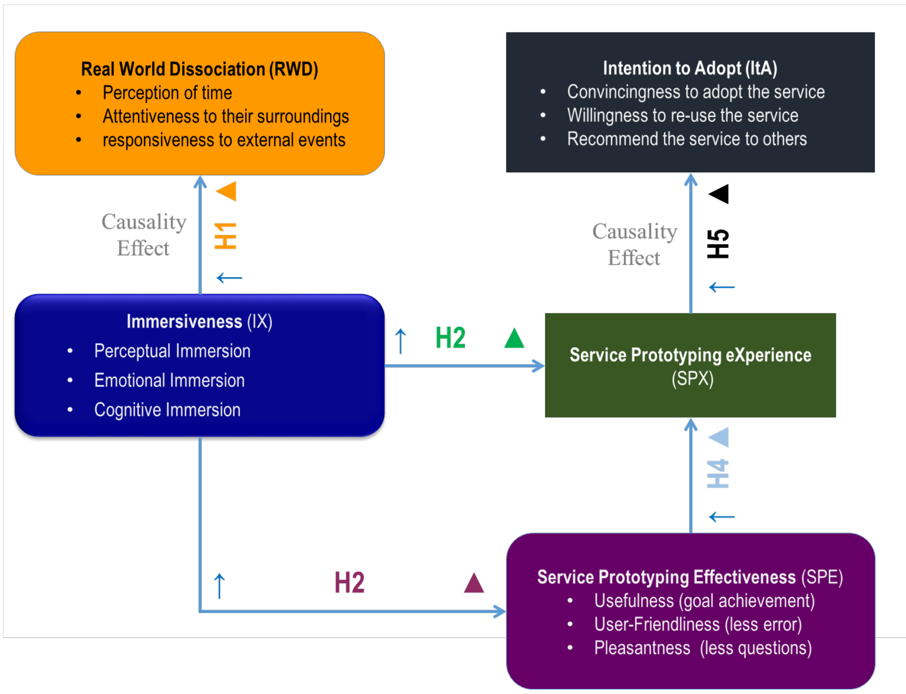

Figure 3.8 Constructs Causality Factors and Hypothesis

As shown in the model in Fig. (3.8) above, Immersiveness consists of the three constructs, is intended to explore a possible validation of the three hypotheses. Starting with the findings from each of the three causality factors. The first hypothesis examines the impacts of immersiveness on the stakeholders on the real-world dissociation in terms of time, attentiveness and surroundings. The second hypothesis examines the impacts of immersiveness on the stakeholders' service prototype experience, and how it will affect the SPX. The third hypothesis examines the impacts of immersiveness on the service prototype ergonomic and hedonic qualities in terms of service prototype effectiveness. The fourth hypothesis examines the impacts of service prototype effectiveness and efficiency on the stakeholders SPX. The fifth hypothesis examines the impacts of SPX on the stakeholders' intention to use in terms of degree of acceptance and adoption. The participants were observed when they completing the task as to write down notes on the participants' verbal feedback from the participants, to observe their reactions in the experiment, and to capture their observations during the experimentation. The duration it took each participant to finish the task was measured, in addition to the knowledge absorption duration that was estimated in the pre-test experiment, the errors and the requested explanations calculations as well. The observations produced from the participant's performance and their attitude during the experiment will be used as interpretations for the survey results. The objective is, after quantitatively validating the model and instrument, to have the experiment and results evaluated from an industrial stand point.

3.5. Statistical Analysis

In this study we are using both qualitative and quantitative approaches to validate our model. The qualitative approach concentrates on the discrete data represented in demographics of the participants, and in continuous data in the performance figures of our participants. The quantitative approach with ordinal data represented in demographics of participants, and in ratio data with the performance of the participants. To be sure which measurement model is the most appropriate for our study, we look at the literature for answers. According to Fornell and Bookstein (1982) if it a trait we are measuring then it is reflective, but if it is a combination then formative. Chin (1998) suggests that if there is a change in the construct and all the items changed in the same manner than the model is reflective, but if not then it is formative. Per Rossiter (2002) if the measurement is of consequences then it is a reflective model and if it of causes then it is a formative model. Jarvis et al. (2003) added that if the factors are mutually interchangeable then it is reflective but if it is not then it is formative.

We are then dealing with a formative model, where the direction of the causality is from the measures to the construct, as the correlation among measures is not required, and the indicators are not interchangeable, where the model starts with the structure and moves towards the factors, where the indicators could have a positive or a negative value (Hulland, 1999). This means a change in one or more of the indicators can cause changes in the latent variable. The focus of the formative measuring approach is to generally minimize the overlap between complimentary indicators (Diamantopoulos and Winklhofer, 2001). We will start with the research gap, which was deduced from the literature review, then create some hypothesis on who we think the research will go, after that we start experimenting. The modelling comes after the experiment, and then followed by the predication. Regression analysis is when we collect data on a system and we believe that a relationship between the variables can be measured and plotted (Ratkowsky and Giles 1990).

According to Abdi (2003) the partial least square regression (PLS) aims to maximize the covariance between the factors, starting by dealing with the outliers, then refining, validating and interpreting. The second stage of PLS is then the predictions, deviations and comparisons. PLS regression is most suitable when we need to predict a set of dependent variables from a large set of independent variables (Abdi, 2003). Regression is made to see why a particular value varies, and PLS is one method to do multivariate regression. Hypothesis testing is when we have a premise or a claim that we want to test or verify (Schaffer, 1995). In the statistical analysis we calculate the sample data used to decided either to reject the null hypothesis or fail to reject it (Lehmann and Romano 2006). Through the statistical analysis we will also check for the model and constructs for (1) construct validity, internal and external, (2) reliability, (3) applicability and replicability, and (4) the goodness of fit.

3.6. Experiment Preparation

The main goal of the study is to investigate the potential impacts of using immersive technologies on service prototypes. The first objective then is to recognize the immersiveness impact factors, which was done through the literature review and in previous studies. The second objective is to assess each of these factor's impact through experiments that will compare CSP and ISP performances. To be able to fully grasp the impacts of using immersive technologies on service prototypes, an instrument, model and experiment was created to determine these impacts and factors. The baseline experiment was conducted to foresee the impact of using a service prototype, or rather the lack of using. This baseline experiment explores the performance benchmark as to foresee how does the use of a service prototype affect the performance. The baseline experiment is done by doing the disassembly and assembly task without the use of any service prototype (assembly guide) as it will show us the performance and experience of completing the task without the use of any service prototype. The second experiment is the main SP experiment where participants used four different types of service prototypes, two of them conventional and two are immersive, and answer a survey after each service prototype task completion. The third experiment is an extension on the SP experiment with the addition of Mixed Reality Service Prototype to the experiment, as participant used the MRSP and then give their feedback in a survey form.

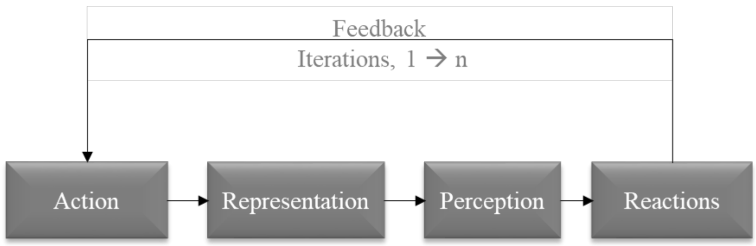

Figure 3.9 Simplified Service Prototyping Process

In Fig. (3.9) we present graphically a simple service prototyping process. This starts with an action or an idea, which could be in any form, this prototype main purpose is exploration and results in a representation of the idea. This representation will imprint an impression on the user, allowing users to experience the service idea before it exists through prototyping. Through this experience, the user will be able to perceive the idea and purpose of the service prototype used by means of experimentation. The reaction to the service prototype mainly to evaluate the prototype, which leads in feedback and then starting a new service prototyping iteration to improve on the prototype until the desired purpose is fulfilled. For any service prototyping process there is a purpose, the service prototype purpose may change with variations dependent on the service environment (Schrage, 1996). The service prototyping purpose was extensively discussed in one of our previous publications (Abdel Razek et al., 2018a) and in the previous chapter.

Table 3.2 Demographic Survey

Q ID	Questions	Rating scope	
		Rating	***Selected Option***
0	Please enter your subject ID and your experiment cycle	1	Cycle 1
		2	Cycle 2
		3	Cycle 3
		4	Cycle 4
1	Gender	1	Male
		2	Female
		3	Unspecified
2	Age Slice	1	17-25
		2	26-35
		3	36-45
		4	46-65
		5	66-75
3	Occupation	5	Professor
		4	PhD
		3	Academic Employee
		2	Student
		1	Other
4	Service Development Knowledge	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
5	Immersive Technologies Knowledge (VR, AR, MR)	1	No Knowledge
		2	Beginner
		3	Practitioner

		4	Specialist
		5	Expert
6	Service Prototyping Knowledge	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
7	Service Prototyping Experience	1	None
		2	Conventional Service Prototyping
		3	Immersive Service Prototyping
		4	Both
8	Immersive Service Prototyping Knowledge	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
9	Location	1	Furtwangen
		2	Laval
		3	Angers

A demographic questionnaire was constructed, as shown in Tab. (3.2) above, to identify the demographics of the participants where they have 10 multiple choice questions to fill out (question shown above in Tab. 3.2). The experiment is designed as a mechanical maintenance service task (disassembling and assembling) that participants perform with the support of the SP forms provided, which mimics a maintenance or service activity. The participant has to disassemble and then assemble a three-part metal construction with multiple bolts in multiple locations, by using a screw driver and the instructions understood or instructed from the SP. Each of these concentric parts are oriented to be assembled in only one orientation and order. These tasks are designed to simulate an industrial service process but in a controlled setting, i.e. academic. The SP forms used in the experiment will come in five different forms, two CSPs and three ISPs, all in the form of an instruction guidance prototype. The participants have to fill in a survey after each SP use and task completion. The first step in the experiments are the pre-test experiments these were done with several participants from all the different demographics, which is to simulate the expected participants' backgrounds to; (a) gauge the ability to efficiently complete the task, (b) asses the average knowledge absorption duration needed for each SP usage, and (c) improve on the current experimentation setup and process. The second step is the baseline experiment is to create a benchmark for the participants' performance, to see how will they fair in doing the task without the support of a SP. The third step is the SP experiments in order to validate the research model and instrument, including the extension MRSP experiment.

The observed performance of the participants in completing the task can be gauged by combing the (1) task completion duration, (2) errors calculations, (3) explanation requests calculations, and (4) participants' attitude. The task completion duration is measured by combining the time needed to absorb the knowledge, finish the disassembly and assembly tasks. The error calculations are: (a) usage error average per participant, (b) error opportunity rate is the number of errors of each participant is divided by the number of opportunities of error, (c) error frequency rate is calculated as participants made at least one error during completing the task are averaged, and (d) error intensity is the maximum number of errors made by one participant. The explanation requests calculations are: (a) usage explanation requests average per participant, (b) explanation requests opportunity rate, where the number of requests of each participant is divided by the number of opportunities of explanation requests, (c) explanation requests frequency rate is calculated by seeing which participants requested at least one explanation during completing the task are averaged, and (d) explanation requests intensity is the maximum number of explanation requests made by one participant. The attitude of the participants was observed by assessing the participants' facial expressions during the experiment and classifying them into three categories (1) happy, as the participants were visibly satisfied and enjoying doing the task, (2) neutral, as the participant looked impartial towards the prototype and task, and (3) frustrated, as the participants seemed visibly or orally irritated by either the prototype of the task itself.

3.6.1. Testing

In these tests several experiment factors and aspects were tested, and developed. These tests are designed to find out any lacking areas in the experiment before starting and to standardize some parameters for the experiment. These parameters might vary from one participant to another but it will give us an average that we can use in the analysis.

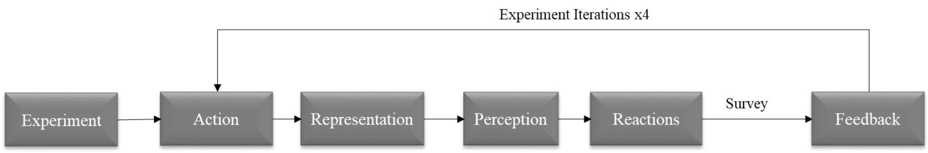

Figure 3.10 Simplified Test Process

The tests involved twelve participants with two conventional and two immersive service prototypes; where they will use the following prototypes; (1) VRSP through a VR simulation immersing participants, by using an Oculus Rift HMD, to explore an instructional manual animation of the three-part metal construction disassembling process and then and then actually disassembling and then assembling the metal construction in real life. (2) ARSP desktop application with a webcam to scan the marker and then overlay the simulation of each disassembling process on top of the live feed on a PC screen. In this case the participant will be simultaneously taking the instructions and completing the task. (3) PSP in the form of a paper instructional leaflet that includes all the required steps and clarification of every step, with also an illustration of each part of the three-part metal objects, the written instructions support the participant in understanding steps and then can be used to guide them through the disassembling and assembling process afterwards. (4) MSP in the form of a simulation instructional video of the disassembling and assembling process, the participants watch both videos then proceed with the physical task, and can use the video as a reference as well.

The participants had to also fill in the demographic survey at the start of the experiment session, and filled in a questionnaire after each SP use as to replicate the proposed SP experiment to foresee the average experiment session duration. These test experiments covered diverse backgrounds and experiences, ranging from students to professors, which was representative with the target group of the validation experiment. The test room was well equipped with cameras for observing the participant, and several screens and monitors to see the participant's action while in the VR simulation AR application, reading the paper leaflet, watching videos, and using the Hololens as well as doing the physical task.

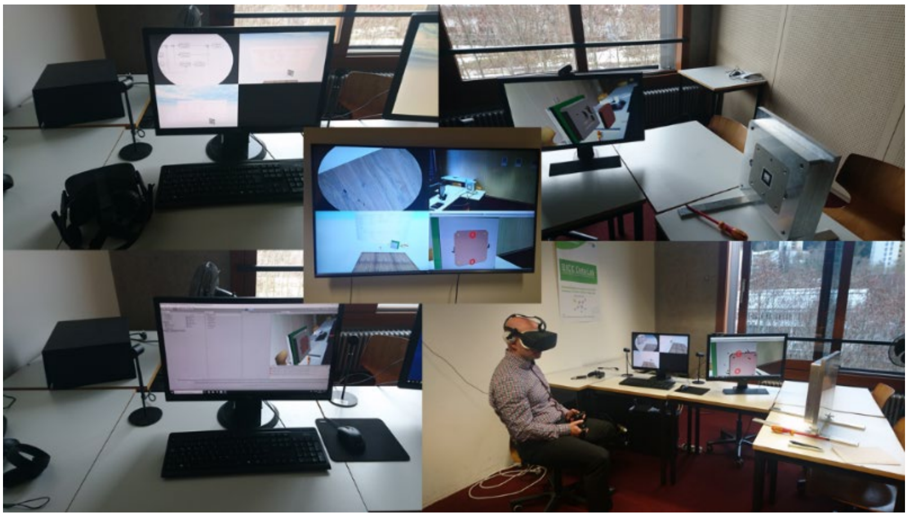

Figure 3.11 Collage of Test Setup

Fig (3.11) above shows the test setup and the shape of the metal object, the video recording technique, the room, the HMD equipment, and a picture of the first test. The test also showed that if the participant felt they were rushed or that there is some kind of time challenge involved they tend to either hurry up and try to cut corners resulting in errors or explanation requests. That is the main motivation to fixing a standard time for the knowledge absorption as to have an average duration that can be used in the calculations and statistical analysis; as some participants might enjoy VR and would want to stay longer just for the fun of it, and others might skim read the paper leaflet as were bored quickly of reading. We experimented separately how long it will take to read the PSP, watch MSP, and explore VRSP. This was done within the test experiments to estimate the average duration of the knowledge absorption for each of these 3 SP forms. This makes sense because there is a difference in speed of reading, exploring and watching these SP forms, so this was made to have a fixed estimated knowledge absorption duration. This was also made to negate the fact that some participants will be playing or having more fun with some SP forms, which will in then will take a longer duration. We should include the duration of learning before starting the task, this was calculated on average from the experiment tests, as there is the possibility that some participants will be playful with the immersive SPs, or some might take longer in reading the PSP or playing within VR or with the AR markers. It was observed with the first 30 participants, that the calculated knowledge absorption duration averages, which were calculated in the test experiment were valid, and didn't have big variations in the knowledge absorption durations.

The number of errors opportunities during the completion of the task was counted on both disassembling and assembling processes. The error opportunity number was found to be 20, as the participants had twenty opportunities to make errors in disassembling and assembling the assembly parts. The number of explanation requests opportunities during the completion of the task was also counted on both disassembling and assembling processes. The explanation requests opportunity number was found to be also 20, as the participants had twenty opportunities to request for further explanations in disassembling and assembling tasks. The average durations needed for knowledge absorption for each of the SP forms was averaged from these tests, as it will be more feasible task to add on the knowledge absorption average on the completion times, as to have an individual clocking and pushing participants to be as "efficient" as possible in the learning and might create more errors. These average durations are (1) four minutes for the VRSP as the four minutes represents the average duration it took the participants to finish the VR simulation (2) four minutes for the PSP, as it takes on average that long to read the paper instructions, and (3) three minutes for MSP, the three minutes was calculated as it is the durations of both the videos used in MSP.

The results of the test were also the reason that we changed the HMD equipment from Oculus Rift to HTC Vive, as the Vive has a much better movement option and higher resolution as well. The duration of the whole test was also optimized after the pre-tests experiment to be one hour for each participant as more than it will be hard to find volunteers for the experiment. Concerning the AR there were also some optimizations. It was decided to use a mobile version on a tablet or a large screen mobile with a stand that holds the device in place right in front of the metal construction for ease of use; as the webcam resolution is outdated and was sometimes flickering or losing the marker causing the participant. The comments of also working hands free was noted from several participants of these tests, that was the motivation on creating an additional SP form to add the experiment that fulfils that need. The Microsoft Hololens allows its users to be able to see and interact with holograms and digital information hands-free. A MRSP simulated digital instructional manual was developed for the Hololens with the same task sequences as an ARSP with an air tap interaction instead of having a marker recognition system. This MRSP will be then used in the SP experiment afterwards.

3.6.2. Baseline Experiment

This base-line experiment is conducted to help establish the benchmark of the experiment; by starting by the most complex situation without any support. A small number, 30 students, of participants will start by directly to do the physical task individually without any use of SP. The participants' objective in this experiment was to try to disassemble and then assemble or vice versa depending on the starting point of the experiment, 15 participants started with disassembling and 15 participants started with assembling. The baseline experiment had three main metrics and observations to take note of (1) Were the participants able to complete the task? If yes, then how long did they require to do so? (2) How many errors did each participant have? (3) How many explanation requests were made by each participant? The participants have to do so without the assistance of any SP form, while allowing them to ask me questions as to guide them to what might be the correct the procedure for disassembling or assembling. The observer's role in this experiment is (a) to clock the duration needed from each participant to complete the task, (b) calculate the errors calculations, (c) explanation requests calculations, and (d) to observe the participant's behaviors while completing the task.

The participants then have to complete the task without the support of any SP, and a small open discussion with the participant after the task completion is conducted, which revolved over three central points: (I) What was most challenging thing during the disassembly and assembly task? And why? (II) What forms of instructional leaflet would provide the best support for this and similar tasks in their opinion? And why? (III) If there were any other comments on the task? The durations were clocked with a computer based stop watch, and all the data directly noted in an excel file, including errors, and explanation requests. The baseline experiment showed that for even a perceived relatively easy task can be challenging when not given any clue on how to start or where to start. This was also shown in the baseline experiments, as the participant's attitude were mostly negative and their average task completion duration was extremely high, with a high amount of errors and explanation requests as well. The baseline was important for having a feel to what a service user would go through if they don't have any kind of support, for example if you get an IKEA piece of furniture and you had to put it together without looking on the instructions.

3.6.3. SP Experiment

The SP experiment has been designed to engage participants perceptual, emotional and cognitive aspects. There is a need of a wide base of participants, more than 100, with different levels of knowledge and experience, which was provided by both institutes of Arts et Métiers ENSAM and Furtwangen

University. The experiment sessions were carried out in an academic context, in order to validate the research model and instrument, as conducting a novel approach like this needs to be tested in a controlled environment first. The industrial workshop and focus group discussions were conducted in an industrial organization with industrial stakeholders to evaluate the service prototyping process and the experiment's results. The experiment results are then aggregated from the survey rating, survey rating justifications, and participants' performance and attitude observed. The observations, task completion duration, errors calculations, explanation requests calculations, attitude of the participants The participants' performance is observed from the task completion duration, error calculations (average per participant, opportunity rate, frequency rate, intensity), and explanation requests calculations (average per participant, opportunity rate, frequency rate, intensity). The participants' attitude is also observed by their visual (facial expressions) and classified into three states, happy, neutral and frustrated. The tasks were clocked from the moment that participant starts the disassembly or assembly task till the end of each of these tasks. The duration needed to complete the task includes the knowledge absorption duration. Explanation requests were the only way the participant got some sort of instructions or guidance in completing the task, as all the participants are allowed to request explanation when they needed it. During the experiment one researcher observed the participant's actions and reactions; even when they were immersed in VR, observation on what they were doing was done through a monitor. Every participant's interactions on using the ARSP was done through the tablet and the AR App. Physical observation was done also while they were using PSP and MSP and see if they needed any support. The duration of each task was recorded as well as noting their attitudes, comments, explanation requests, and errors.

The demographic survey consisted of 10 multiple choice questions (see Table 3.2): The 15 questions bipolar survey that the participants filled after each use of an SP form and the completion of the assembly task was constructed to gauge their (1) immersiveness or the immersive experience (IX), (2) real world dissociation (RWD), (3) service prototype effectiveness (SPE), (4) service prototype experience (SPX), and (5) intention of acceptance and adoption of the service prototype (ItA). The survey was constructed with an embedded quantitative qualitative bipolar questionnaire with a semantic scale, where each bipolar question has a justification element to justify the rating in free text form. The survey allowed each participant to justify their given rating, as these justifications give an overview on the usage: To give an overview on the justification a table was constructed with the three most mentioned justification of each question, and the number of times that these comments were mentioned. The sentiment of the participants was also deduced from the wording used in their comments. The sentiment analysis was done with the same methodology as before where +1 is positive, 0 is neutral, and -1 is negative. The participants used many words to justify their ratings, and by combining them all together in a cloud of words.

These physical tasks are guided by the different instruction forms: (1) PSP includes all the necessary steps and explanation of every step through the CAD drawing of each part of the three-part metal object (Video: https://youtu.be/YcQ6fn9KN_c); (2) MSP contains a replication video of the assembling and disassembling processes to show to the user how to do it correctly (Video: https://youtu.be/JQTmSKRnqcQ); (3) VRSP for immersing the user through an HTC Vive HMD to explore and interact with the instructions in a virtual environment (Video https://youtu.be/j7Oai6jqKO4); (4) ARSP uses a tablet device to overlay the instructions of each disassembling and assembling step directly on the physical metal construction (Video https://youtu.be/37ZXbGF1npI); and (5) MRSP that uses a MR Hololens to project a holographic instructional guidance for each of the disassembly and assembly process by projecting the necessary steps on the metal part (Video https://youtu.be/QgSxmYYNR_I). The first experience with the SP forms results in stakeholder's experience that induces user's reactions and feedback that is collected and analyzed along with my observations. These service prototype forms will have different user first time reactions and feedbacks, so a form cycle was devised to have each SP form used as the first form to eliminate biasing.

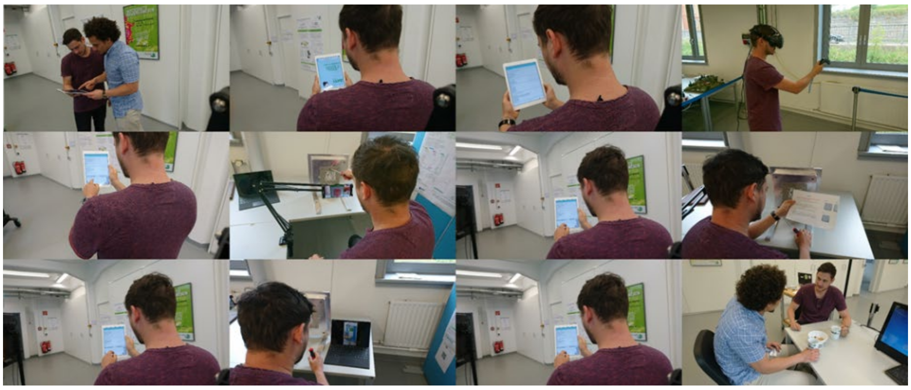

Figure 3.12 Experiment Picture Protocol

Fig. (3.12) above illustrates the experiment protocol where every participant: (1) receives a verbal briefing and a video briefing (in some cases printed put in PDF); (2) fills out demographic questionnaire; (3) proceeds with their experimentation part according to their experiment cycle, (4) answers the bipolar survey after each completing each SP and assembly task, and (5) experiencing all of the SP forms, and then debriefing. The experiment will be conducted in four different cycles; meaning that each group of participants will start with a different service prototype type. The SP cycle that the participant starts with changes every set of participants to eliminate biasing as well, a depiction of the experiment can be seen in the following video (https://youtu.be/o8K18Q_cG4k).

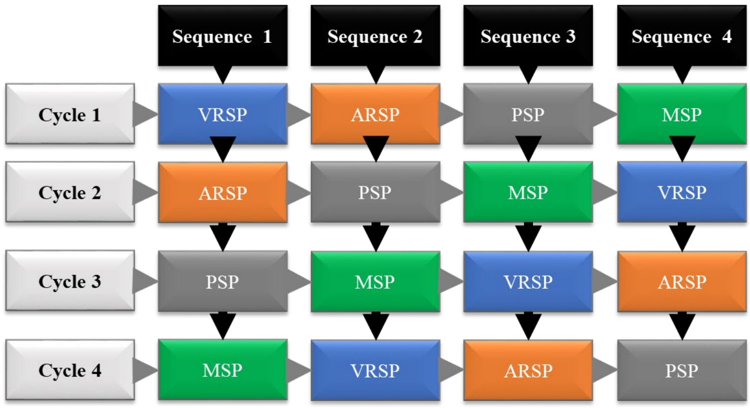

Figure 3.13 SP Cycle and Sequence

The experiment cycle consists of the combination of the SP forms used in a specific order, as shown in Figure (3.13) above. Every participant had to experience each service prototype form and provided their feedback in filling out a bipolar survey. The overall duration of a participant's session was about one hour to complete the two tasks four times using the four different forms of service prototype and filling out the survey as well. During the experiment one researcher observed the participant's actions and reactions; even when they were immersed in VR, observation on what they were doing was done through a monitor. Every participant's interactions on using the ARSP was done through the tablet and the AR App, which could be observed from a distance. They were also observed when using PSP and MSP to see if they needed any support. The duration of each task completion was recorded as well as noting down their attitudes, comments, explanation requests, and errors.

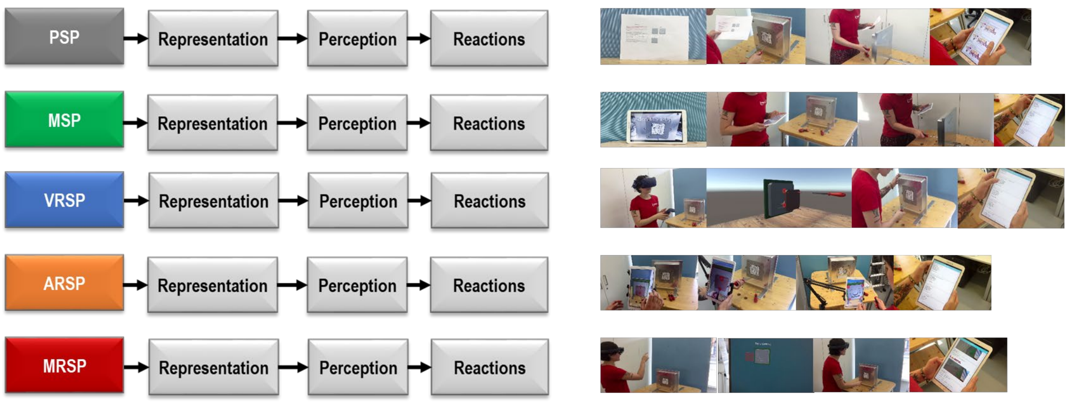

Figure 3.14 SP experiment Process

The participants had to fill out four bipolar surveys throughout each individual SP form use, as shown in Fig. (3.14) above. The experiment is conducted in different cycles as the same order might influence the answers of the participants due to implicit knowledge. The participants were all assigned different SP cycles, as to eliminate biasing from doing the task with the same SP form at the start or end of a cycle. Our strategy is to identify the difference in performance, eXperience, intention to adopt and attitude of the participants according to their demographics identifiers. Then we classify these differences and foresee if there are similarities between the participants' demographic identifiers groups and SP forms. The aim is that after validating our model and instrument, to present it in an industrial focus group to see their opinion. This industrial focus group engages industrial service stakeholders in presenting the service prototyping process, and the experiments results and findings opening a discussion over service prototypes and to evaluate the experiment, this all is discussed in a later chapter.

3.6.4. Experiment Mixed Reality Extension

Unfortunately, the Hololens device was not available for use at the same time as the other devices. The MRSP part was not done concurrently with the other four SP forms as the Hololens, MR device, was not available for use at the same time of the VR and other devices. A Mixed Reality holograms guiding the user by projecting holograms through the Hololens of the user to guide them in the disassembly process. The experiment sessions were conducted at the Furtwangen University at the Service Competence Centre with 30 volunteer participants, mostly students. In MRSP the participants have to air tap on the hologram instructions to get the next steps in the disassembly and assembly guide. The participants answered a smaller demographic survey as all of the volunteers were contacted through the courses that I teach or through direct conversation in the service competence center, where the experiment was conducted. The participants then proceeded with using the Hololens with the MRSP instructional visualization to simultaneously complete the task. They then fill in the same survey used in the validation experiment. The collected data were clustered to several data sets; the first set of results is the demographic data of the participants; the second set of results addresses the answered bipolar survey; finally, the third results set reflects the observation metrics. After the SP experiments, there will be future testing in an industrial context, with industrial stakeholders this is to test the refined validated model in a real scenario to be able to see the impact in an industrial context. I will also conduct several industrial workshops with industrial partner organizations to demonstrate the facets and applications of ISP.

3.7. Industrial Workshop and Focus Group Discussion

The aim of the industrial workshop and focus group discussions is to gauge the industrial acceptance for service prototyping process and the use of service prototype in an industrial setting. Liebherr company was very interested in conducting further service prototyping disucssions as we had a previous cooperation with them in a research project, and we conducted several workshops at their headquarters to clarify what could be done with service prototypes, and how to develop services by using service prototypes. Another reason for choosing Liebherr is that actually hired new employees to handle service prototyping processes after we conducted our workshop there, which shows that they were convinced on the advantages of using service prototypes. Liebherr management asked us also to conduct the focus group discussions after we finished the experimentation, so the interest was mutual from both sides. They then invited me to their headquarters for two days of focus group discussions, where they invited all the service interested employees from the different divisions to attend the focus group sessions within the two-day span. Two days of focus group discussions to explore, evaluate and communicate service prototyping, service prototypes, and SP Experiment. An elaboration on what has been done in the field of service prototyping in the past three years, and what was found through the investigation was presented. Also the three purposes for service prototyping exploration, evaluation, and communication were interpreted; while using the experiment as an example of using service prototyping for industrial service training. The main objective is to help foresee the industrial applicability, acceptance, adaptability and degree of recommendation.

As we already conducted several service prototyping workshops at the Liebherr group, they contacted us to inform us that they would be interested in partaking in a workshop and several focus group discussions. Liebherr was founded in1949 by Hans Liebherr where it started out as a machine factory in Kirchhoff, Germany, now as the foundation stone for the Liebherr group with over 46,000 employees worldwide. The workshops were conducted before for the head of divisions and also for the employees of the earthmoving technologies division. This division generates the highest turnover within the Liebherr group of companies with almost 3 billion euros in 2018, as seen on their website, and is characterized by a diverse portfolio in the field of earthmoving technologies and material handling machines. The focus group discussion participants were from several divisions from Liebherr, with almost all of them working in industrial services.

3.7.1. Workshop

The industrial workshop was divided into three sessions on two days, as there were several industrial participants that were interested and it was better not to have too many participants at the same time. Before presenting the workshop, a survey was conducted to know more about the demographics of the participants, and to gauge their knowledge, interest, confidence and acceptance levels in service prototyping and immersive technologies. Each participant had to fill an entry survey before the presentation and then an ending survey after the discussions was over. The entry survey inquired about the participants’ (1) age slice, (2) vocational area, (3) number of years employed, (4) familiarity with the service prototyping, (5) familiarity with immersive technologies, (6) level of knowledge in service development, (7) level of knowledge in service prototyping, (8) level of knowledge in immersive technologies, and (9) expectation from workshop and focus group discussion. The workshop included a presentation on service prototyping to introduce the concept and the definitions needed to be able to grasp the topic. The workshop then proceeded with explaining the latest findings about service prototyping in the literature. Some of the participants already had either a good idea or at least some sort of an idea on what is service prototyping, as we have had several workshop at Liebherr before.

The next part of the workshop was mainly to explain the added value from service prototyping for an industrial company, and especially Liebherr. The workshop also covered the why use and how to-use service prototyping. The support of service development process was the main focus, however the tools and methods that are used to integrate multi-dimensions of the service in a prototype were also discussed. A simplified and rapid service prototyping process was presented to be utilized by the company in the future. The second part of the workshop was mostly about the study, and the context, goals, plan and experiment. The results of the SP experiment were presented and discussed in the presentation of the workshop. Then it proceeded with asking them about their actual use cases at Liebherr. The workshop ends by discussing with the participants their specific questions on the study, experiment, results, and implications, and them filling in an exit-survey after the group discussions.

Figure 3.15 Collage of Pictures of the Workshop at Liebherr

3.7.2. Focus Group Discussion

The focus group discussions were conducted on two days after the three separate workshops. They were conducted at the Liebherr training academy, where each session took approximately three hours including the presentation and discussions. The workshop included a presentation of our latest findings in service prototyping and experiment results. This included the experiment reasoning, setup, results and conclusions, while the focus group discussions included open ended questions.

Table 3.3 Focus Group Discussion Open-ended Questions

Questions	Open ended Questions
1	To what extent are you ready to use service prototypes?
2	What do you think of the results of the research study?
3	How do you assess the effects of:
3.a	Experiencing a service that does not exist yet?
3.b	Communicating a service idea that does not exist yet?
3.c	Evaluating a service that does not exist yet?
3.d	Learning a service that does not exist yet?
4	Do you see benefits for using service prototypes?
5	How do you see the use of service prototypes in service development at Liebherr?

We proceeded with asking the participants five open questions to engage in a discussion with the participants, these discussions will be crucial on gauging the participant's state of mind on the topics of service prototype application and immersive service prototypes. The open ended questions that were asked are shown in Tab. (3.3) above. After the workshop and the focus group discussion the participants had to fill the second survey after the workshop and focus group discussion. The participants fill out a bipolar survey on their satisfaction, acceptance and also their feedback, where they answered question: (1) rate current level of familiarity with service prototyping (2) rating current degree of technical acceptance, (3) rate current degree of adoption, (4) rate current level of service prototyping knowledge, (5) rate level of immersive technologies knowledge, (6) if their expectations were fulfilled. The discussions will be recorded and the data will be combined with their survey results, as the relevant information was collected and presented in the findings section and the discussions transcript used to create a cloud of concepts. The participants were also given handouts after the discussions were over for future reference and utilization.

3.8. Summary

The experiment engages the participants with two CSPs where participants read a leaflet, watch a video and use three ISPs where participants interact with objects within a virtual reality environment, in an augmented reality environment, or in a mixed reality environment. All participants utilize these SPs to complete the disassembling and assembling tasks by using the support of each of the different SP forms. The mechanical element to disassemble/assemble is composed of a three-part metal construction with coinciding unique components. The three-part metal construction has multiple screws and bolts in multiple locations, which needs to be unscrewed/screwed. Participants' attitudes were observed during the completion of the disassembling and assembling tasks when each participant reacts in the stressful situation of completing these tasks. The observations made during the two experiment sessions were noted and saved in an excel sheet as following: (1) clocking with a chronometer the duration of disassembling and assembling tasks; (2) counting the number of errors; (3) counting the number of explanation requests; and (4) capturing participants' attitude (facial expressions) during the completion of the two tasks (including 3 attitude options: (a) happy meaning that the observer could detect a smile or positive facial expressions; (b) neutral meaning that the observer could not decode the participant's facial expression; (c) frustrated meaning that the observer could see that the participant is sad or has a negative facial expression).

Every participant had to experience each of the service prototype form, complete the task, and provided their feedback in filling out a bipolar survey. The survey contained fifteen semantic scale bipolar questions, each question represented one UX property, and each three of these properties constituted a lower construct, and each several lower construct constituted a higher construct. The ratings ranged had a semantic scale from [-2] representing very weak, [-1] weak, [0] moderate, [+1] strong, and [+2] very strong. The overall duration of a participant's session was about one hour to complete the two tasks four times using the four different forms of service prototype and filling out the survey as well. This survey is composed of bipolar questions with justifications space for each user to elaborate on their answer, allowing the data to be collected, analyzed and interpreted at the same time. This bipolar questions data will flow in the quantitative findings and the data from the questions' justification part will flow in the qualitative ones.

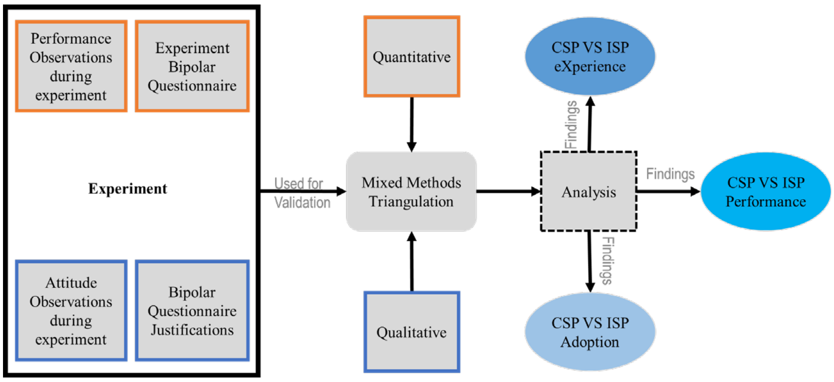

Figure 3.16 Summary of the Methods

In Fig. (3.16) above we summarize the methods and expected findings in a graphical form for a better understanding of the methods, and the findings. As shown in the baseline experiments, validation experiments, and industrial focus group discussions collected data combined with my observations during the experiment will be used to validate the model and instrument. The validation will be done with the triangulation approach to enable the proof through cross verification from more than one data set. Since this is a novel research stream of service innovation and immersive technologies. Then an experiment to verify this conceptual explorative research, according to a predetermined set of SP forms, in a specific service use case that can be scalable and feasible as well.

4. Findings

4.1. Introduction

The SP experiments were conducted at the Furtwangen University in Germany, and Art et Métiers ENSAM at both Angers and Laval campuses in France. The academic setting was best suited for such an exploratory research, which a wide-base of participants is present. The campuses all offer a wide-base of participants with diverse backgrounds, knowledge levels and experiences. The experiment was created to dynamically engage the participants starting with (1) answering a demographic survey, (2) then proceeding with several conventional and immersive service prototypes and mechanical four-part construction; where they will use the prototypes to complete the disassembling then assembling tasks, afterward (3) filling in a bipolar survey on what they used and did. The experiments comprise of baseline experiment, validation experiment, and MR extension experiment. The experiment objective is to uncover the impacts of using service prototypes and immersive service prototypes, and if there are significant differences between the SP forms. The findings presented in this chapter are the results of the SP experiments, and the industrial focus group discussions done afterwards.

The demographic questionnaire is intended to make distinctions on some specific attributes, such as: (a) gender; (b) occupation; (c) age; (d) knowledge; (e) experience levels, among the participants later on during the analysis. The baseline experiment's objective is to foresee the impact of not using a SP to support the completion of the task. The baseline experiment was conducted with thirty student participants with an experiment duration average of thirty minutes per participant. There were several tests conducted to establish the duration needed for knowledge absorption for each SP form, and to improve on the experiment overall methodology and setup. The SP experiment starts then by the participant using each one of the SP forms resulting in an experience that provokes a reaction that in turn creates feedback, which then results into different experience and feedback from each SP form and each participant. The SP experiments main objective is to show the differences between different SP forms and to verify the research model and instrument. The main SP experiment was conducted with four SP forms, VRSP, ARSP, PSP and MSP this experiment had an average of one-hour per participant with a total of one hundred and two participants from various backgrounds. The SP experiment was conducted in different cycles; meaning that each group of participants started with a different SP form, to eliminate biasing due to latent knowledge from use of any SP form. The extension experiment was conducted with only MRSP as the Hololens (MR) device was not available at the same time as the other VR and AR devices. This extension experiment was conducted to compare the performance, experience and acceptance of MRSP with the other four SP forms. The extension experiment was also conducted with thirty participants where each experiment session took approximately twenty minutes. The experiments findings are shown in the following order, (I) baseline experiment results; (II) model statistical validation findings (III) SP experiment results; (IV) industrial workshop and focus group findings, and the (V) summary which recaps the results of the experiments.

4.2. Baseline Experiment

The baseline experiment sessions were conducted to create a benchmark for the task observations and to get participant's feedback. The performance measurements observed were the (a) task completion duration, (b) errors made and (c) explanations requested; as to compare it with the performance of SP Experiment. The participants have to complete the task without the use of any SP form to support them. The baseline experiment was conducted fully in the service competence center at the Furtwangen University, as it was the best-equipped location to accommodate the 30 participants that volunteered to participate in the experiment. These 30 participants were all students, ranging from 18 to 28 years old, mainly engineering and computer science students. For this baseline experiment, participants had to fill out a three qualitative questions survey. The three questions were to ask about the what was the biggest hurdle, what would they recommend to use to complete the task, and if they had any other comments. These answers were then translated from German and transferred into the excel file for further analysis. The results are divided into (1) durations results, (2) errors results, (3) explanations results, and (4) participants' survey feedback.

4.2.1. Observations Results

The baseline experiment performance results are the durations, errors, and explanation requests calculations from the 30 participants that participated in the baseline experiment. The durations were clocked by using a chronometer, and was then typed into the excel file, the durations were clocked from the start of the participant trying to disassemble or to assemble until the task has been completed. The participants were allowed to ask as much as they needed, which most participants did, and they mostly used the trial and error method. Almost all the participants had some kind of issue with the starting point that reflected on the durations captured, explanation requested, and errors made as well.

The participants in the baseline experiment were all students of the service management program, where most of them had some form of immersive technology and service prototyping experience through classes or lab experiments. The ratio of volunteered participants was 27% for female and 73% for male, which is also similar to the population of the SP experiment participants. The participants' observed attitude according to their facial expressions was noted to gauge their attitude towards completing the task with no support of any SP form. The participants were visually frustrated as only 2% of the participants were visually happy, while 77% were frustrated and 35% were neutral or uninterested.

4.2.1.1. Task Completion Duration (disassembly/assembly)

The durations are representing the time each participant took to complete the dissembling and assembling task of the metal construction. Half of the participants started with disassembling and then proceeded to assemble, and the other half of the participants did it vice versa. The total task completion duration ranges from the fastest to the slowest duration of all the participants of the baseline experiment. The fastest participant to complete the task took a duration of four minutes and forty-three seconds, and the slowest was nineteen minutes and thirty-seven seconds, while the average duration was eleven minutes and nine seconds. The task completion durations show that most of the participants faced challenges in completing the task. This indicates that even for such a simple disassembling and assembling mechanical task some kind of instructions or guidance is needed to make the task much more doable for the participants. The task completion duration could be considered as a sign of efficiency, so the faster the participant finishes the task the more efficient the participant in completing the task. The slow task completion durations can be attributed to several things, but the lack of any guidance or instruction manual to orient neither disassembling nor assembling process might have been the main hurdle. It was found that many participants tried to complete the task as fast as possible but then made many errors due to the complexity of the part’s shapes and sequence, as each part fits only in one position and in one place. Some participants thought that they completed the task and then found an unused screw or an incorrect fit between the mechanical parts, which led to an abundance of errors and explanation requests (i.e. trial and error). The participants were mostly approaching the task with a trial and error mindset, where they tried to put the parts together and when they felt they made a mistake they either asked, or started again from the previous step.

4.2.1.2. Error Calculations

The error figures show there were a number of issues and challenges that the participants faced to complete the task. The average SP usage error rate can be construed partially as an effectiveness indicator, as it decreases when the number of errors made increases, meaning that errors is inversely proportional to the degree of effectiveness. The ranges of the errors committed by the participants during task completion is ranging from zero errors, which was the case from only two participants whom didn’t commit any errors while completing the task. The error opportunity rate was 21.50%, which means that the participants committed errors in more than fifth of the opportunities available to make errors. The error frequency rate was 90% of which participants have committed one or more errors either in route of finding the next step or when unsure about a fit or sequence. The error intensity was eleven errors, which is a considerable number of errors compared to the other participants, as most of the participants committed between two and six errors. The minimum amount of errors done by any participant was zero errors, and only two participants managed to achieve that. The mean is approximately four errors, and only three participants had exactly four errors while completing the task. The most errors committed by one participant in both disassembling and assembling combined was eleven errors, and only one participant committed that many errors. These numbers show that more than 90% the participants were not effective in completing the task without an SP, as they committed one or more errors in the process.

4.2.1.3. Explanation Requests Calculations

Explanation requests were the only way the participant got some sort of instructions or guidance in completing the task, as all the participants are allowed to request explanation when they needed it. As shown from the number of errors, the participants were having a hard time completing the task that led to more explanation requests from the participants. The explanation requests could be considered as an indicator of effectiveness, as the more participants request explanations the less efficient they become as they will require more time. The average explanation request per participant was around four and the least amount of explanation requested was zero, where only two participants from the thirty participants managed to finish the task with no explanation requests. The explanation request opportunity rate was 21.67%, which means that they request explanations in more than fifth of the opportunities available. The frequency rate was 93.33% of which participants requested explanation while doing either disassembling, assembling or both. Most of the participants requested between two and six explanations, as the explanation requests intensity from one participant was nine. The mean average also lies within the median range, and only four participants had exactly four explanation requests, where only four participants managed to finish the task after asking for four explanation requests each. The most explanations requested was nine requests, and there were three participants that requested that amount of explanation. This shows that 10% of the participant had the most amount of explanation requests compared to the rest of the participants. The efficiency and effectiveness is also then low, as the participants will take longer due to requesting explanations and making more mistakes.

4.2.2. Qualitative Results

There was a small survey for the participants to fill out where the participants were asked three questions after completing the task in an open discussion setting. Their answers were written down on a paper, and discussed verbally afterwards. The first question was to see what was the biggest hurdle or challenge in completing the task without the use of any instructions. The second question was to ask if they can think of any kind recommendations of tools or technologies that they could use to make completing the task more efficient. The third question was if they had any other comments after completing the experiment not related to the first two questions.

4.2.2.1. **“What was the biggest challenge that you faced in completing this task?”**

That is the first question in the survey that participants answered after they have completed the task. The participants had almost a consensus on the biggest challenge that they faced; as twenty-two participants, which is more than 70% of them, had challenges with the positioning, order, fit or combination of several of them. This is due to the fact that the metal construction is made out of three concentric-nested metal pieces that might look simple in construction, but each piece only has one orientation, fit and position to assemble or disassemble from. This is understandable as the participants were students and most of them have less experience with such assembly tasks, which can include intricate details to the process. The second most mentioned challenge issue was the lack of visualization of the final shape or design, where five participants, which is more than 15% of the, mentioned that they either can’t visualize the steps or the final design or both. This shows that it is an issue if the participants don’t have an idea about the final step or what would be the desired result of the process. The third most mentioned comment on the challenge faced, was the missing information that they don’t have, like dimensions, weight, hazard instructions, etc. These comments were from three participants (10%), so this might be also an issue with having no instructional manual for the process as you might have a higher risk of injury due to the lack of information.

Table 4.1 Participants’ Feedback: Top Commented Challenges

Top Comment about Challenges	Number of Comments
Issues with positioning and order	22
Can't visualize the steps or final design	5
Weight and dimensions of the parts	3

The top comments concerning the hurdle in completing the task is summarized in Tab. (4.1), where the top challenges that faced the participants, as communicated by them in the discussion afterwards, are listed with the number of times that participants mentioned them in the evaluation stage. The challenges can be summarized as (a) the positioning one of the parts, as each part fits in only one position and orientation, (b) disassembling and assembling order was problematic for the participants as seen from their feedback, (c) the parts were heavy and non-uniform and hard to handle, and (d) the information about weight and dimensions are lacking.

4.2.2.2. **“what would you recommend to complete the task more efficiently?”**

After they completed their task, participants were asked to answer this second open-ended question. The participants had mixed answers to this question, which shows diversity in the answers in contrast to the first question. The most mentioned comment for recommendations was to use a video demonstration to help in completing the task, where six participants mentioned that comment, which is 20% of the participants. The MR hands-free recommendation was the second most stated comment, with five participants or almost 17% of the participants recommending it. The participants also mentioned that a paper instruction would be sufficient or at least helpful in completing the task, this comment was mentioned only four times, which is almost 14% of the participant, making it the least mentioned recommendation comment provided.

Table 4.2 Participants' Feedback: Top Commented Recommendations

Top Comment about Recommendations	Number of Comments
Video demonstration	6
MR Hands-free guide	5
AR step by step instructional manual	5
VR Simulation for training	5
Combination of different instructional forms	5
Paper instructions	4

The participants' comments can be summarized, as shown in Tab. (4.2) above, in that they all recommended using some form of (a) demonstrator, (b) assembly guide, (c) instructional manual, (d) training simulation, (e) instructions manual, and (d) a combination of different instructional or guidance forms. This shows that the participants were up-to-date with the newest advancements in the assembly and instructional manual services as 50% of the participants recommended some form of immersive instructional manual, guide or training. The feedback also showed that the participants also had a similar thinking to what the SP experiment has to offer. As in the SP experiment a VR training simulation (VRSP), an AR step by step instructional manual (ARSP), a video demonstration (MSP), and a paper instructional manual (PSP) are used. To be able to graphically display the recommendation comments from the participants in a meaningful manner, a word cloud was generated from their comments as shown in the appendix.

4.2.2.3. "what other comments do you have not related to the first two questions?"

These comments concern the baseline experiment as a whole, as the participants were given the freedom to give their feedback on any part of the experiment. As shown from their comments, it mostly revolves around the same concepts as before, (1) assembly task steps, (2) potential of hands-free working, (3) complexity of assembly process, and (4) instructional manual form, these comments were also mentioned in the previous two questions. The majority of the participants found it hard to start the experiment without any instructions or a finished design to orient themselves on. All the participants were all students, as such they are mostly not trained for such situation as they have limited real life industrial assembly experience.

4.2.3. Summary

The participant with the most errors and explanation requests commented in the challenges questions that "*Positioning and fitting of the parts were the biggest issue*", they added that the participant "*would recommend a video of the task being completed for replication of task*", and they finish the comments by adding that he "*didn't understand how it will look, very hard to visualize without a manual or guide*". The comments that the slowest participant replied for the biggest challenge question was "*Didn't know how and where to take off the parts first? And what to do next?*", and this is what he had to say for the recommendations question "*An AR guide would have been good to have for step by step instructions*", and the last thing the participant added in the other comments section was that "*MR would work better for an industrial environment*". The fastest participant had previous experience with mechanical assembly from their previous technical studies, which they mentioned that "*did similar process in my practical studies*" in the answer of the biggest challenge that faced them, they answered the recommendation question that they think "*paper with simple drawing*" would suffice, and added in the other comments section that "*MR would be better for understanding*". A performance, and experience comparison was made to foresee if there are any differences in the of the participants in regards to their gender.

The baseline experiment succeeded in showing that even for such a simple process, communication is crucial for completing the task successfully and efficiently. The participants were able to finish the assembly tasks but they faced many challenges and issues in the process, which is represented in the comments, as well as the performance metrics. The fastest participant to complete the task was one of the two participants to complete the task without any errors and explanation requests as well, finishing the task in only four minutes and forty-three seconds. The slowest participant to complete the task had a task completion duration of nineteen minutes and thirty-seven seconds with eight errors, and four explanation requests. The average task completion duration was just over eleven minutes, and the average errors committed and explanation requested were both 4.3 per participant. The participant who made the most errors also requested for the most explanations, this participant had a task completion duration of fourteen minutes and forty-one seconds with eleven errors and nine explanation requests. The participant's feedback show that the participants wished for any kind of support or guidance, which shows that even some simple 3D drawings, pictures, or animations would have made a big difference. The participants also expressed that a step by step guide is somehow necessary even for simple processes. They also added that MR devices offer the extra advantage of hands-free working, which would be more appropriate for similar assembly tasks. They also argued that visualizing the final design or even the next steps without any support is challenging. One participant even added that he had a totally different concept of the design before finishing the task, which shows that even for such a simple assembly task, confusion is bound to happen when no communication takes place.

Table 4.3 Summary of Baseline Experiment Results

Observations	Average	Female	Male	Diff. Female/Male
Task Completion Duration (TCD) [min:sec]	11:09	11:21	11:04	3% slower
Usage Error Average Per Participant (EA)	4.3	3.63	4.55	20% lower
Error Opportunity Rate (EOR)	21.50%	18.13%	22.73%	20% lower
Error Frequency Rate (EFR)	90%	87.50%	90.91%	4% lower
Error Intensity (EI)	11	10	11	9% lower
Explanation Requests Average Rate (XA)	4.33	4.63	4.23	9% higher
Explanation Requests Opportunity Rate (XOR)	21.67%	23.13%	21.14%	9% higher
Explanation Requests Frequency Rate (XFR)	93.33%	87.50%	95.45%	8% lower
Explanation Requests Intensity (XI)	9	9	9	No diff
Green = Higher (Positive), Yellow = Equal (Neutral), Red = Lower (Negative)				

A sentiment of frustration was observed from most of the participants as soon as they started the task, and it worsened for some throughout the disassembly and assembly. It was also observed that most of the participants preferred to start first with trying to figure out where and how to start then they tended to ask after they faced their first issue or challenge. Some participants started directly by requesting explanation for starting the task to ask for position or orientation of the constructions parts, this could be observed from the high number of explanation requests. Several participants faced challenges in the first and final steps of the task the most. This shows that even for a simple mechanical assembly task several explanation requests were necessary, as communication is crucial for completing the task in an efficiently and effective manner. The average difference between female and male participants in the task completion duration could be negligible as it is only 3%, which could be due the heavy metal pieces of the metal construction. The amount of errors committed by the participants was due to the absence of any guidance or instruction on how and where to start, which led to disorientation and discontent for most of the participants. The errors show that the participants weren't able to be as effective as they could be as they lacked the guidance for completing the task. The experience of the participants is also a factor, as more experienced participants may have had been more efficient and effective in completing the task even without the use of any support, as they will have experience that might help them in the challenge. The females had 20% less errors on average per participant than the males, and also 20% lower opportunity rate. The females had an error intensity of 10, while the males had 11. This might indicate that the females were able to more effectively complete the tasks than the males.

The average amount of explanation requests by the participants was 4.33, which show that it was for most of the participants it was challenging to complete the task without the use of any support. The explanation average opportunity rate was 21.67%, and the explanation requests frequency rate was 93.33% while the explanation request intensity was 9. This shows that training, instructions, or guidance would have made a huge difference in not only the performance but also the experience and sentiment of the participants. Female participants requested on average 9% more explanation than male participants did, they also had a 9% higher explanation request opportunity rate. Female participants had an 8% lower explanation request frequency than males, and both had the exact same explanation requests intensity of 9. This shows that females asked more questions on average, and took more opportunities to ask, but more females complete the task without using explanation requests than males. The main observations from the experiment revolved around three elements concerning (1) the participant's attitude towards the experiment which was majorly negative; (2) the participant's performance in completing the task which was sub-par compared to experiment average durations, errors, and explanation requests; and (3) the participant's feedback which was insightful as it had a lot of useful comments that even included similar descriptions of the assembly support resembling that in the SP experiment.

4.3. Model Statistical Validation

To check the association of Immersiveness (IX) to the variables of Service Prototyping Effectiveness (SPE), Real World Dissociation (RWD), Service Prototyping eXperience (SPX), and. Intention to Adopt (ItA). IX is a higher order construct which is formed by the 3 immersion experience variables, Perceptual (PX), Emotional (EX), and Cognitive (CX). These variables are measured by the questions in the survey represented in 2 UX properties each. The RWD is formed by the three properties but is caused by the IX, which is the first hypothesis is that IX has a positive impact on RWD. The second hypothesis is that IX is a predecessor (causality effect) of the SPX, SPX is formed by IX and SPE. The third hypothesis is that IX has a positive impact on SPE, which is formed by three properties from the survey. The fourth hypothesis is that SPE is predecessor (causality effect) of SPX, where the higher the SPE the higher the SPX. The fifth and final hypothesis is that SPX has a positive impact on ItA, as the intention is formed by three UX properties.

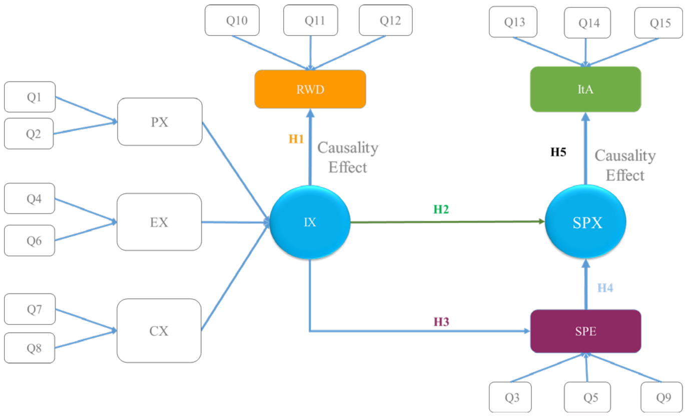

Figure 4.1 Proposed Research Model and Instrument

Considering the model in Fig. (4.1) as the starting point to attempt the research model and instrument validation. The developed model attempts to verify the lower and higher constructs of the model; by using a formative construct where the questions (Q1 → 15) are forming the construct of IX, RWD, SPE and ItA. As the starting sequence of the prototype that participant started with (variable Seq.) could affect the measurements, a part of all respondents are bundled together for analysis, additionally it will be checked separately into four groups given by the variable Seq. Considering the analysis in 5 different cases, as we looked at (a) all the respondents, (b) sequence 1, (c) sequence 2, (d) sequence 3, and (e) sequence 4.

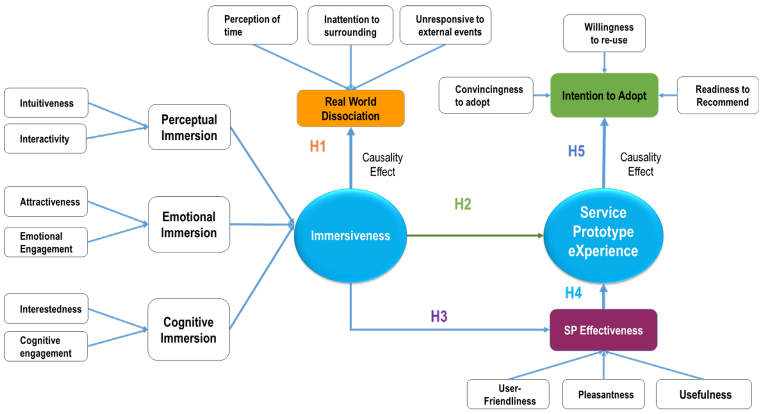

Figure 4.2 Hypothesized SP Research Model

The model in Fig. (4.2) was analyzed by using Partial Least Squares method (PLS) (Hair et al., 2011). This method is used to estimate model coefficients, and it does not require observable variables to be normally distributed, which is important when using semantic scales. This method was used successfully in similar research of validating UX models (Krawczyk et al., 2017; Topolewski et al. 2019). To validate the model statistically we started by assessing the measurement model. The approach is used to enable testing of the SP theoretical framework through series of hypothesis that are formulated at the level of the constructs. UX properties Q1 to Q15 are measured on a bipolar semantic scale, where values range from -2 to +2. There is only one missing value (item Q9). There were 103 participants that filled out the UX survey instrument including quantitative measures, which has to be calculated based on the 440 entries to test the hypotheses.

Table 4.4 Descriptive statistics of the UX Properties

Survey	Missing	Mean	Median	Min	Max	Standard Deviation
Q1	0	0.847	1	-2	2	1.115
Q2	0	-0.025	0	-2	2	1.533
Q3	0	0.468	1	-2	2	1.247
Q4	0	0.391	1	-2	2	1.303
Q5	0	0.416	1	-2	2	1.213
Q6	0	-0.532	-1	-2	2	1.347
Q7	0	0.433	1	-2	2	1.353
Q8	0	0.651	1	-2	2	1.276
Q9	1	0.888	1	-2	2	1.016
Q10	0	-0.364	-1	-2	2	1.401
Q11	0	-0.376	-1	-2	2	1.477
Q12	0	0.455	1	-2	2	1.333
Q13	0	0.599	1	-2	2	1.151
Q14	0	0.752	1	-2	2	1.206
Q15	0	0.696	1	-2	2	1.187

The statistical properties of the measurement model are presented in the descriptive statistics of Tab. (4.4). The statistical significance was assessed using the bootstrap method with 5000 iterations. In the original model (see Figure 4) property Q11 was not significant The Q11 was not precisely formulated, as it was asking the participants to rate the degree to which each of them perceived attention capacity to external events. The issue was that the survey was done is three languages and this question was somehow lost in translation, as we had three contradictory sets of answers from this question, meaning that each of the three languages used (French, German, and English) were understood differently. Since Q11 was not significant, thus not valid property of RWD, it was excluded from the final model. All of the other properties are significant and are taken in the consideration for the final model.

Table 4.5 Relative and Absolute Importance of Indicators and Collinearity

Model	Weights			Loadings			VIF
	Original Sample	***Sample Mean***	***p-Values***	***Original Sample***	***Sample Mean***	***p-Values***	
Q1 → PX	0.548	0.547	0.000	0.788	0.786	0.000	1.151
Q2 →PX	0.661	0.661	0.000	0.860	0.859	0.000	1.151

Q4 → EX	0.874	0.873	0.000	0.981	0.98	0.000	1.297
Q6 →EX	0.223	0.223	0.000	0.641	0.64	0.000	1.297
Q7 →CX	0.82	0.821	0.000	0.947	0.947	0.000	1.156
Q8 →CX	0.345	0.343	0.000	0.646	0.644	0.000	1.156
Q3 →SPE	0.272	0.268	0.000	0.785	0.782	0.000	1.687
Q5 →SPE	0.673	0.674	0.000	0.945	0.944	0.000	1.719
Q9 →SPE	0.228	0.23	0.000	0.660	0.662	0.000	1.344
Q10 →RWD	0.756	0.749	0.000	0.894	0.887	0.000	1.096
Q12 →RWD	0.468	0.468	0.000	0.692	0.69	0.000	1.096
Q13 →ItA	0.429	0.43	0.000	0.935	0.933	0.000	3.072
Q14 →ItA	0.155	0.154	0.027	0.875	0.874	0.000	3.243
Q15 →ItA	0.486	0.484	0.000	0.954	0.952	0.000	3.779

As shown from Tab. (4.5) above that All variance inflation factors (VIFs) are lower than 5, therefore we conclude there are no multi-collinearity problems. Relative importance of an item is assessed by its weight and weight significance. The important thing here is that all properties (except Q11) are significant (p-values are smaller than 0.05). In an ideal situation one would also expect that properties of one construct would have roughly equal weights and values of the weights would not be greater than $1/\sqrt{n}$ (n stands for the number of items within the construct). It means that the maximal limit of a single weight for two properties constructs is 0.71 and for three properties constructs is 0.58. This requirement is not must be condition for the statistical validation, it is just the perfect condition scenario. By considering the table above we can see that Q4 is visibly stronger than Q6 in explanation of EX, similarly Q7 is stronger than Q8 at CX and Q10 a bit stronger compered to Q12 to explain RWD. For SPE, Q5 over performs compering to two other items. Summarizing, we assume convergent validity is established for all items, though we can observe some disparity in explanatory power between properties. Absolute importance of a property is assessed by its loading and loading significance. All properties have significant loadings (see Table. 4.5). There are some loadings that are lower than 0.7 but they are still greater than 0.6, a typical threshold for an exploratory study; as such they are considered to be valid. The properties of Q6, Q8, Q9, and Q12 had relatively small weights compared to the other property in each of their corresponding construct. To assure discriminant validity, it is expected that the loadings within the corresponding construct will be higher than cross-loadings on the other constructs.

Table 4.6 Loadings and cross-loadings

Properties	PX	EX	CX	SPE	RWD	ItA
Q1	**0.788**	0.5	0.528	0.619	0.176	0.543
Q2	**0.86**	0.65	0.651	0.58	0.449	0.446
Q4	0.686	**0.981**	0.738	0.773	0.373	0.639
Q6	0.466	**0.641**	0.542	0.427	0.447	0.376
Q7	0.679	0.739	**0.947**	0.709	0.435	0.629

Q8	0.473	0.463	**0.646**	0.553	0.118	0.444
Q3	0.612	0.612	0.618	**0.785**	0.237	0.55
Q5	0.697	0.765	0.734	**0.945**	0.332	0.679
Q9	0.383	0.393	0.483	0.66	0.141	**0.681**
Q10	0.342	0.383	0.36	0.268	**0.894**	0.219
Q12	0.288	0.291	0.268	0.251	**0.692**	0.184
Q13	0.553	0.596	0.62	0.705	0.24	**0.935**
Q14	0.507	0.54	0.596	0.674	0.215	**0.875**
Q15	0.57	0.624	0.639	0.731	0.237	**0.954**

Table (4.6) above shows the highest loadings on each construct are indicated in red, additionally the hypothesized properties of each of their corresponding construct are framed. Ideally it expected to have red items in the frames that belong to each of the corresponding constructs. But as shown from the frame patterns indicated; there are no major issue except Q9 highly loads on ItA instead on SPE, showing lack of discriminant validity. It was also reflected in somehow relatively low weight of this item pointed above. It may be somehow explained, because Q9 has indirect effect in ItA, so naturally it must be correlated with ItA. For all other items loadings are sufficient. In summary, the discriminant validity is established for all constructs, with exclusion of weak performance of Q9 at SPE. Considering the findings in Tab. (4.6) above, it is concluded that convergent and discriminant validity is established. There is also two Higher Order Constructs (HOCs) in the model, namely IX and SPX, which consist of Lower Order Constructs (LOCs). Therefore, we need to evaluate paths between LOCs and HOCs.

Table 4.7 Path Characteristics

Path	Original Sample	Sample Mean	p- Values	VIF
PX → IX	0.273	0.271	0.000	2.349
EX → IX	0.42	0.419	0.000	2.74
CX → IX	0.404	0.405	0.000	2.875
IX → SPX	0.314	0.314	0.002	3.478
SPE→ SPX	0.711	0.708	0.000	3.478

Table (4.7) above shows that all relationships between LOCs and HOCs are significant, have expected direction and adequate strength. There are no problems with multi-collinearity since all the VIFs are lower than 5. Determining the path significance investigate the impact of IX on RWD, SPX and SPE as well as impact of SPE on SPX, and SPX on ItA to test our research hypotheses.

Table 4.8 Path significance and coefficients of determination

Path	Original Sample	Sample Mean	p- Values	R Square	Conclusion
IX → RWD	0.431	0.435	0.000	0.186	Hypothesis H1 supported
IX → SPE	0.844	0.847	0.000	0.712	Hypothesis H3 supported

SPX → ItA	0.805	0.811	0.000	0.649	Hypothesis H5 supported

Results are summarized in Table (4.8) above. The null hypothesis is rejected when the p value is very low ($p < 0.05$) then we can support our hypothesis. As expected, the impact of IX on RWD is positive and significant, which supports our research hypothesis H1. It is worth to add, that IX has rather low impact on RWD since coefficient of determination equals only R^2 = 0.186. IX also positively affects SPE, here with high coefficient of determination R^2 = 0.712, which supports the H3 Hypothesis. Finally, there is statistical evidence to support research hypothesis H5 about positive impact of SPX on ItA, here R^2 = 0.649. Considering the research hypotheses about the predecessors and their significance, it was found that both hypotheses H2 and H4 are supported. The H2 stating that IX is predecessor of SPX and H4 that SPE is predecessor of SPX are supported since in the valid model this two paths are significant (see Table 4.7). To assess if the paths of the LOCs and HOCs are significant a specific indirect effects are measured.

Table 4.9 Specific Indirect effects

Path	Original Sample	Sample Mean	p-Values
CX →IX → SPX → ItA	0.102	0.104	0.008
EX → IX → SPX → ItA	0.106	0.107	0.005
IX → SPX → ItA	0.253	0.255	0.003
PX → IX → SPX → ItA	0.069	0.069	0.008
CX → IX → SPE → SPX → ItA	0.195	0.196	0.000
EX → IX → SPE → SPX → ItA	0.203	0.204	0.000
SPE → SPX → ItA	0.572	0.573	0.000
IX → SPE →SPX → ItA	0.483	0.485	0.000
PX → IX → SPE → SPX → ItA	0.132	0.132	0.000
CX → IX → RWD	0.174	0.176	0.000
EX → IX → RWD	0.181	0.182	0.000
PX → IX → RWD	0.118	0.118	0.000
CX → IX → SPE	0.341	0.343	0.000
EX → IX → SPE	0.355	0.355	0.000
PX → IX → SPE	0.231	0.23	0.000
CX → IX → SPX	0.127	0.128	0.007
EX → IX → SPX	0.132	0.131	0.004
PX → IX → SPX	0.086	0.085	0.007
CX → IX → SPE → SPX	0.242	0.242	0.000
EX → IX → SPE → SPX	0.252	0.251	0.000
IX → SPE → SPX	0.6	0.599	0.000
PX → IX → SPE → SPX	0.164	0.163	0.000

Additionally, we can assess specific indirect effects of each LOC and HOC on endogenous constructs. As we can see in Tab. (4.9) above that all paths are significant. The most significant path is the SPE to SPX to ItA, which also explains that the effectiveness of the prototype is directly related to eXperience and also tied to the intention of adopting a prototype. To be able to complete the analysis of the model, the goodness of the model's fit has to be measured.

Table 4.10 Model fit of the final model

Goodness Model	Values
SRMR	0.026
d_ULS	0.019
d_G	0.006
Chi-Square	13.48
NFI	0.994

Goodness of fit of the model is summarized in Tab. (4.10) above. What is most important is that Standardized Root Mean Square Residual (SRMR) is lower than the typical maximum threshold of 0.08 and that the Normed Fit Index (NFI) is higher than the typical minimum threshold of 0.95. Therefore, it can be concluded that the model has a good model fit.

4.4. SP Experiment

The SP experiment was conducted as such that every participant had to use and experience each service prototype form afterwards they had to complete a task then provided their feedback by filling out a bipolar survey. The experiment was originally planned to include all VRSP, ARPS, MRSP, PSP, and MSP in one session. However due to the time constraint and the fact that the Hololens MR device was not available at the same time as the other VR HMD and AR tablet, MRSP was conducted in a separate extension experiment. The main SP experiment engaged 103 participants, while in the extension MRSP experiment were only 30 participants volunteered, which add to a total of 133 participants the whole SP experimentations. The overall duration of a the first SP experiment sessions was about one hour per participant; including the time for (a) briefing, (b) experiencing, (c) experimenting, and (d) feedback. During the experiment observations were noted on the participant's attitude, interactions and reactions to the tools and devices used; even when they were immersed in VR. The participant's sentiment is based on the emotion of their provided feedback in form of the free text ratings justification.

Table 4.11 SP Experiment Survey Decomposition

High Construct	Middle Construct	Lower Construct	Survey	Properties
		Perceptual eXperience (PX)	Q1	Intuitiveness
			Q2	Interactivity

Service Prototype eXperience (SPX)	**Immersive eXperience (IX)**	**Emotional eXperience (EX)**	Q4	Attractiveness
			Q6	Emotionally Engagement
		Cognitive eXperience (CX)	Q7	Interestingness
			Q8	Cognitive Engagement
	Real World Dissociation (RWD)		Q10	Timelessness
			Q11	Attentiveness
			Q12	Responsiveness to external events
	Service Prototype Effectiveness (SPE)		Q3	Friendliness
			Q5	Pleasantness
			Q9	Usefulness
Intention to Adopt/Accept (ItA)			Q13	Convincingness to adopt
			Q14	Willingness to re-use
			Q15	Readiness to recommend

To give a better representation of these properties and constructs a table was created to show the questions representing each property and construct, this is represented in Tab. (4.11) above. A more in depth analysis of the survey observations, quantitative, and qualitative results are found in the appendix. The participants' performance is observed from (1) Task Completion Duration (TCD) in minutes and seconds, (2) Errors Average per participant (EA), (3) Error Opportunity Rate (EOR), (4) Error Frequency Rate (EFR), (5) Error Intensity (EI), (6) Explanation request Average per participant (XA), (7) Explanation request Opportunity Rate (XOR), (8) Explanation request Frequency Rate (XFR), and (9) Explanation request Intensity (XI). The participants' attitude is also observed by their visual (facial expressions) and classified into three states, happy, neutral and frustrated. The bipolar survey that the participants filled after each use of an SP form and the completion of the assembly task was constructed to gauge their (a) immersiveness or the immersive experience (IX), (b) real world dissociation (RWD), (c), service prototype effectiveness (SPE), (d) service prototype experience (SPX), and (e) intention to adopt the service prototype (ItA). The survey contained fifteen semantic scale bipolar questions, each question represented one UX property, and each three of these properties constituted a lower construct, and several lower construct constituted a higher construct. The ratings had a semantic scale from [-2] representing very weak, [-1] weak, [0] moderate, [+1] strong, and [+2] very strong.

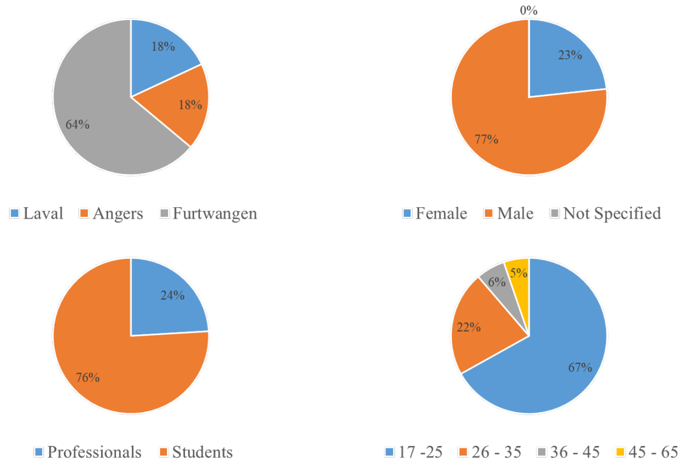

Figure 4.3 SP Experiments Demographics

The number of participant in each of the three locations where the experiment sessions took place is shown in Fig. (4.3). Furtwangen university was the location with the most participants with 64% of the total participants, and longest as well as the experimentation took around one year. While Angers and Laval both with the same amount of participant of 18% each, however each of them had an experiment span of only week each, with 48 participants in 8 days of experimentation. The experiments were mostly conducted at the Service Competence Centre at the Furtwangen University, the Laval Virtual Centre at the Arts et Métiers Laval campus, and the VR lab at the Arts et Métiers Angers campus. These academic locations were selected as service competence center is one of the most advanced labs in Germany for testing and prototyping services, and the Laval Virtual Centre is an immersive technologies hub for the newest innovation in the technology, and at Angers VR lab enabled having the pure strong engineering background that lacked in the both the other locations.

The number of participants from each of the genders is graphically displayed in Fig. (6) above, 77% of the participants were male, 23% of them were female with a total of 133 participants. This means the male participation quote in the experiment is three times that of the female one, this might be attributed to several factors. The first factor is that the experiments were all conducted in either engineering or IT laboratories, which has traditionally higher male to female student's quote. The second factor might be due to the fact the male participants might be more interested in testing a new technology or SP form than female ones. The third reason might be due to the assembly nature of the experiment, which might be more interesting for male participants than female ones. The participants were mostly from an academic background, either professionals or students, as the experiments were all conducted in an academic setting. The number of professional participant, including professors, doctors, and academic employees, and the number of students that participated in the experiment are shown in Fig. (4.3) above. The experiment had a good ratio of professionals to students, which constitutes one to three, 24% of the participants were professionals, while 76% of the participants were students. The ages of the participants are also representative of the demographics of the participants as shown in Fig. (4). 67% of the participants were between the ages of 17 to 25, while 22% between the ages of 26 and 35, and the rest were divided with 6% for the age slices of 36 to 45 and 5% for the age slice between 45 and 65. The SP Experiment then is divided into four SP forms, VRSP, ARSP, PSP and MSP, with a total participant of 103 participants. The SP experiment with 103 participants had more than 70% male participants, and less than 30% were female, more than 60% of them were students, while less than 40% were professionals.

4.4.1. Paper Service Prototype

Paper Service Prototype (PSP) is the most familiar form of prototypes as all the participants would have used a paper instructional manual for something even in their daily life, like assembling IKEA furniture to making an oven backed cake. The knowledge absorption is done before the disassembling and assembling tasks. The participants used a conventional paper instructional leaflet to guide them in the steps to complete the task.

4.4.1.1. Observations Results

PSP offers a traditional method for information communication, through written words and printed illustrations the participants to aid in completing the task. The observations consist of the duration needed to complete the task, the errors made by the participant in the process, and the explanation requests enquired by the participants in order to complete the task. The fastest participant to complete the task took five minutes and forty-nine seconds, the slowest took ten minutes and thirty seconds, and average was seven minutes and fifteen seconds. Most of the participants were able to complete the task in a one minute and twenty second gap from each other, making it the least consistent SP form used from the duration range perspective. The attitudes of the participants while completing the task was also observed. The observations show that 86% of the participants were neutral or uninterested while completing the task by using PSP, while 10% were visually happy or satisfied, and 4% were frustrated or angry for some reason.

The fastest participant was able to complete the task 45% faster than the slowest, and 20% faster than the average. The participants committed some mistakes, the maximum amount of mistakes done by one participant was two errors, and the average was 0.08, which could be considered as insignificant. This shows that paper was successful in communicating the information needed to correctly complete the task, and that the participants were able to complete the task without making many errors. The participants also had a relatively low average for the explanations requested, which was 0.11 and a maximum of two explanation requests. This shows also that paper was able to communicate the steps and guide the participant to complete the task effectively. PSP was used in four different sequences; the starting position is the most important as it shows the duration needed without the effect of learning as the task is the same every time. PSP was the slowest SP form on average compared to all other experimented SP forms, this shows that paper is outdated as a way of communicating information.

Table 4.12 Task Completion Durations Through PSP Sequences (min:sec)

Sequence	Average(min:sec)
PSP 1	08:01
PSP2	07:10
PSP 3	07:16
PSP 4	06:37

The PSP application sequences and their respective sequence task completion durations are list in Tab. (4.12) above. The durations of the participants were decreasing from the first sequence to the last, this might be due to the learning effect of doing the task multiple times. This shows that PSP has a normal learning curve, where the participants gradually improve as they perform the task more times. The performance difference between the first sequence and the of the fourth sequence is could be contributed to the learning effect discussed previously. The difference in the participants' performance could be due to several factors, some might be the length of the instruction text, as some participants were "*bored*" or due to the fact that the metal construction is heavy. so to be able to clarify on these factors, a comparison of the participants' demographics identifiers was constructed.

Table 4.13 PSP Observations Gender and Occupation Difference

Observations	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
TCD (min:sec)	07:15	07:20	07:15	1% slower	07:14	07:16	<1% faster
EA	0.08	0.1	0.07	43% higher	0.04	0.09	55% lower
EOR	0.39%	0.50%	0.35%	43% higher	0.20%	0.45%	55% lower
EFR	5.83%	5%	5%	No diff.	4%	7%	43% lower
EI	2	2	2	No diff	1	2	50% lower
XA	0.11	0.2	0.08	150% higher	0.14	0.09	55% higher
XOR	0.53%	1%	0.40%	150% higher	0.70%	0.45%	55% higher
XFR	9.90%	15%	8%	87.5% higher	11%	9%	22% higher
XI	2	2	1	100% higher	2	1	100% higher
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)							

Regarding the gender identifier as shown in Tab. (4.13) above, the task completion duration difference between females and males was only 1% as such it could be considered insignificant. This shows that PSP offers a relatively gender neutral form of communication where both gender perform equally. The average usage errors made by the females was 43% more than males, which could be due to the weight of the mechanical construction as it could be challenging as it is made out of iron and weighs about 10 kilograms. The error opportunity rate for females was 43% higher, the error frequency rate for females was the exact same for males with 5%, and also the error intensity was identical with 1 error per participant. This might indicate that the females used more opportunities to make errors, but the number of female and male participants that made errors was the same and also the maximum amounts of errors committed by one participants as well. The explanation requests showed a significant difference as females enquired 150% more than their males, which could be due to the fact that females ask more question to be able to fully understand the process, positioning and fit and males might tend to rush in and start and then ask questions when needed. The females had also a much higher explanation request opportunity rate with 150% that of the males. The explanation request frequency rate was also 87.5% higher than that of the males, and the explanation requests intensity of females was also 100% higher that of males. These might show that the females asked much more questions when they had the opportunity, requested more explanations than the males, and even had more requests in the maximum number per participant.

Considering the occupations of the participants, which was divided into two categories, professionals and students as to keep it more coherent. The professionals had insignificant performance advantage as they had less than 1% improvement in the duration of the task in comparison to the students, which confirms the stability of the form as it had almost the same performance in comparing genders as well. Professionals made 55% less errors per usage per participant compared to the students, they also had 55% more explanation requests opportunity rate, and 50% less explanation request intensity. This could be attributed to the experience and knowledge that these professionals possess that give them the edge to complete the task with less mistakes. Although the professionals were minimally faster than students, and had less errors in completing the task they requested 55% more explanations than students. Professionals also had 55% higher explanation request opportunity rate, and frequency rate, while the explanation request intensity was 22% higher than that of the students. Professionals participating were mostly from an academic background, as such questions, studies and investigations are in their job description, which an explanation on why professionals requested more explanations than students.

4.4.1.2. Survey Quantitative Results

The participants rated PSP survey, and almost all of the properties in the survey, negatively. This could be a big sign that the participants think that paper is outdated and is now a redundant form of communication or an archaic method of delivering information from one place to another. This issue could be also due to the fact that the PSP instructional leaflet was created in English, then translated into German and French, which was the case also with the survey. The PSP survey rating were the lowest amongst all the other SP forms, as mentioned before that could be due to different reasons. To be able to clarify on these reasons a deeper dive in the constructs and their ratings is needed.

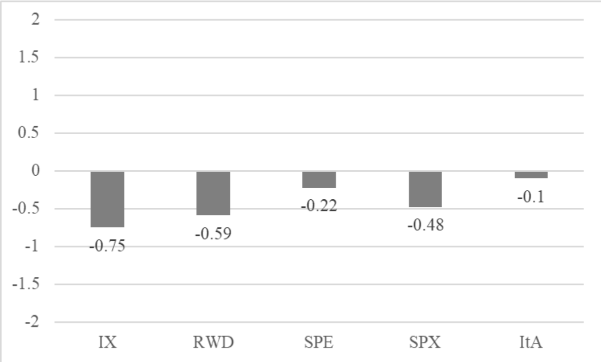

Figure 4.4 PSP Constructs Average Ratings

The participants rated the IX, RWD, and SPE all with almost the same negative rating, showing almost consensus on the negative rating on the SP form, which is also represented in the average survey rating as shown in Fig. (4.4) above. The participants' ratings for PSP constructs shows that paper is an outdated and not an environmentally friendly form of communication, which also lacks immersion factors that leads to a deficit in the usage experience. The only construct that rated higher than the average survey rating was the intention to adopt, as paper showed that is still well accepted as a form of communication for many of the participants. The differences in the ratings could be due to several factor, as such considering the two demographic identifiers to foresee if there are any significant difference between them.

Table 4.14 PSP Survey Rating Differences in Gender and Occupation

UX	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
IX	Weak (-0.75)	Weak (-0.85)	Weak (-0.73)	16% lower	Weak (-0.57)	Weak (-0.82)	30% higher
RWD	Weak (-0.59)	Weak (-0.57)	Weak (-0.6)	5% higher	Weak (-0.31)	Weak (-0.71)	56% higher
SPE	Weak (-0.22)	Weak (-0.32)	Weak (-0.56)	43% lower	Weak (-0.41)	Weak (-0.23)	78% higher
SPX	Weak (-0.48)	Weak (-0.61)	Weak (-0.45)	36% lower	Weak (-0.31)	Weak (-0.55)	44% higher
ItA	Weak (-0.1)	Weak (-0.45)	Weak (-0.01)	450% lower	Neutral (0.08)	Weak (-0.17)	146% higher
Green= Positive (higher), Red = Negative (Lower), (UX Ratings: -2 → 2)							

Regarding the gender, where differences between female and male participants' average ratings are shown in Tab. (4.14) above. Females rated the IX 16% lower than males, as they might have found the mechanical illustration and assembly explanation not as interesting as the males did. RWD rating from both female and male participants were similar and therefore the difference of the 5% can be considered as insignificant, that shows that both genders have the same real dissociation tendencies towards PSP.

Females also rated the SPE 43% lower than males, it could be due to the factor mentioned before. The SPX rating differences are significant, as the females rated on average 36% lower than males, this could be to the several factors as mentioned in the acceptance explanation, but also could be due to the nature of the experiment itself as the mechanical task could be more interesting for males than females. Females rated the ItA 450% lower than males, that is a significant difference, which might be contributed to design and nature of the paper leaflet, which is functional and lack any storytelling elements, also the illustrations are purely mechanical with neutral colors.

Considering the occupation, as such the rating differences between professionals and students are compared. The professionals rated all the PSP constructs significantly higher than the students, this could be due to the fact the professionals have more appreciation for paper, and the students are younger and therefore more biased towards digital ways of communication. The professionals rated the IX 30% higher than students, showing that they felt that the paper was more immersive than the students did, which could be attributed to that the younger students tend to be more attracted to digital solutions than analog solutions. Professionals rated the RWD 56% higher than students, this might be an effect of the age difference as the younger student participants felt more dissociated with the paper than the professionals. Professionals rated the SPE 78% higher than students, which could be due to the fact that the professional participants are older than the students and may have worked much more with similar paper instructions. Professionals rated SPX 44% higher than that of the students, confirming that the more experienced participants tended to have a better experience while using paper than the younger participants did. Professionals rated the ItA 146% higher than students, this a significant difference might indicate that the professionals accepted more paper as a method of communication while the student were more rejecting it.

4.4.1.3. Survey Qualitative Results

The survey allowed each participant to justify their given rating, as these justifications give an overview on the usage of the PSP. The sentiment analysis was done with the same methodology as before where +1 is positive (green), 0 is neutral (yellow), and -1 is negative (red).

Table 4.15 PSP Survey Sentiment Results Top Justifications

Question	Sentiment 1→+1	Top Comments 1	Top Comments 2	Top Comments 3
How **intuitive** is the prototype?	Negative (-0.1)	Typical instructional manual	Drawings lack information and intuition	No visualization (each step visualization is not there)
How **interactive** is the prototype?	Negative (-0.79)	No interaction	You can only read	There is no instant practice after readying
How **friendly** is the prototype?	Negative (-0.6)	Easy to understand	Reading intensive to boring	No real-time test

How **attractive** is the prototype?	Negative (-0.65)	It's not new, classical but not modern	Too much text and little visual	Rather unattractive as the pictures are rather boring and the text does not make it attractive.
How **pleasant** is the prototype?	Negative (-0.49)	Neutral	Boring	Normal
How **emotionally engaging** were you with the prototype?	Negative (-0.64)	No emotions	factual information only	Just a paper, boring
How **interesting** is the prototype?	Negative (-0.6)	Not interesting, long	Classic learning method, very common	Not innovative, old fashioned
How **cognitively engaging** was the prototype?	Negative (-0.17)	It's a method that has worked, but boring	Just a to-do list	It requires a lot of concentration to imagine the object in volume and the way to proceed
How **Useful** is the prototype?	Positive (0.31)	It transmitted the information I needed	OK for this purpose	Fulfills the purpose, however, it is rather demanding
Please rate the feeling of **time** while using the prototype	Negative (-0.6)	Normal	Reading takes time	You are in the real world, there is no immersion
How **attentive** were you of your **surroundings?**	Negative (-0.34)	Very aware	I was focused on the task	Concentrate
How **responsive** were you to external events, during the prototype use?	Neutral (-0.06)	I was concentrated on the paper	Normal and common	There was as far as I noticed no distraction on which I could have reacted
Please rate the degree of convincingness to **adopt**	Negative (-0.23)	We must innovate	Could you better design in terms of guidance	Normal, common operating instructions
How willing are you to **re-use** this prototype?	Negative (-0.13)	Classic format and simple to set up but not intuitive	If it is the only option	That made me bored
Please rate the level of **recommendation** of the prototype	Negative (-0.27)	Depending on the situation	I would not recommend	Easiest and cheapest to setup and use

The participants' sentiment is overall negative, with only the usefulness property rating positive, and responsiveness as almost neutral as shown in Tab. (4.15) above. The positive sentiment of the usefulness property might be due to the convenient nature of paper, as almost all the participants have used a similar instruction paper leaflet to assemble or disassemble something. The PSP sentiment average value was -0.36, which is due to the negative sentiment in interactivity, attractiveness, and emotional engagement properties. Paper doesn't offer any kind of interactivity, as such it was excepted to have a negative sentiment, but as the participants are mostly students they are mostly more technology affine and more environmentally aware as well so this might have been a big factor inducing this negative sentiment. PSP as a prototype was not constructed to be visually appealing as such the sentiment when asked about how attractive is the prototype was also negative, which could be attributed to the nature of an instructional leaflet with only text instructions and mechanical schematics for the parts used in the task. PSP didn't connect with most of the participants, as it lacked storytelling elements, and didn't have any drawings that might evoke emotions. The participants mentioned in their comments that they felt that PSP was a "*typical instructional manual*" with "*no interaction*" and some even mentioned that they "*cannot read and screw at the same time*". The also felt that PSP was "*boring*" with only "*factual information*". The participants also found PSP "*nothing special*" and found it to be "*less attractive*" as "*reading takes time*". However, they mentioned also that they were "*concentrated on the task*" as it is "*easy to understand*". They also added that they would use it "*but if it is the only option*" and only "*depending on the situation*" they might recommend it.

4.4.2. Mock-Up Service Prototype

Mock-Up Service Prototype (MSP) where the participants watch two video, one for disassembling and one for assembling, and then proceed to complete the task. The participants showed consistency in their performances in completing the task while using MRSP. Several participants also verbally commented on how easy it was to replicate the task after watching, yet some other participants complained that they forgot the steps after watching the videos. To have a better understanding on how did the participants actually performed while using MSP, an analysis on their performance, and feedback.

4.4.2.1. Observations Results

The observations here are the task completion durations of each of the participant, the amount of errors that they made during completing the task and explanation requests in the process. The fastest participant to complete the task took four minutes and thirty-nine seconds, slowest in eight minutes and fifty-seven seconds and the average in six minutes and one seconds. Most of the participants completed the task in the forty-seven seconds gap between five minutes and thirty-three seconds and six minutes and twenty seconds. This gap is the smallest in all the SP forms showing the consistency of the MSP as a form of communication. There were several outliers to upside, which is significantly more than the other SP forms, which shows that some participant found it challenging to replicate a process after directly watching it two times (one-time disassembly, one-time assembly). The participants were fairly neutral while completing the task by using MSP as shown from their attitude throughout the experiment. 82% of the participants were neutral or impartial to using MSP, while 12% were visually happy, and only 6% were frustrated or gave visual cues of unhappiness.

The participants were able to complete the task in relatively faster than PSP. This difference in performance might be due the fact that they needed only to replicate the task as seen in the videos, where in the case of PSP they had to read and understand the instructional leaflet first. This could be due to the fact that video is a well-established method of communication, and learning, as almost every participant had seen an instructional or learning video, and most probably in the future it will be the same with XR. The fastest participant was able to finish almost 50% quicker than the slowest one, and 23% quicker than the average, the maximum amount of errors committed by one participant was only two errors, with an average of 0.14, and exactly the same values for the maximum explanation requested per participant and the average enquiry per participant as well. This shows that most of the participants were able to replicate the task with relative ease, as the average errors made and explanations requested are both insignificant.

Table 4.16 Task Completion Durations through MSP Sequences (min:sec)

Sequence	Average (min:sec)
MSP 1	06:05
MSP 2	05:59
MSP 3	05:57
MSP 4	05:48

The MSP four different sequences used in their respective positions are presented in Tab. (4.16) above. The first sequence average duration is the slowest among all four sequences, as this could be expected as the participants are facing the task for the first time, so it is logical that they will take therefore the longest time to complete the task. The average duration of sequence one decreases as expected in the following sequences through sequence position four, which represented a 5% improvement in the performance. The improvement in the performance can be considered insignificant, as the MSP offers a relatively high learning capabilities in all the positions, whether at the start or as supplementary learning tool. To be able to understand more about the differences that might impact the performance, experience or acceptance we compared the performances of the participants in regards to their demographic identifier.

Table 4.17 MSP Observation Gender and Occupation Differences

Observations	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
TD (sec)	06:01	06:05	06:01	2% slower	05:49	06:06	5% faster
EA	0.14	0.2	0.12	67% higher	0.14	0.13	8% higher
EOR	0.68%	1%	0.6%	67% higher	0.7%	0.65%	8% higher
EFR	10.68%	15%	9.64%	56% higher	14%	9.33%	50% higher
EI	2	2	2	No diff.	1	2	50% lower
XA	0.14	0.15	0.13	15% higher	0.11	0.15	27% lower
XOR	0.68%	0.75%	0.65%	15% higher	0.55%	0.75%	27% lower
XFR	11.65%	5%	13.25%	62% lower	11%	12%	8% lower
XI	3	3	1	200% higher	1	3	67% lower
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)							

The gender and occupation of the participants will be used as the two identifiers to compare each other to see if there are any significant dissimilarities as shown in Tab. (4.17) above. Considering gender, the difference between the female and male participants in the performance was insignificant, with only 2% difference in the task completion duration. This shows that video is an appropriate tool for all genders as there was no significant advantage for one gender on the other, which presents consistency in communication. Females made 67% more average usage errors than males that could be attributed to the nature of the task, as it is a mechanical task a lower error quote was expected from males as they tend to have more experience with such mechanical tasks. Females also had a 67% error opportunity rate and 56% higher error frequency rate, which might indicate that the females had more errors per participant on average and also committed more errors per task completion. The error intensity for both was identical with maximum of 2 errors per participant. Females requested 15% more explanation per usage than males this might be due to the fact that females tend to ask more questions than males to be able to complete the task more efficiently. Females also had 15% higher explanation request opportunity rate than males but had a 62% lower explanation request frequency rate. This might indicate that females took the opportunity to request more explanations than males, but they had a lower percentages of participants that requested explanations on average. The explanation request intensity of the females was 200% higher than males, which shows that that the maximum amount of explanations per female participant was much higher than the males. This might be attributed to the mechanical nature of the task and the positioning of the mechanical parts, as such females will tend to ask more than males, who might be more versed in such assembly tasks.

Regarding the occupation, professionals were able to finish the task 5% faster than students, this confirms that video is a great tool for not only all gender, but all ages and knowledge levels as well. Professional and students had a similar average usage error quote, where professionals had 8% more errors on average than students, 8% higher error opportunity rate, and a 50% higher error frequency rate. These difference could be attributed to that the students might watch more instructional videos on average than the professionals. While the professionals had a 50% lower error intensity than students, which might be due to the experience and knowledge difference. Professionals requested 27% less usage explanations on average than the students and also 27% less explanation request opportunity rate, which might be due to short attention span of some of the students that they tend to forget the step of the task and then have to ask for clarifications. The professionals had an 8% less explanation request frequency rate and a 67% lower explanation request intensity. This difference might be due to the added knowledge, experience and age, as the students tend to be younger therefore have less experience and knowledge as well. Also the professionals might have more assembly experience, even some of them might have industrial experience, which is very advantageous.

4.4.2.2. Survey Quantitative Results

The MSP ratings were the highest amongst the conventional SP forms, and rated positive in almost all of the survey properties. This could be an indication that the participants think that video has a good use and could be used as a good form of communication. The major challenge in creating the video was trying to deliver the information without any audio, as it would have meant that there will be three different versions from each video to cover the three languages as used in the survey. The average ratings of all the MSP constructs are shown in the appendix.

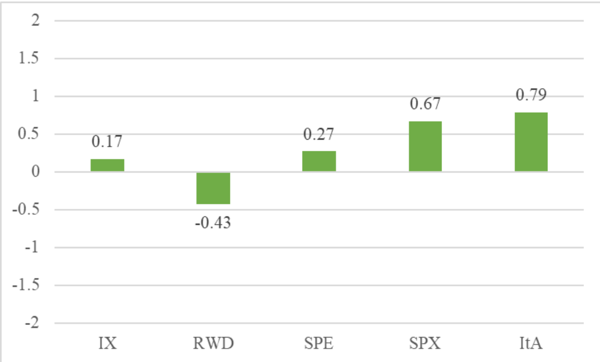

Figure 4.5 MSP Constructs Ratings

The participants rated MSP positively overall with an average rating of 0.27 and the only negative rated construct was the RWD with -0.43 as shown in Fig. (4.5) above. The highest rated construct is ItA with 0.79, which could be interpreted from that video is already used in similar instructional guides and is widely utilized as an effective learning tool. IX was rated 0.17 this shows that some of the participants felt that the video is more or less immersive. The participants also rated SPE with 0.67, which could be due to the fact that the participants found MSP to be effective. The participants also rated the SPX with a 0.27 that shows also that the participants mostly enjoyed using MSP, however the majority found it neutral or were impartial to using it. To be able to grasp the differences in ratings, a deeper analysis in the ratings of the different demographics of the participants, to maybe elaborate more on the differences in the survey ratings.

The participants rated MSP overall positively, where most of the properties were positively rated. However, the interactivity, emotional engagement, sense of time, and sense of surroundings properties were all negatively rated. These negative ratings might be due to the fact that a video is not immersive if it is not a 3D video nor a video that has a strong storyline to immerse the viewer. Video also doesn’t distort the time and doesn’t interrupt, as such the participants might have rated it lower than the other properties. The participants rated the intuitiveness and usefulness properties especially positively, as it is apparent that the video offers a replication of both disassembling and assembling which is intuitive to follow and redo, and also useful tool for learning new information and it is widely used.

Table 4.18 MSP Ratings Difference in Gender and Occupation

UX	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
IX	Strong (0.17)	Strong (0.17)	Strong (0.17)	No diff.	Strong (0.33)	Strong (0.11)	200% higher
RWD	Weak (-0.43)	Weak (-0.58)	Weak (-0.4)	45% lower	Weak (-0.08)	Weak (-0.57)	85% higher
SPE	Strong (0.67)	Strong (0.62)	Strong (0.69)	10% lower	Strong (0.87)	Strong (0.6)	45% higher
SPX	Strong (0.27)	Strong (0.24)	Strong (0.28)	15% lower	Strong (0.46)	Strong (0.2)	130% higher
ItA	Strong (0.79)	Strong (0.82)	Strong (0.78)	5% higher	Strong (0.86)	Strong (0.76)	13% higher
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Ratings: -2 → 2)							

The participants rating can be distributed according to two main identifiers the participant's gender and occupation as shown in Tab. (4.18) above Taking the gender aspect into consideration, there are some significant and some insignificant differences between the female and male participants' ratings. Females rated IX exactly the same as males, these similar ratings show that both genders rated the experience with high similarity, showing that video offers a gender neutral experience that all the participant felt impersonal or impartial after using it. Female rated RWD 42% lower than males, this might be contributed to the fact that males felt more less disassociated with the video due to the assembly mechanical nature of the video and task as well. Female rated ItA 5% higher than males this shows that video is accepted by both genders equally; making it an optimal tool for gender neutral learning. Female rated SPE 10% lower than males, which could be also due to assembly nature of the video and task as they might have found it less effective. Females rated SPX 15% lower than the males, which might be due to mechanical assembly nature of the video as it is more engaging to the males as such didn't enjoy the experience as much.

Regarding the occupation of the participants, where professionals rated IX 200% higher than students, this might be due to the fact that the professionals are mostly educators and researchers, whom have either used or made videos to explain and elaborate on some concept. Professionals rated RWD 85% higher than students, as the students rating was a negative rating, while the professionals rating was neutral. This difference in RWD rating could be due to the fact that the professional participants felt more neutral towards the video, while the students were more critical in that aspect about the speed. Professional rated the ItA 13% higher than students, which can be considered that the professionals are more willing to adopt, use and recommend MSP. The professionals rated SPE 45% higher than the students, which might be due to the fact that professionals found MSP to be an effective form to deliver information. Professionals rated SPX 130% higher than students, this huge discrepancy could be attributed to the fact that professionals might have more experience with producing and creating instruction videos as such their experience was more enhanced.

4.4.2.3. Survey Qualitative Results

The quantitative qualitative embedded survey had justification elements, where each participant has to justify their given rating. These justifications will give the overview on the usage of the MSP and an explanation to the observations and rating discussed previously. The sentiment analysis was done by giving values to comments, positive comment is +1, negative is -1, and neutral comment represents 0, which then resulted in a sentiment average values for each property and for the whole MSP survey.

Table 4.19 MSP Survey Sentiment Top Justifications

Questions	Sentiment 1→+1	Top Comments 1	Top Comments 2	Top Comments 3
How **intuitive** is the prototype?	Positive (0.75)	Easy to understand; clear	The video gives a good representation of the task	Seeing another Person do the task helps to understand
How **interactive** is the prototype?	Negative (-0.35)	No interaction	I just have to watch the video	I can only pause or rewind
How **friendly** is the prototype?	Positive (0.25)	Easy to understand	I see someone do the task	I just watch the person do the disassembly to reproduce it
How **attractive** is the prototype?	Positive (0.21)	A little bit too long	Not special but helpful	Visual and easy to watch
How **pleasant** is the prototype?	Positive (0.25)	Easy to understand but long	Expedient	Missing voiceover or subtitle (tone)
How **emotionally engaging** were you with the prototype?	Negative (-0.52)	Neutral	Little to no emotion	Touched as the tips came through subjective process experience from the video
How **interesting** is the prototype?	Positive (0.14)	Operational video mode	Not really interesting, too long	Video as medium interesting
How **cognitively engaging** was the prototype?	Positive (0.17)	Just copy the video, self-explanatory	Step by step instructions	Not fun but it is so easy that it relaxes your mind you don't really have to think about what you are doing
How **Useful** is the prototype?	Positive (0.61)	Simple and accurate	Clear explanations, it lets you know where to start	Good presentation and explanation, also suitable for people with hearing loss
Please rate the feeling of **time** while using the prototype	Negative (-0.43)	The videos are quite long and repetitive	Video of the same length as the procedure	Videos do not distort the time, more time than VR and AR
How **attentive** were you of your **surroundings?**	Negative (-0.28)	I was more focused on what was going on inside the video	You are in the room and you get everything because you do not have to concentrate so much on the video	100% sensation of the real environment despite the acoustic and optical focus
How **responsive** were you to external events, during the prototype use?	Neutral (0.06)	Focused on the video	I can be distracted from our attention and miss a piece of information	No distraction
Please rate the degree of convincingness to **adopt**	Positive (0.49)	The instructions are simple to realize and understand	Depending on the case but to explain something complex step by step it is well	It's easy to understand and the most engaging, but not the most interesting. Less fun but

				effective. The best explanation of the task so far
How willing are you to **re-use** this prototype?	Positive (0.53)	I will always use instructional videos	It is easy to use and to create and to helps you to understand the task	It is nice for a short amount of time. But a longer Video like this would have been harder to sit through.
Please rate the level of **recommendation** of the prototype	Positive (0.53)	Practically well-applicable	Possibly, if supplemented by sound or subtitles	It is easy to understand, share and use

The MSP rating sentiment represents the average value of the qualitative results as shown in Tab. (4.19) above, where the participant's sentiment shows how the participants feel about the SP form from their justification feedback. The average sentiment of MSP is positive as seen from the sentiment value is 0.16, as the participants commented positively on how the video was both intuitive and useful, and that most of them were positive towards the acceptance construct as well. The participants also showed a negative sentiment in the justifications of the emotional engagement property, this could be due to the fact that the video didn't have any verbal instructions and also no subtitles with the instructions. The participants top comments are summarized in three categories, each representing the most mentioned comments, the comments were sometimes altered as the comments were given in three different languages, so it was all translated to English to keep all the comments uniform. The top three mentioned rating justifications for each of the fifteen questions. The participants mentioned that they "j*ust have to watch and replicate the task being done in the video*", but it seemed that for some it was "*long, so you have to remember all the steps*". The MSP interaction with the participants seemed to be limited as several of the participants mentioned that they "*can only pause or rewind*", while one of the participant justified that MSP was "*not special but helpful*" and even "*not exciting but informative*". The also thought that MSP was "*very passive*" and some faced "*distraction from noises*", which suggests that they were not immersed. The participant felt that MSP is "*missing voice instructions*" or "*subtitles*", otherwise they felt that it is "*very useful for complex tasks*" and "*it is easy to share and use*".

4.4.3. Virtual Reality Service Prototype

The VRSP experiment engaged the participants in a VR environment with an interactive 3D immersive training simulation. The training simulation consisted of an interactive instructional manual of the disassembling and assembling processes, so that the participants can go through the steps in an immersive manner and learn without risk. The VR simulation was built with Unity by using the CAD drawings of the metal constructions, and by using a screwdriver rendering to increase the understanding of the disassembly/assembly steps. The participants had the chance to explore the steps to disassemble and assemble in VR from a 3rd person perspective, with the ability to observe the process from every angle. Some information concerning the dimensions, and weight are also displayed for the participants in the VR simulations.

4.4.3.1. Observations Results

The fastest participant was able to complete the task in five minutes and fifty-three seconds., while the slowest in ten minutes and twenty-four seconds; and the average duration was six minutes and fifty-five seconds. Most of the participant's durations lied between six minutes and thirty seconds and seven minutes and eight seconds, which shows that most of the participants completed the task in a thirty-eight seconds gap showing the consistency of VRSP. There are also several participants that their durations are almost twice that of the fastest participant, showing that there might be few challenges that some participants faced that led to this sluggish performance, some participants mentioned cyber sickness and others mentioned that felt some discomfort or unbalance after they used VRSP. The participants were much happier after experiencing VRSP than any other SP form, this was apparat from their facial expressions as well their verbal comments afterwards. 63% of the participants were visually happy while and after completing the task by using VRSP, while 34% were neutral or disinterested after using VRSP and only 3% were frustrated or visually affected after using VRSP. These visually affected were also the same participants that had cybersickness issues after using VR simulation for the first time.

The usage error average per participant was 0.14, while the error opportunity rate was 0.69% and the error frequency rate was 7.77%. This shows that they had a low percentage of the participants committed errors, and also they committed less errors compared to the error opportunities available. The error intensity rate of the maximum amount of errors made by one participant was three and that is 273% more than the average errors made; this shows that the most of the participants have retained the knowledge and were able to efficiently apply it to complete the task with less errors. The usage explanation request average per participant was only 0.12, while the explanation request opportunity rate was 0.58% and the explanation request frequency rate was 8.65%. This shows that the participants requested less explanations on average and even low compared to the amount of explanation opportunities available. The explanation request intensity was 3 as a maximum amount of explanation requested by one participant, which is 215% more than the average that shows that most participants understood the instruction from the VR simulation and didn't need any further assistance. The VRSP duration is the average of all the durations of each of the four different VRSP sequences used. VRSP was used as the first, then second, then third, and then in the fourth position in a rotation with the other three SP forms (ARSP, PSP, and MSP). The most relevant sequence is the first one; as it gauges the effect of the VRSP without the learning effect of the other SP forms used before that or any latent knowledge. As such a full analysis and comparison of the first sequences is displayed in the appendix.

Table 4.20 Task Completion Durations Through VRSP Sequences (min:sec)

Sequence	Average (min:sec)
VRSP 1	**07:38**
VRSP 2	**06:40**
VRSP 3	**06:43**
VRSP 4	**06:27**

The overall sequences average durations are displayed in the Tab. (4.20) above. The VRSP sequences data shows that the average duration needed in the first sequence is the slowest in all the sequences, which is understandable as the participants have to try it for the first time so it is logical that it would take the longest. In comparison the fourth sequence average duration was the fastest, which is also logical as it is the last cycle where the participants have already completed the task three times by using the other SP forms and have latent knowledge. This the latent knowledge might have well caused this acceleration in the average durations throughout the sequences. The differences in performance in completing the task, including the number of errors and explanation requests might have several reasons to it. To have a better understanding of these performance differences, demographics from the entries of the demographic survey filled by the participants before starting the task are used as identifiers. Some performance difference might be also attributed to the weight of the mechanical construction as it was a bit heavy for some of the participants. Another factor could be due to the participants' mechanical assembly knowledge and experience as some students might not have had much experience with such processes compared to professionals.

Table 4.21 VRSP Gender, and Occupation Differences

Observations	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
TCD (sec)	06:55	07:10	06:50	5% slower	06:40	07:01	5% faster
EA	0.14	0.3	0.06	400% higher	0.08	0.13	38% lower
EOR	0.69%	1.5%	0.3%	400% higher	0.4%	0.65%	38% lower
FR	7.77%	20%	6%	233% higher	8%	9.33%	14% lower
EI	3	3	2	50% higher	1	3	67% lower
XA	0.12	0.35	0.07	400% higher	0.15	0.13	15% higher
XOR	0.58%	1.75%	0.3%	483% higher	0.75%	0.65%	15% higher
XF	8.65%	20%	5%	300% higher	12%	6.67%	80% higher
XI	3	3	2	50% higher	2	3	33% lower
Green= Positive (higher), Red = Negative (Lower)							

As such a comparison was made to foresee if there are any performance differences between the participants' genders and occupation as shown in Tab. (4.21) above. Considering the gender identifier to compare between female and male participants' performance where, the average duration needed to finish the task for females was 5% slower than the males. This difference in speed might be due to that the piece to disassemble and assemble is around 10 kilograms, which might have cause the female participants to lose that 5% in performance. The females made 400% more errors than the male ones did, also had a 400% higher error opportunity rate, and 233% higher error frequency rate with a 50% higher error intensity with a maximum of 2 errors per male participant. This might be attributed to that mechanical part is heavy and also because the 3D complex shapes of the parts are unique. As each part individually fit only to their counterpart in one unique position and fitting, so it might have been harder to recognize, as some females have less contact with mechanical parts. The females had on average 400% more explanation request per usage than the males, also 483% higher explanation requests opportunity rate, with a 300% higher explanation request frequency rate and 50% higher explanation request intensity with a maximum of 3 explanation requests per female participant. This might be due to the fact the females wanted to know more about the construction and process to make sure of the steps and parts positioning. The numbers of the explanation request are also mirrored in the amount of errors that the females had, which was also much higher than the males.

By looking at the occupation as an identifier, we decided to differentiate between the professional participant and the students one, as the knowledge and experience difference might be a factor on the task performance. The average task completion duration for professionals was 5% faster than the students average, which shows that experience had a slight advantage in the speed area, but still could be considered as insignificant. The knowledge and experience effect can be seen from the average of the errors made per usage, where the professional participants committed 38% less errors than the students, had 38% lower error opportunity rate and 14% lower error frequency rate with a 67% lower error intensity. This could be due to the experience advantage and also the capability of extracting information and implementing it might be more mature in professionals than in students. The professionals requested 15% more explanations than the students, had 15% higher explanation request opportunity rate and 80% higher explanation request frequency rate however had an 33% lower explanation request intensity than the students. This could be due to the fact these professionals are mostly from an academic background and as academics "why" is an important question and even part of the job, and asking about the process is something that most academic tend to do, and also some student might tend to be shy to ask questions or further clarifications.

4.4.3.2. Survey Quantitative Rating

VRSP was the most satisfying in regards to UX, and also the participants attitude was positive and most of them verbally commented on how much they enjoyed it. This above average participants' rating could be due to the immersion factors of the VR Immersiveness, as most participants found the VR environment attractive, interesting, and responsive The survey is created to gauge if participants did enjoy using the form and to know more about the usage in the form of the feedback and justification. The survey covered several constructs and properties that are displayed in detail in the appendix.

Figure 4.6 VRSP Constructs Ratings

The VRSP constructs average ratings are displayed in Fig. (4.6), which shows that the ItA was the highest rated construct, this could be expected as VR has the highest level of involvement, and as such might have been interesting for the participants. The figure above shows that (1) IX, RWD, and SPE ratings were near the VRSP average rating of SPX, (2) ItA was rated higher than the average survey rating with 0.96, which might suggest that the participants were more than happy to accept and adopt this SP form and (3) RWD rating was 0.86, which could be expected as VR disassociates the user with their environment. To be able to grasp the impacts of the immersions, a deeper analysis in the differences of the participants' performance and ratings in the experiment. The differences might arise from several factors, but as we can easily find out the demographics of the participants, we choose the gender and occupation aspects.

Table 4.22 VRSP Survey Results Gender and Occupation Differences

UX	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
IX	Strong (0.87)	Strong (0.68)	Strong (0.93)	26% lower	Strong (0.7)	Strong (0.93)	25% lower
RWD	Strong (0.86)	Strong (0.68)	Strong (0.91)	26% lower	V. Strong (1)	Strong (0.81)	23% higher
SPE	Strong (0.85)	Strong (0.69)	Strong (0.9)	24% lower	Strong (0.74)	Strong (0.9)	18% lower
SPX	Strong (0.88)	Strong (0.71)	Strong (0.93)	24% lower	Strong (0.77)	Strong (0.93)	17% lower
ItA	Strong (0.96)	Strong (0.85)	Strong (0.99)	15% lower	Strong (0.7)	V. Strong (1.07)	35% lower
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Ratings: -2 → 2)							

The differences in survey rating regarding the gender, and occupation is displayed in Tab. (4.22) above. If we take the gender construct, the differences between female and male participants ratings are significant as shown in the table above. In regards to the IX construct, females rated IX 26% lower than males, which could be attributed to the fact that males and females differ in their sense of presence, sense of being and realness feeling according to Felnhofer et al. (2012). This effect could be also noticed in the difference in the RWD average rating, where the females gave a 26% lower rating than males. There was also a small difference in the acceptance construct rating, the females ItA rating was 15% lower than males, this might show that the male participants tend to accept more VR as a technology, and VRSP as a service prototyping form. In the SPE construct ratings, females rated both SPE 24% lower than males, this could be attributed to aforementioned factors related to the immersion differences, and effectiveness. To conclude the differences in rating between genders of the participants, females gave SPX on average 24% lower rating than males, this might be due to the fact that males usually conveyed a higher sense of spatial presence, a more perceived realism and a higher level of the sense of being in the environment than females according to Felnhofer et al. (2012).

The differences in the survey rating regarding the professions varies from one construct to the other, where professionals tend to mostly give a lower rating than the students, due to the difference in experience and knowledge. This difference in experience and knowledge makes professionals harder to impress and convince. Professional participants rated IX 25% lower than the students, this could be attributed to the fact that a lot of students didn't have any prior VR experience that might attribute to their higher rating. In contrast to all other constructs, professionals rated the RWD 23% higher than the students, this might be attributed to the fact that professionals tend to gauge the time distortion better than the students. The most significant difference in ratings comes in the acceptance of the VRSP form, as professionals rated the ItA 35% lower than the students, this could be due to the fact that the professionals were more critical of the VR environment and their critical thinking is more advanced than the students due to their experience and knowledge levels. The least significant difference was in the service prototyping experience, as the professionals rated the SPE 18% lower than that of the students, this could be due to excitement factor in using a new technology like VR as most of the students have less experience with VR. When looking at the SPX rating, we can see that the professionals rated VRSP 17% lower than the students, this could be attributed to that the younger the participant, the more fascination of the participant, which is reflected in the average rating.

4.4.3.3. Survey Qualitative Results

The participant's justifications were then sorted into three categories, positive comments where valued with a value of +1, neutral comments were valued with 0, and negative comments the value of -1.

Table 4.23 VRSP Sentiment Top Comments

Question	Sentiment 1→+1	Top Comments 1	Top Comments 2	Top Comments 3
How **intuitive** is the prototype?	Positive (0.57)	A mix of immersive and spatial feelings	Lacks a bit more detailed info	Easy and simple

How **interactive** is the prototype?	Positive (0.52)	Freedom of interaction with the parts	Easy interaction via controller in VR	The steps are controllable and repeatable, like a simulation
How **friendly** is the prototype?	Positive (0.42)	Visually good and somewhat interactive	Easy to handle	New and only after the briefing does it become intuitive
How **attractive** is the prototype?	Positive (0.62)	Effective	Needs more interaction and instruction but is promising	Visually very attractive
How **pleasant** is the prototype?	Positive (0.58)	Visually engaging	Clearly highlighted what needs to be dismantled	Original and good design
How **emotionally engaging** were you with the prototype?	Neutral (0.06)	Not emotionally engaging	Curious and interested	It was just animated
How **interesting** is the prototype?	Positive (0.76)	Interesting new technology	Other prototypes could do the job as well	Interesting as it is playful
How **cognitively engaging** was the prototype?	Positive (0.69)	It give the freedom to move and explore	Very engaging and informative	Easy to understand in VR
How **Useful** is the prototype?	Positive (0.61)	Easy to understand	Effective and accurate in instructions	Useful for more complex tasks
Please rate the feeling of **time** while using the prototype	Positive (0.34)	No sense of time	I felt cut off from the outside	The time went by so fast
How **attentive** were you of your **surroundings?**	Positive (0.53)	I was focused and immersed	I had issues with the cable and physical objects	Immersed and isolated
How **responsive** were you to external events, during the prototype use?	Positive (0.71)	I was completely immersed and submerged	I did not noticed anything around me	I was distracted a bit by noises from the real environment
Please rate the degree of convincingness to **adopt**	Positive (0.48)	Depending on the task	Open to new possibilities	good support, but expensive in terms of equipment
How willing are you to **re-use** this prototype?	Positive (0.59)	Can be very effective, I think	It requires a lot of space and investment	Only for more complex activities
Please rate the level of **recommendation** of the prototype	Positive (0.58)	If the devices necessary are available and the task in accordance	Recommendation depending on the field of application	Very well suited for "risky and covert" processes

The participants have had similar justifications on the questions, as such a summation of these comments in Tab. (4.23) above to show the most mentioned comments on each of the survey questions. The VRSP average justification value was 0.54, which constitutes a positive sentiment. The participants' feedback was mostly positive confirming the positive survey rating outcome, which shows that the participants gave VRSP a positive rating and had a positive sentiment as well. Participants' sentiment of IX was positive with a value of 0.54, RWD was also positive with 0.53, SPE with a positive 0.53, ItA was positive with a value of 0.55, and the SPX was also positive with a value of 0.54. The comments vary, but mostly the comments left by the participants were positive. Participants mentioned that VRSP is "*very intuitive and self-explanatory*", some found it "*user-friendly because it is simple*" while others found "*not user-friendly for people who have never tried VR*". The participants also mentioned that

VRSP is “v*isually very attractive*”, but they said that they “h*ad no emotions towards it*” while using it and even added that it is “*very useful for projects*”. The participants mostly had “n*o sense of time*” and were “*completely isolated from reality*” and they “*highly recommend it, especially for complex tasks*”.

4.4.4. Augmented Reality Service Prototype

ARSP form is one of the two forms, ARSP and MRSP, that the participants have the knowledge absorption done concurrently with the disassembling and assembling tasks. The participants used an AR App installed on a Tablet that is mounted on a fixed stick arm for ease of use, as they get the instruction for the task from the markers fixed on the mechanical construction. The markers on each of the parts give the participants a visualization of how to disassemble the part, and at the end of the sequence informs them as well.

4.4.4.1. Observations Results

The ARSP observations consist of the total task completion duration, errors made, and explanation requests. The task duration includes the knowledge absorption, disassembling, and assembling durations of each participant, and in the case of ARSP the learning is concurrently done with the disassembling and assembling tasks. The fastest participant finished the task in one minute and forty-one second, while the slowest took seven minutes and thirty-eight seconds; and the average was three minutes and three seconds. There were several participants that took much longer than the average range, this could be contributed to the fact that some participants were playing with the AR app and marker, as it was their first contact with AR. Some participants also faced challenges with identification of the markers, as they were not able to position the tablet correctly, which meant they lost time trying to adjust the tablet location and position. The participants were mostly happy while using ARSP, where 56% of the participants were visually happy or satisfied, while 40% were visually impartial or neutral, and only 4% were visually frustrated or unhappy.

This shows that the fastest participant was four times faster than the slowest, and 50% less than the average. Most of the participants were able to finish the task within a one-minute range of each other, between two minutes and twenty-six seconds and three minutes and twenty-eight seconds, which shows consistency in the task completion durations. The fastest to complete the task was four times faster than the slowest one, which is quite a large gap. The average errors made by each participant is 0.14, which can be considered as insignificant. The maximum numbers of errors made by one participant were two errors which is 1430% more than the average errors made, this shows that the AR instructions were clear and concise that most of the participant didn’t have any errors at all. The average explanation requested per participant was 0.31 and the maximum number of explanation requested from one participant was four, which is 1300% more than the average explanation requests. This shows that even for such an innovative technology some required further explanation.

Table 4.24 Task Completion Duration through ARSP Sequences (min:sec)

Sequence	Average (min:sec)
ARSP 1	03:43
ARSP 2	03:35
ARSP 3	02:41
ARSP 4	02:58

As shown in the ARSP task completion durations from Tab. (4.24) above, which shows the task completion durations in each of the sequences. Sequence one (ARSP1) means that the participants used ARSP as the first SP form, so there is no learning advantage or latent knowledge. This is shown as the average duration needed in the first sequence is the slowest in all the sequences, which is understandable as the participants performs the task for the first time, so it is reasonable that it would be the slowest. According to the average; the participants in the third sequence were the fast while using ARSP. This might be contributed to the fact that more professional participants in the third sequence than the fourth, which might explain that insignificant difference. To be able to understand the differences and discrepancies in the observation results, a comparison to compare the averages between the demographic indicators to determinate if there were any significant differences. The genders, and professions of the participants could be easily identified as they were asked to provide them in the demographic survey, which allows us to use these data for this comparison. These difference could be due to several reasons, like the weight, dimension, and positioning of the mechanical construction and it parts. The participants were impressed with ARSP and its simplicity to complete the task simultaneously as they absorbed the knowledge, which also shows in their attitude during completing the task.

Table 4.25 ARSP Observation Gender, and Occupation Differences

Observations	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S
TCD (min:sec)	03:03	03:09	03:02	4% slower	02:58	03:06	4% faster
EA	0.14	0.2	0.12	67% higher	0.07	0.16	56% lower
EOR	0.68%	1%	0.6%	67% higher	0.35%	0.8%	56% lower
EF	10.68%	20%	8.43%	137% higher	7.14%	12%	40% lower
EI	2	1	2	50% lower	1	2	50% lower
XA	0.31	0.35	0.3	17% higher	0.18	0.36	50% lower
XOR	1.55%	1.75%	1.5%	17% higher	0.9%	1.8%	50% lower
XF	18.45%	15%	19.28%	22% lower	14.29%	20%	29% lower
XI	4	4	4	No diff.	2	4	50% lower
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)							

Accordingly, a comparison between gender and occupation of the participants is represented in Tab. (4.25) above. Starting with the gender identifier, the performance difference between female and male participants in the experiment were insignificant in regarding to the duration as females were only 4% slower than males, which could be contributed to the weight of the metal construction's parts. The errors made during the task have a significant difference, as females made 67% more usage errors on average than males, 67% higher error opportunity rate, 137% higher error frequency rate but a 50% lower error intensity. This might be due to positioning of the parts which only fit in one position, which might have been more challenging for the females that didn't perform mechanical tasks before. The average of the usage requested explanations by the females was 17% higher than males, the explanation request opportunity rate was also 17% higher, while the explant nation requests frequency rate was 22% lower than the males. These differences might be due to the fact that females needed to ask more questions to inquire about the fit, order or positioning of the mechanical parts. There was no difference in the explanation request intensity between females and males.

Considering the occupations of the participants, which could be categorized by two categories professionals and students. The task completion duration of professionals was only faster by 4% than that of the students, which is not a significant difference. That shows that the AR instructions were clear that the students were able to keep up with the professionals to some degree. In contrast to duration, there is a significant difference in the errors, as the professionals made 56% less usage errors on average; had 56% lower error opportunity, and 40% lower error frequency rate compared to the students. The professionals also had 50% lower error intensity than the students. This might be attributed to the fact that professionals have more experience in such task as such they committed less errors. The requested usage explanations by professionals on average was 50% lower, and the explanation requests opportunity rate as well. While the explanation requests frequency rate was 29% lower than the students, and they had 50% less explanation requests intensity than the students. This might be due to the fact that most of the students don't have that much experience with mechanical assembly, and especially by using AR instructional manual. In this case the higher the errors the higher the explanation requests as seen from the case of the students.

4.4.4.2. Survey Quantitative Results

The survey is created to see if participants did enjoy using the form and to know more about the usage in the form of the feedback and justification. The survey covered several constructs and properties that are displayed in the appendix.

Figure 4.7 ARSP Constructs Ratings

The ratings of each of the aforementioned constructs shown alongside each other in Fig. (4.7), where we can see that the highest rated construct is the ItA with a 1.17 rating, which is considerably higher than the other constructs. This might be contributed to the acceptance of the main stream to AR, and the emergence of games like Pokémon Go that made using AR cool and fun as well. AR instructional guides are also used widely in the industry and some participants might have seen it before and had a positive bias towards it as its seems like the most logical solution. The service prototyping experience average rating is 13% less rated than the average, which is not a significant difference however it could be due to the differences in gender or occupation of the participants. To have a better understanding of the participant's ratings; a comparison was devised to compare the ratings given from the different genders, and occupations.

Table 4.26 ARSP Survey Rating Differences in Gender and Occupation

UX	Average	Female	Male	Diff F/M	Professionals	Students	Diff P/S.
IX	Strong (0.91)	Strong (0.66)	Strong (0.98)	33% lower	Strong (0.88)	Strong (0.96)	8% lower
RWD	Weak (-0.17)	Weak (-0.1)	Weak (-0.18)	45% higher	Weak (-0.01)	Weak (-0.22)	95% higher
SPE	V Strong (1.06)	Strong (0.88)	V Strong (1.1)	20% lower	V Strong (1.03)	V Strong (1.08)	5% lower
SPX	Strong (0.78)	Strong (0.65)	Strong (0.81)	20% lower	Strong (0.75)	Strong (0.79)	5% lower
ItA	V Strong (1.17)	V Strong (1.15)	V Strong (1.18)	3% lower	V Strong (1.13)	V Strong (1.19)	5% lower
Green= Positive (higher), , Red = Negative (Lower), (UX Ratings: -2 → 2)							

The ratings comparison analysis is conducted in two different categorizations, genders and occupations are compared as displayed in the Tab. (4.26) above. Considering the difference in the gender where it showed that females rated IX 33% lower than males, which could be considered as significant. These differences could be due to the mechanical assembly nature of the task as some males might have been more impressed with the AR immersive visualization than the females. The mechanical nature of the instructional step by step AR guide might have then intrigued more males than females. RWD had the largest discrepancy with females rating it 45% higher than males, which might be contributed to the fact that the AR visualization were on a tablet and the participants had awareness of all their surroundings. RWD negative average ratings from both genders can still be considered as neutral due to the fact that the rating is near to 0 rating which is the neutral rating. ItA was a rated highly from both females and males, and the difference was only 3% which can be considered insignificant. This overall ItA high rating could be attributed to the effectiveness of AR, and its visualization great functionality, which makes it easy to use and understand. Females rated SPE 20% lower than the males. This difference in SPE rating could be contributed to the fact that in any mechanical or guidance task, more males than females tent to have a better experience as conventionally more males enjoy such mechanical tasks. Females rated SPX 20% lower than males, which could be due to the nature of the AR visualization and the nature of the task itself as the mechanical parts are heavy we tend to see lower rating from females than from males.

In regards to the occupation, it was decided to make the distinction between the professional and the student participants, as such gauging what the experience and knowledge level difference will reflect in their ratings. The professionals rated IX 8% lower than the students, this might be due to the fact that students might have been easily fascinated with such technologies as they might not have seen, but professionals would be more skeptical and critical for their first time usage. Professionals rated the RWD 95% higher than the students, which might due to the fact the AR was done a tablet, and for many professionals getting immersed in such devices might happen fast than students whom had their whole lives with such screens and distractions. Both ItA and SPE were rated 5% lower by professionals compared to students, which could be considered as an insignificant. Professionals also rated on SPX 5% lower than the students, which is could be also considered as an insignificant difference. These insignificant differences show that there is a positive consensus on ARSP as both professionals and students highly rated the acceptance properties even had a similar overall rating.

4.4.4.3. Survey Qualitative Results

These justifications will give the overview on the usage of the ARSP and an explanation to the ratings discussed previously. The sentiment is calculated by giving a value to the participant's justifications with +1 for positive comments, 0 for neutral comments and -1 for negative comments.

Table 4.27 ARSP Survey Sentiment Top Justifications

Question	Sentiment (-1→+1)	Top Comment 1	Top Comment 2	Top Comment 3
How **intuitive** is the prototype?	Positive (0.79)	Fairly clear but method of explaining unique	The instructions only Show when you finished the previous task	Not absolutely intuitive because the direction of rotation is not explicitly displayed

How **interactive** is the prototype?	Positive (0.54)	Most important movements are displayed interactively	You can view things from a different angle.	The prototype reacts to the work steps carried out in reality with the next step.
How **friendly** is the prototype?	Positive (0.7)	Easy to understand	Fun to superimpose reality and virtuality	No problems as long as the markers are recognized correctly
How **attractive** is the prototype?	Positive (0.79)	It's easy to see how things should be for the pieces	Less attractive but functional and direct	Easy and fun to use
How **pleasant** is the prototype?	Positive (0.62)	New so nice but a little gadget like	Could use with more functions and detail	Very appealing, because it is directly connected to reality
How **emotionally engaging** were you with the prototype?	Negative (-0.14)	Does not trigger any emotions	Great animation and interesting presentation of the tasks to be done but nothing more	It was not a particularly emotionally engaging task
How **interesting** is the prototype?	Positive (0.72)	It's learning in real time, which is positive and pro-active for users	Visually interesting, many possible usage scenarios	Since I have already developed examples of such, the prototype is normal for me
How **cognitively engaging** was the prototype?	Positive (0.66)	I felt like a natural thing to do to look at how the pieces should be by looking through the device	No need to memorize, just follow the instructions	Immediately understood
How **Useful** is the prototype?	Positive (0.77)	Simplifies everything - no unnecessary "thinking"	No possibility for incorrect operation	Self-explaining because of sequencing and animations
Please rate the feeling of **time** while using the prototype	Positive (0.15)	I was not focus on anything else	Relatively fast, because things have been well presented	I didn't have to learn prior to doing the task so it went fast
How **attentive** were you of your **surroundings?**	Negative (-0.33)	Only focused on the piece	Due to the simplicity of the process, I was relatively aware of the environment	Senses were free
How **responsive** were you to external events, during the prototype use?	Neutral (0.08)	I was concentrated and focused on the task	Concentrated on the representation on the screen	The focus was in the task thus could not influence any external factor
Please rate the degree of convincingness to **adopt**	Positive (0.66)	I think you could use this everywhere as well	Effective but not to learn but to work	Meaningful because self-explanatory, saving time through several process steps at once
How willing are you to **re-use** this prototype?	Positive (0.72)	A better remedy than written instructions or an extra YouTube video	I would do that again and again	With my smartphone to complete the assembly of a piece of furniture, it would be really practical
Please rate the level of **recommendation** of the prototype	Positive (0.7)	No real Need for previous time for learning? Just bring the device with you.	Simple and effective to use	That would make my girlfriend even understand

The participants survey qualitative results for ARSP show a positive sentiment, as the average sentiment value was 0.5, and also almost all the properties ratings justifications were positive except two properties as shown in Tab. (4.27) above. The emotional engagement rating sentiment was negative, confirming also the negative rating from the participants as AR lacked an emotional connection with the participant. Awareness to the surroundings rating sentiment was also negative, which shows that the participants felt that they were distracted from completing the task. The intuitiveness and attractiveness ratings sentiment both were positive showing that the participant enjoyed the intuitive of the AR instructions, and were also attracted to the visualizations. To be able to identify the reasons of these positive sentiment in most property ratings, and the negative sentiment in only two of them a table with the most mentioned justification comment was constructed with the survey question as well. The participants' comments were mostly positive and showed the excitement toward AR as a technology, and ARSP as a service prototyping form. The participants mentioned several times how it is "*visually intuitive*" and that it is "*easy to understand*", some also mentioned that it "*helps a beginner solve the task*", and even calling it a "*good solution in the future if it is more improved*". The participants also mentioned that ARSP "*has a lot of potential*" and that "*if it works properly*" they "*would recommend this prototype to anyone*".

4.4.5. Mixed Reality Service Prototype

MRSP was conducted after the experiment, with VRSP, ARSP, PSP and MSP, as the Hololens device was not available for use at the same time with the VR device and the AR tablets. The issue also was that it would have extended the time of the experiment by about twenty minutes, which would have made it hard to get volunteers for participating in the experiment as the total duration of the experiment will be an hour and half for each participant. The MRSP experiment starts by giving the participants the MR Hololens devices with the holographic instructional manual. The participants' performance is measured from observing their task completion duration, errors committed and explanations requested. Then they fill in the questionnaire on the use of the prototype in regards to the experience and intention to accept and adopt.

4.4.5.1. Demographics

The experiments were solely conducted at the Furtwangen University in Germany, where most of the participants were either IT and engineering bachelor and master students. The participants were from diverse backgrounds as half of the participants were from outside of Germany, and the rest were German students. We were able to acquire these volunteer students from the two courses that I teach at the Furtwangen University, smart service innovation and immersive technologies experimentation, it is challenging to acquire a large number of volunteers at the Furtwangen University, due to the stringent German privacy laws and the lack of motivation from students as the work load is high all around the semester. The majority of the participants were males, with 63%, and the rest 37% were females. This might be attributed to the fact that the experiment was conducted in the industrial service lab, as the majority of the students are males. As all the participants were students at the facility of engineering and computer science, with an age average of twenty-five years old, so we decided to differentiate between the under and over that average age. Most of the participants were under twenty-five years old with 70% of the participants under 25 and 30% of the participants over the age of twenty-five. This shows that most of the participants are of a young age and are well versed in using technological advanced equipment as well as more open to new and innovative technologies.

4.4.5.2. Observation Results

The most obvious observation noticed was that there is an absence of errors and explanation requests which is remarkable, as this shows the high effectiveness of the MRSP as method of communication. The durations are also showing promising signs as the durations are much shorter compared to the other SP forms. This could be due to the fact that most of the students had in some way contact with immersive technologies in their studies, and that all the participants were relatively young so they are more adaptable in using new technologies. The task duration consists of the duration of the knowledge absorption, disassembling, assembling processes. As the knowledge absorption process was done concurrently with the task, the total duration is the combined durations of the disassembling and assembling tasks. The participants get a step by step holographic instruction on the assembly process of the three-part construction. The participants can then proceed with the disassembling and reassembling as they have their hand-free as they get the instructions to complete the task. The participants managed to finish the task on average in only two minute and fifty-three seconds making it the fastest and most efficient SP form in all the experiments conducted. The task completion duration represents the time needed to learn, disassemble and then assemble back again, as the learning is done concurrently to the other two task; the duration needed is much shorter.

The fastest participant to finish the task was two minutes and one second, while the slowest was three minutes and fifty-one seconds; and the average was two minutes and fifty-three seconds. Most of the participants finished the tasks between the two minutes thirty-four seconds and three minutes eleven seconds, with a box plot mean of two minutes fifty-two seconds which is almost identical to the calculated average. The longest time taken to finish the task by using MRSP was three minutes and fifty-one seconds, while the shortest was two minutes and one second, and average was two minutes and fifty-three seconds. The fastest participant completed the task 30% quicker than the average duration time, which is also 50% quicker than the slowest. This shows that even for a relatively interactive SP form as MRSP there is a big discrepancy in the durations of the participants, which might be attributed to that the participants were mostly students; as for some of them it was the first time to use a MR device. The attitude of most of the students was positive, as they were really impressed with the Hololens and the graphical holograms. 87% of the participants were visually happy while and after using the MRSP, while 10% were neutral and 3% were frustrated or feeling unease. Few participants felt unease as they were affected by cybersickness, which was verbally discussed with them after they finished completing the task. The differences in task completion durations between the participant could be attributed to several factors, as first time use, or fascination or some differences in their demographics or backgrounds, as such a short analysis was done to foresee if there are difference between identifiers within the demographics of the participants.

Table 4.28 MRSP Observations Results Gender Differences

Observations	Average	Female	Male	Diff F/M
TCD (min:sec)	02:53	03:05	02:46	11% slower
EA, EOR, EF, EI	0	0	0	No diff
XA, XOR, XF, XI	0	0	0	No diff
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)				

The gender of the participants can be used as an identifier as each participant declared their gender at the start of the experiment, so the performance of the female and male participants can be compared to check for dissimilarities. The main difference between MRSP and the other SP forms that the participants didn't have any explanation requested and didn't commit any errors. The differences in participants' performance is shown in Tab. (4.28), the female participants were able to complete the task in three minutes and five seconds on average, while males completed the task in two minutes and forty-six seconds, which is only a 12% decrease in the performance. This difference is insignificant as it could be attributed to the fact that the part is heavy, almost ten kilograms, and females might have had some challenges in completing the mechanical part. There were not errors made during the thirty experiments conducted in this extension experiment, also there were no explanation requests inquired. The process was straight forward and most of the participant felt at ease while using the Hololens, as more than half have already used the Hololens in some capacity. This shows the added advantage for using such technologies in guiding and instructing, as it showed a high efficiency and accuracy as well.

4.4.5.3. Survey Quantitative Results

The Hololens MRSP experiment was planned to be conducted concurrently with the other forms, but due to unseen circumstances it was done later on with different participants that the ones that did the SP experiment. It was then decided to use the same survey to see what the participants feel and think about this SP form and to be able to compare to the other SP forms. MRSP Experiment sessions were conducted in an academic setting with students, mostly under the age of twenty-five years. The MRSP allows the participants to learn and perform the task concurrently, which is a more efficient way of completing the task as seen from the results of the SP experiment, where ARSP was the most efficient SP form in regards to the task completion duration. The participants rated MRSP positively, in fact the rating is much higher than that of the other SP forms and much higher if compared to only the first sequences of the other SP forms but this is discussed later on in the chapter. The MRSP survey ratings and their corresponding properties and constructs, according to the survey instrument, are shown in appendix. Participants rated MRSP positively overall, with an excellent rating in almost all the constructs. Participants rated the cognitive engagement with the highest rating of 1.6, which is the highest rating, that stems from the holographic overlaying of information that happens directly on the glasses, and the eyes are then total engaged with these visualizations. The participants also rated the acceptance construct especially high, with all its building properties rated way above the average survey rating, which shows that the almost all of the participant are willing to adopt MRSP, re-use it and even recommend it to others.

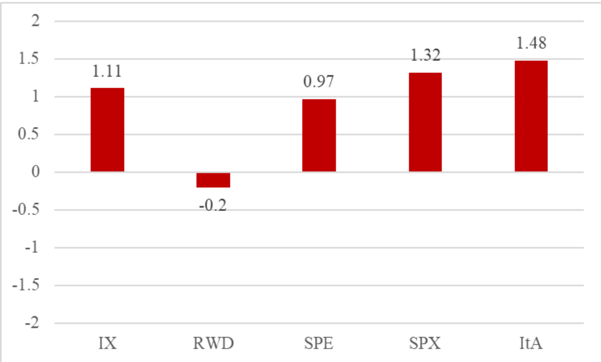

Figure 4.8 MRSP Constructs Ratings

The participants rated almost all MRSP constructs positively as shown in Fig. (4.8), however RWD was rated negatively, but it is more near to the neutral rating that means that could mean that there was no significant dissociation from the real world. ItA was the highest rated construct, which shows participants consensus on the recognition of MRSP as a viable prototyping solution for similar service processes. SPX was rated lower than the average, that might be attributed to the fact that some of the participants were using the Hololens for the first time or some that might have had some challenges in using the air tap or due to cyber-sickness while using the Hololens. The immersion ability of the Hololens is shown in the IX rating, which reflects the cognitive stimulating effects of MR on the participants. To see if there are any significant difference in the demographics of the participants, and as there were only three professional volunteers in the MRSP experiment, their number is insignificant in comparison to the twenty-seven other student participants as such only the gender aspect will be investigated.

Table 4.29 MRSP Survey Quantitative Results Gender Differences

UX	Survey	Female	Male	Diff Female/Male
IX	V. Strong (1.11)	V. Strong (1.09)	V. Strong (1.13)	4% higher
RWD	Weak (-0.2)	Moderate (0.09)	Weak (-0.37)	125% higher
SPE	V. Strong (1.32)	V. Strong (1.42)	V. Strong (1.26)	13% higher
SPX	Strong (0.97)	V. Strong (1.01)	Strong (0.94)	8% higher
ItA	V. Strong (1.48)	V. Strong (1.36)	V. Strong (1.54)	12% lower
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Rating: -2→+2)				

The differences in the quantitative results of the female and male participants in MRSP experiment are shown in Tab. (4.29) above, where there were some significant differences between the genders' ratings. Female rated IX 4% higher than males, this difference could be considered insignificant. This shows that there were no variances in the MRSP immersiveness between the participants whether females or males. Females rated RWD 125% higher than males, this shows that they felt more dissociated by the holograms from sense of time and awareness, while males were most likely more distracted by the information overlaid on their visors. This could be attributed to the nature of the male where multitasking is challenging and they had to focus on the holograms and tended to have a distorted sense of time, and were less aware of their surroundings. Females rated ItA 12% lower than males, this could be due to weight factor of the Hololens, as it might make it challenging for some females to wear regularly due to the weight and the dimension of the device. Females rated SPE 13% higher than males, this might be due to the fact that females found the instructional guidance sequencing and the holograms used for this process more effective than the males did. Females rated SPX 8% higher than males, which could be due to that females enjoyed the experience more and had a higher dissociation than males. It seemed as the females enjoyed the semi immersion more than males did, which showed in the ratings. SPX represents how much did the participant enjoy the use of the prototype. MRSP performance and survey ratings are a great way to see the impacts of using immersion, but a vital point in understanding these impact are the participant's rating justifications.

4.4.5.4. Survey Qualitative Results

The participants were excited after using the MR Hololens device, as for some it was the first time to use such an immersive device, for the most they have had some sort of contact with immersive technologies within their studies. The participants rating justifications can be regarded as their sentiment, and as such a sentiment analysis was done on their feedback, by giving values to comments where a positive comment equates +1, a neutral comment equates 0, and a negative comment was valued at -1.

Table 4.30 MRSP Survey Sentiment Top Justification

Question	Sentiment -1→+1	Top Comments 1	Top Comments 2	Top Comments 3
How **intuitive** is the prototype?	*Positive (0.52)*	Showed the actions step by step by tapping, immediately reacted to the "taps"	Once you understand when and how to get to the next step, it's intuitive	It's pretty easy to understand how to use it. And also with the instruction of that.
How **interactive** is the prototype?	*Positive (0.25)*	Every step is animated in detail, so you immediately understand what to do	When I tapped to continue, the system answered back correctly.	Sometimes there is a very small delay in time when I tap it. And it moves out of the structure quickly.
How **friendly** is the prototype?	*Positive (0.52)*	very user-friendly because it is understandable and you get well guided through the assembly	It is so close to reality, and the colors also help a lot	Gesture control imprecise
How **attractive** is the prototype?	*Positive (0.59)*	Very simple, which I personally like a lot. All important information is available.	It's vivid and easy-understanding. When people see long sentences and words of instructions it's time-consuming.	Could be lighter and smaller, otherwise very good
How **pleasant** is the prototype?	*Positive (0.42)*	As I am using MR technology for the first time it seemed very realistic and exciting to me.	Simple, nice and simple design, understandable	futuristic, at the same time very practical, because a lot of useful things can be realized.
How **emotionally engaging** were you with the prototype?	*Positive (0.25)*	I don't feel any emotions towards the prototype.	MR can help and make people's life more convenient!	It would be better with sound effects.
How **interesting** is the prototype?	*Positive (0.8)*	Never really used anything like this for operation and instructions, so it arouses my interest.	it makes the task fun but I think that it can be done without it	New way of knowledge transfer for me using mixed reality.
How **cognitively engaging** was the prototype?	*Positive (0.57)*	Working steps were clear and straightforward. They did not lead to misinterpretations.	I can see and understand the process.	Yes, but it took me a while to understand how to use it in the beginning.
How **Useful** is the prototype?	*Positive (0.74)*	In this example, the task would have been easy even without a prototype. In more complex examples, it is certainly very useful.	It overcomes the disadvantages of boring instructions. Very useful!	It will help new employees to learn specific tasks in a short time.
Please rate the feeling of **time** while using the prototype	*Positive (0.1)*	I didn't really feel any distortion.	Due to the focus and the environment, it seems as if the time passes a little more slowly	Because it's my first experience, time passed really fast. Felt myself as Tony Stark :)
How **attentive** were you of your **surroundings?**	*Positive (0.15)*	Mainly real, since the virtual environment is only displayed in a certain area.	You still perceive the real environment very well	Concentrated on the prototype, it's so appealing so you get unconscious of the outside world!

How responsive were you to external factors, during the prototype use?	*Positive (0.67)*	can't really hear the external sound. Feeling inside the world.	I was able to respond to questions and answer them, but I didn't pay attention to anything else	I wasn't distracted from using the prototype at all. I was able to perceive the real environment around me as if I would without MR glasses.
Please rate the degree of convincingness to adopt	*Positive (0.75)*	The benefits are clearly recognizable. Especially when used with more complex products.	very convincing, lots of practical, interesting and cost-saving opportunities for the future	Helps especially if you have no idea how to do something. For me this is the future
How willing are you to re-use this prototype?	*Positive (0.53)*	Was definitely fun. I see no reason not to use the prototype again.	For certain complex applications I am convinced and ready to use it again.	if I have to do this task again I prefer to do it with the glasses, it is more fun
Please rate the level of recommendation of the prototype	*Positive (0.63)*	It is more intuitive, funnier and faster than the other tools.	Simple tasks are also possible without AR but the more complex or less know-how, the better is AR support	There is potential, further research and technical improvement are possible. Highly recommended!

The participants' justifications' average sentiment, as shown in Tab. (4.30) above, was positive with an average value of 0.5, all the properties were found to have a positive sentiment were the interestingness, usefulness, adoption degree, and cognitive engagement properties with a high positive sentiment, and the sense of time and awareness had neutral sentiment. The participants' accepted fully MRSP as the sentiment was especially positive in the acceptance construct properties. The top comments of the participants are noted below as well but as the number of the participants were only thirty, and the survey was done on paper, as the participant had to write down their justification many of the participants didn't leave any comments, or some left comments referring to previous written ones. The participant was able to use the MR although many of them never used an immersive technology before, one participant even said "*it's my first experience, time passed really fast. Felt myself as Tony Stark*", and another participant added "*I am using MR technology for the first time it seemed realistic and exciting to me*". The participants mentioned that MRSP "*showed the actions step by step by tapping*" while "*sometimes there is a very small delay in time when tapped*". The participants also add that "*every step is animated in detail, so you immediately understand what to do*" and while "*it is so close to reality*", however there is the imprecision issue of "*gesture control*". The participants also mention that MRSP "*overcomes the disadvantages of boring instructions*" and that "*it will help new employees to learn specific tasks in a short time*". The participants confirm their high acceptance to MRSP by adding that "*for certain complex applications I am convinced and ready to use it again*" and that "*it is more intuitive, funnier and faster than the other tools*" think about.

4.5. Overall Analysis

The experiments were conducted successfully in an academic setting, with more than 100 participants. The research model was statistically validated and the hypothesis were all supported. There were differences in the experiments results between the two countries (France and Germany) where the experiments took place. The three locations that the experiment took place had three different main educational and research areas, from immersive technologies oriented (Laval), mechanical engineering (Angers), service management and IT (Furtwangen). For example, in France, (1) PSP from UX point of view is the least satisfying form, and had most explanation requests, (2) MSP appears to be effective as it had 0 explanation requests, and appeared to have a neutral experience, (3) VRSP has the second highest UX satisfaction, and was the second fastest, it had the least errors calculations, and (4) ARSP had the highest UX satisfaction and the fastest in regards to performance. While in Germany, (1) PSP had the slowest task completion average duration and the most negative participants UX rating, (2) MSP had the second fastest task completion average duration and the least amount of incurred errors on average, (3) VRSP has the highest UX satisfaction rating, was also the most impressive for most of the participants, and (4) ARSP incurred the most errors and explanation requests, and it took longer than expected as participants played with capturing the markers (from observations)

Table 4.31 SP Forms Observations Comparison

Observations	BSL	PSP	MSP	VRSP	ARSP	MRSP
Task Completion Duration (min:sec)	11:09	07:15	06:01	06:55	03:03	02:53
Average Usage Error per participant	4.3	0.08	0.14	0.14	0.14	0
Error Opportunity Rate	21.50%	0.39%	0.68%	0.69%	0.68%	0
Error Frequency Rate	90%	5.83%	10.68%	7.77%	10.68%	0
Error Intensity	11	2	2	3	2	0
Average Usage Explanation Requests	4.33	0.11	0.14	0.12	0.31	0
Explanation Requests Opportunity Rate	21.67%	0.53%	0.68%	0.58%	1.55%	0
Explanation Requests Frequency Rate	93.33%	9.90%	11.65%	8.65%	18.45%	0
Explanation Requests Intensity	9	2	3	3	4	0
Happy Participants' Attitude	2%	10%	12%	63%	40%	83%
Neutral Participants' Attitude	25%	86%	82%	34%	56%	10%
Frustrated Participants' Attitude	73%	4%	6%	3%	4%	7%
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)						

The summary of the participant's performance is represented in the observations captured during the experiment, as shown in Tab. (4.31) above. The fastest participant to complete the task was using the MRSP, which represents the most efficient way to complete the task, as it was much faster than other SP forms, and much less errors and explanation requests. The participants tended to make less errors surprisingly while using PSP, which might suggest that the participants were able to decode the instructions from the paper instruction leaflet effectively cause on average less errors. The participants also requested less explanation requests while using PSP, this shows that the paper instruction is widely used that most of the participants didn't need further clarification on the task as they are used to extract information from paper more than any other medium immersed or otherwise.

Table 4.32 SP Forms Quantitative Results Comparison

UX	PSP	MSP	VRSP	ARSP	MRSP
Immersiveness	Weak (-0.75)	Strong (0.17)	Strong (0.87)	Strong (0.91)	V. Strong (1.11)
Real World Dissociation	Weak (-0.59)	Weak (-0.43)	Strong (0.86)	Weak (-0.17)	Weak (-0.2)
Service Prototype Effectiveness	Weak (-0.22)	Strong (0.67)	Strong (0.85)	V. Strong (1.06)	V. Strong (1.32)
Service Prototype eXperience	Weak (-0.48)	Strong (0.27)	Strong (0.88)	Strong (0.78)	Strong (0.97)
Intention to Accept and Adopt	Weak (-0.1)	Strong (0.79)	Strong (0.96)	V. Strong (1.17)	V. Strong (1.48)
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Rating: -2→+2)					

The survey quantitative results show us what the participant thought about each SP form, based on five constructs as shown in Tab. (4.32) above. The participants rated IX construct highest in ARSP and then in VRSP, which was not as excepted as they are both use immersive technologies and as such will have a higher immersiveness than the two conventional SP forms. The participants rated ARSP as the most neutral SP form in regard to the RWD construct as it offers an overlaying of the information on the real environment in real time, so the sense of time will be the most neutral or like "real time" and not highly distorted as VRSP which has a high sense of time distortion factor. The participants rated ARSP the highest in regards to the intention to accept and adopt, which shows that the participants are most likely to accept and adopt ARSP as their favored form of service prototyping. The participants also rated ARSP the highest with regards to the effectiveness, as this might be due to the guiding nature (doing it while experiencing it) of the ARSP compared to the other SP forms. The participants rated VRSP experience as the highest in comparison to all the other forms, which might suggest that they found it to be the most interactive and immersive SP form with the superior experience.

Table 4.33 SP Experiment Qualitative Results Comparison

Sentiment	PSP	MSP	VRSP	ARSP	MRSP
Immersiveness	Negative (-0.49)	Neutral (0.07)	Positive (0.54)	Positive (0.56)	Positive (0.50)
Real World Dissociation	Negative (-0.33)	Negative (-0.22)	Positive (0.53)	Neutral (-0.03)	Positive (0.31)
Service Prototype Effectiveness	Negative (-0.26)	Positive (0.37)	Positive (0.54)	Positive (0.70)	Positive (0.56)
Service Prototype eXperience	Negative (-0.36)	Positive (0.16)	Positive (0.54)	Positive (0.5)	Positive (0.5)
Intention to Accept and Adopt	Negative (-0.21)	Positive (0.52)	Positive (0.55)	Positive (0.69)	Positive (0.64)
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (Sentiment Value: -1→ +1)					

The participants gave a justification for each of the survey questions, as such these justification was analyzed by using sentiment analysis as represented in Tab. (4.33) above. The participant's justification concerning the immersiveness construct were positive for the ARSP, VRSP and MSP, while negative for PSP, which shows that ARSP had the most positive comments concerning immersion properties. The participants' justifications for the real world dissociation construct were positive for only VRSP, and negative for PSP and MSP, while ARSP had a neutral value, which shows that the participants felt positively in the immersive VR environment. The participants also justified the intention to accept construct positively in the VRSP, ARSP, and MSP, while PSP rating qualitative results were negative, showing that the participants didn't accept PSP or at least were negatively biased towards. The participants positively justified the rating of the SP effectiveness in the case of ARSP, VRSP and MSP, while ARSP was highly regarded in the comments in regards to the effectiveness. The participants' sentiment of the SPX was positive in VRSP, ARSP and MSP, however negative in PSP. The sentiment of the participants shows that the they enjoyed the VRSP experience most. This analysis is not sufficient enough to gauge the impacts of immersive technologies, as the metrics of the second, third and fourth sequences are affected due to the effect of learning, as each participant will most probably get better after each task completion. For this reason, another analysis where only the first sequences from these SP forms are compared, and also they will have to compared to the performance of the participants when they didn't use any SP form, and also when they used the MRSP as well. To be able to complete this analysis, an analysis of MRSP has to be concluded first, then an inclusive analysis is conducted to determine these impacts, if any.

An analysis to compare the first use of each SP form is needed, as the first experience of each participant is one of the most important indicators to gauge the performance and experience of each the forms. The analysis was done on the metric observations and survey ratings of each SP in the first sequence, comparing the observation metrics of baseline experiment, with all the SP forms used and also the survey quantitative results in the first sequence. The performance and experience differences between each SP form can be measured by comparing their first time use. The comparison is in regards to the performance observations from the first sequence of each SP and that of the baseline experiment as it would give a better idea about the differences in efficiency, effectiveness, and comprehension levels. The results enabled us to compare the performance of the SP forms based on the gender and occupation of the participants participating in the SP experiment. The results show that there are differences for some SP forms between the different genders and occupations, however other SP forms show a more neutral effect. To show these difference as shown in the table below, as the comparison of the observed performance, and given rating results according to each identifier and SP forms are shown. The color coding is the same as the findings, the green indicates positive, red means negative and orange is neutral. Each of the experimented SP forms are compared against each other in regards to the genders and occupations.

Table 4.34 SP Forms Comparison of the Participants Performance in regards to Gender

Obs.	BSL F	BSL M	PSP F	PSP M	MSP F	MSP M	VRSP F	VRSP M	ARSP F	ARSP M	MRSP F	MRSP M
TCD	11:21	11:04	07:20	07:15	06:05	06:01	07:10	06:50	03:09	03:02	03:05	02:46
EA	3.63	4.55	0.1	0.07	0.2	0.12	0.3	0.06	0.2	0.12	0	0
EOR	18%	23%	0.5%	0.35%	1%	0.6%	1.5%	0.3%	1%	0.6%	0	0
EFR	87%	91%	5%	5%	15%	10%	20%	6%	20%	8%	0	0
EI	10	11	2	2	2	2	3	2	1	2	0	0
XA	4.63	4.23	0.2	0.08	0.15	0.13	0.35	0.07	0.35	0.3	0	0
XOR	23%	21%	1%	0.4%	0.75%	0.65%	1.75%	0.3%	1.75%	1.5%	0	0
XFR	87%	95%	15%	8%	5%	13%	20%	5%	15%	19%	0	0
XI	9	9	2	1	3	1	3	2	4	4	0	0

TCD: Task Completion Duration, **EA**: Errors Average per participant, **EOR**: Error Opportunity Rate, **EFR**: Error Frequency Rate, **EI**: Error Intensity, **XA**: Explanation request Average per participant, **XOR**: Explanation request Opportunity Rate, **XFR**: Explanation request Frequency Rate, **XI**: Explanation request Intensity

Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)

Considering the observed performance results of the participants with regards to the gender identifier as shown in Tab. (4.34) above, several differences were apparent: (1) the baseline experiment results show that the performance of both genders in the case of not using any SP was similar, although males finished faster, they had more errors but also asked less questions than the females. (2) The PSP results show that male participants performed better than females however there were no significant differences between them and there was no difference at all in the case of error frequency rate and error intensity. (3) The MSP results show that no significant differences between the participants' genders performance, but male participants were minimally faster, required less explanations on average and committed lesser errors than females did. (4) The VRSP results shows a significant difference in all the aspects of the observed performance factors in the favour of the male participants. (5) The ARSP results show that male participants had a slight advantage in terms of performance, however the females made less maximum amount of errors per participant, and had a less percentage of participants asking at least one question, while the maximum number of participants asking questions was the same for both genders. (6) The MRSP results showed that in terms of speed there is a slight advantage for male participants. other than that they were no difference at all in all the performance aspects. (7) The SP observed performance differences regarding genders show that there was no significant difference in the cases of PSP, MSP, and ARSP, while in the case of VRSP there was a significant difference that might be due to the immersive 3D form of VR, however MRSP had the least differences in performance which might indicate that it is the most gender neutral SP form.

Table 4.35 SP Forms Comparison of the Participants Performance in regards to Occupation

Observations	PSP P	PSP S	MSP P	MSP S	VRSP P	VRSP S	ARSP P	ARSP S
Task Completion Duration (min:sec)	07:14	07:16	05:49	06:06	06:40	07:01	02:58	03:06
Average Usage Error per participant	0.04	0.09	0.14	0.13	0.08	0.13	0.07	0.16
Error Opportunity Rate	0.2%	0.45%	0.7%	0.65%	0.4%	0.65%	0.35%	0.8%
Error Frequency Rate	4%	7%	14%	9%	8%	9%	7%	12%
Error Intensity	1	2	1	2	1	3	1	2
Average Usage Explanation Requests	0.14	0.09	0.11	0.15	0.15	0.13	0.18	0.36
Explanation Requests Opportunity Rate	0.7%	0.45%	0.55%	0.75%	0.75%	0.65%	0.9%	1.8%
Explanation Requests Frequency Rate	11%	9%	11%	12%	12%	7%	14%	20%
Explanation Requests Intensity	2	1	1	3	2	3	2	4
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)								

Considering the observed performance results of the participants with regards to the occupation identifier as shown in Tab. (4.35) above, several differences were apparent: (1) the PSP results show that there was a slight advantage for the professionals in the completion speed and number of errors committed, while the students had a lower explanation requests. (2) the MSP results show that the professionals were faster than the students but the professionals committed more errors and requested less explanations on average while completing the task. (3) the VRSP results show that there was a significant difference in the performance, as the professionals were much faster, committed lesser errors but they also request more explanations than the students did. (4) the ARSP results show also a significant difference in the performance as the professionals were able to complete the task faster, with less errors and explanation requests. (5) There is a slight performance advantage for the professional in the case of CSPs, but even a more significant advantage in the case of ISPs. While there was advantage for using VRSP for the professionals from the efficiency point of view the effectiveness had less of a significant difference. However, in the case of ARSP there were significant differences in the efficiency and effectiveness of the participants as professional had performed much better than students. This might indicate that ARSP is a good SP form, if the prerequisite knowledge or experience is existing

Table 4.36 SP Forms Comparison of the Participants Survey Ratings in regards to Gender

UX	PSP F	PSP M	MSP F	MSP M	VRSP F	VRSP M	ARSP F	ARSP M	MRSP F	MSRP M
Immersiveness	-0.85	-0.73	0.17	0.17	0.68	0.93	0.66	0.98	1.09	1.13
Real World Dissociation	-0.57	-0.6	-0.58	-0.4	0.68	0.91	-0.1	-0.18	0.09	-0.37
Service Prototyping Effectiveness	-0.32	-0.56	0.62	0.69	0.69	0.9	0.88	1.1	1.42	1.26
Service Prototyping Experience	-0.61	-0.45	0.24	0.28	0.71	0.93	0.65	0.81	1.01	0.94
Intention to Accept and Adopt	-0.45	-0.01	0.82	0.78	0.85	0.99	1.15	1.18	1.36	1.54
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Rating: -2 → +2).										

Considering the survey results of the participants with regards to the gender identifier as shown in Tab. (4.36) above, several differences were apparent: (1) looking at PSP, there were no significant differences in the ratings of the participants as males rated the IX, SPX and ItA higher than females, while females rated the RWD, and SPE higher than the males. (2) In the case of MSP, there were also slight differences but both females and males rated the IX exactly the same, while males rated RWD, SPE, and SPX slightly than the females, and the females rated the ItA somewhat higher than the males. (3) Regarding VRSP we can see a significant difference in the ratings, as males rated all UX constructs higher than females did. (4) Concerning ARSP there was also a significant difference in ratings, as females only rated the RWD higher than males, otherwise the males rated all the other UX constructs higher. (5) Concerning MRSP, there were slight differences in the ratings of the participants, as females rated the RWD, SPE and SPX higher than the males did, and the males rated the IX and ItA higher. These rating differences show us that the VRSP was the favourite SP form for the male participants, while the females much preferred the MRSP. The differences also illuminate the fact that the male participants almost always rated the immersiveness and the adoption intention of the prototype higher than females, except in the case of MSP.

Table 4.37 SP Forms Comparison of the Participants Survey Ratings in regards to Occupation

UX	PSP P	PSP S	MSP P	MSP S	VRSP P	VRSP S	ARSP P	ARSP S
Immersiveness	-0.57	-0.82	0.33	0.11	0.7	0.93	0.88	0.96
Real World Dissociation	-0.31	-0.71	-0.08	-0.57	1	0.81	-0.01	-0.22
Service Prototyping Effectiveness	-0.41	-0.23	0.87	0.6	0.74	0.9	1.03	1.08
Service Prototyping Experience	-0.31	-0.55	0.46	0.2	0.77	0.93	0.75	0.79
Intention to Accept and Adopt	0.08	-0.17	0.86	0.76	0.7	1.07	1.13	1.19
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Rating: -2 →+2)								

MRSP was not included in the survey rating comparison in regards to the occupation as the number of professionals' participants (2 Masters students that work part time) in the MRSP was low considering the overall numbers. Considering the survey results of the participants with regards to the occupation identifier as shown in Tab. (4.37) above, several differences were apparent: (1) In the case of PSP there were significant rating differences as professionals rated almost all the UX constructs higher than the students, only the SPE was lower than the students' rating. (2) Regarding MSP, there was a significant difference in the ratings as the professionals rated all the UX constructs much higher than the students did. (3) Considering VRSP, there were significant differences in the ratings as the students rated the IX, SPX and ItA higher than the professionals did, while the professionals rated the RWD and SPE higher than the students. (4) Looking at ARSP, there were significant differences in the ratings as the professionals only rated the RWD slightly higher than the students, while the students rated all the other

UX construct higher than the professionals. The differences in the ratings here show us that the professionals much preferred the conventional over the immersive SP forms, where the students preferred the immersive ones most. The results also highlight the significant differences in ratings of the real world dissociation as the professionals rated it higher every time, meaning that the students were more associated with the real world while using each SP form. The SP sequence position one comparison shows the differences between the performances of each SP form in contrast to the baseline experiment. The sequence 1 is important especially for the observations as it shows the performance of the first time use for the participant with each of the SP forms; which eliminates any bias of any prior experience or latent knowledge due to prior SP use.

Table 4.38 Sequence Position One Observations Comparison

Observations	BSL	PSP 1	MSP 1	VRSP 1	ARSP 1	MRSP
Task Completion Duration (min:sec)	11:09	07:27	05:50	07:10	03:02	02:53
Average Usage Error per participant	4.3	0.19	0.08	0.25	0.21	0
Error Opportunity Rate	21.50%	0.96%	0.40%	1.25%	1.04%	0%
Error Frequency Rate	90%	11.54%	8.00%	17.86%	16.67%	0%
Error Intensity	11	2	1	3	2	0
Average Usage Explanation Requests	4.33	0.19	0.12	0.21	0.58	0
Explanation Requests Opportunity Rate	21.67%	0.96%	0.60%	1.07%	2.93%	0%
Explanation Requests Frequency Rate	93.33%	15.38%	12.00%	10.71%	33.33%	0%
Explanation Requests Intensity	9	2	1	3	4	0
Happy Participants' Attitude	2%	12%	20%	65%	52%	83%
Neutral Participants' Attitude	35%	84%	72%	27%	41%	10%
Frustrated Participants' Attitude	77%	4%	8%	8%	7%	7%
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)						

The participants, as shown in Tab. (4.38), were able to complete the task the fastest with the support of the MRSP with only two minutes and fifty-three seconds, and ARSP as second with three minutes and two seconds. This suggests that MRSP is the fastest SP form to complete the task, as it took the least amount of time to complete the task. The slowest SP form was the PSP, as it took more than twice as much as MRSP took, which was seven minutes and twenty-seven seconds, but still it takes less than it would have taken if no SP form was used at all as it took on average 11 minutes and nine seconds to complete the task without any SP support. The participants made many mistake while completing the task without using SP, they averaged 4.3 errors per participant, which is quite high even with comparing it with the SP form with highest error quote VRSP with 0.25. This shows that the participants made the most mistakes while completing the task was after using the VRSP, this could be due to the lacking interactions in the prototype, but as it is a prototype a certain fidelity and resolution had to be adjusted to make all the prototypes equal in that sense.

MRSP showed a fantastic result as the participants didn't commit any errors while completing the task, which was incredible as the second lowest error quote from a SP came from MSP, which shows that video is effective in delivering the information necessary to successfully complete the task but not as much MRSP. The baseline experiment showed that average explanation requests per participant was 4.3, which is comparatively high when looking at the requests quote from the other SP forms. ARSP had the highest explanation requests quote 0.58, which was due to the fact that some of the participants didn't know how to operate an AR device, and how markers are captured and also about the AR functionality. MRSP performed excellent in that field as all the participants were able to complete the task without asking any further explanation requests. These results suggest that the MRSP is the most efficient SP form for completing this task and similar instructional or guidance based tasks. The data also suggests that ARSP is a viable option if concentrating on the guidance based tasks, while MSP (Video) offers a relatively universal way of communicating repetitive instructions that needs to be done directly afterwards. We think that VRSP might have a great potential in training prototyping and could be utilized to communicate information in a fun and immersive manner. MRSP was the fastest seconds, followed by ARSP, which might be due to the fact that the participants had to absorb the knowledge and do the task at the same time, which saves time. The slowest form was the PSP, and close second is VRSP, this might be due to the fact that participants had to experience around four minutes in a virtual simulation on average, and also the participants had to read the instructional leaflet before starting which was also around four minutes on average.

The error quotes are marginal as the quotes are all under 0.25, which is for VRSP which suggests one out of each four participant made an error while completing the task. MRSP had a 0 error quote, which might be attributed to the fact that the MR device is mounted directly on the head and the eyes are covered from all sides with the visualization so the mind is being guided step by step through colored visualizations, which left no place for error. The participants showed that even such a simple disassembling and assembling tasks could be challenging for many participants, in the baseline experiment, where the participants didn't use any SP form they had a quote of 4.3 request per participant. In comparing the baseline explanation requests quote with the highest SP form quote, the ARSP which has 0.58, it is still 7.5x more explanation requested. The participants had several questions while using ARSP, one of every two participants had a question while using ARSP, many of them due to the markers recognition and the tablet functionality. To have a better understanding of the participants' survey ratings, we selected the ratings from only the first sequence from each SP form and compared it MRSP. The ratings of the participant could be best measured in the first use of each respective SP form, as it will capture their first impressions after first experience. The sentiment will also indicate that they will not be biased by having prior experience of any other SP forms, which is great in gauging the real ratings of the participants for each of the SP forms, as the rating goes from very weak (-2) to very strong (+2).

Table 4.39 Sequence Position One Survey Ratings

UX	PSP 1	MSP 1	VRSP 1	ARSP 1	MRSP
Immersiveness	Weak (-0.45)	Weak (-0.13)	Strong (0.78)	Strong (0.75)	V Strong (1.12)
Real World Dissociation	Weak (-0.55)	Weak (-0.61)	Strong (0.65)	Weak (-0.26)	Weak (-0.20)
Service Prototyping Effectiveness	Weak (-0.04)	Strong (0.51)	Strong (0.69)	V. Strong (1.11)	V Strong (1.32)
Service Prototyping Experience	Weak (-0.27)	Strong (0.07)	Strong (0.79)	Strong (0.69)	Strong (0.97)
Intention to Accept and Adopt	Strong (0.14)	Strong (0.71)	Strong (0.89)	V. Strong (1.09)	V. Strong (1.48)
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower), (UX Rating: -2→ +2)					

The survey main constructs and their ratings alongside the survey average from sequence position one for each SP form are presented in Tab. (4.39) above. The participants rated MRSP with the highest rating in every construct, except the RWD which shows that the participants felt that it does disassociate them from the real world as it was the nearest rating to the neutral rating of 0. The participants rating in the first sequence didn't change much from the overall survey, other than that MSP is nearer to neutral than positive, and PSP is less negatively rated as in the survey total by 50% to be precise. This shows that the participants that used PSP in the later sequences felt that it is lacking as they could compare it to the other SP forms, which could be also the case for MSP.

4.6. Industrial Workshop

To be able to understand more about the practicability of service prototyping and the use of XR in creating and experiencing service prototyping; a workshop with industrial stakeholders was conducted. This workshop was to gauge the industrial intention to accept and adopt service prototypes and the use of XR in service prototyping. The workshop also included an explanation of the SP experiment and its results, to foresee if they think that this is feasible in an industrial service setting. The workshop had a focus group discussion with open ended question after the SP presentation to be able to collect data from their answers. Focus group interview is a well-known method for researchers to search for ways to improve their products (Krueger, 2002). Focus group method offers a way to explore a group's understanding of a topic and why do they think this way as well (Morgan, 1988). Focus group is a research tool involving an organized open discussion with a selected group of individuals to gain communal opinions about a subject (Gibbs, 2012). Thus for this dissertation, group discussions were used to explore industrial group opinions on the service prototyping process, the SP experiment, and its results.

4.6.1. Focus Group Discussion

The industrial stakeholders had only one thing in common, which is that they all work for Liebherr organization and they are all interested in services. The demographic analysis on the entry survey shows that they were a homogenous group of different individuals and work in different divisions and from different age slices; this is vital to have a broad spectrum of opinions from across the board. The results of the demographics of the participants are shown in the (a) age slice of the participants, (b) vocational area, (c) service importance, (d) knowledge levels, (e) terms familiarity, and (f) expectations from the experiment.

Figure 4.9 Industrial Stakeholders' Age Slice, and Occupation

The stakeholders were from diverse age-slices, as 60% of them were between the ages of 26 and 35, 30% of them were between the ages of 36 and 45, and only 10% between the ages of 46 and 65 as shown in Fig. (4.9). This shows that the stakeholders are of a relatively young age, which shows interests from the younger industrial stakeholders in hearing new research and seeing how they could leverage this new knowledge for their own work processes. All the participants were employees of Liebherr, but they came from different divisions as such the stakeholders were not selected but they volunteered to participant in the focus group workshop. Most of the participants came from the business development services and digital services with 23% each, 15% of them were from customer service and portfolio management each, while 8% of the volunteers were from marketing, and other divisions. This shows that the stakeholders interested in services are not concentrated in only one division, which will also give a more unbiased opinion as the stakeholders from the same division were mixed in different group discussion sessions.

Figure 4.10 Importance of Service and level of Service Development Knowledge

The question about the importance of services for the majority of the stakeholders was answered as important, which is the highest rating, meaning that services is their main focus in the vocational job as shown in Fig. (4.10). This shows that services are important for the participants. This shows that service is the main job for almost all of the participants. The stakeholders' level of knowledge was self-rated, and 62% of them rated themselves on a practitioner level in service development, while 38% of them rated themselves as novice in service development. This shows that none of the participants considered themselves as experts or even specialist.

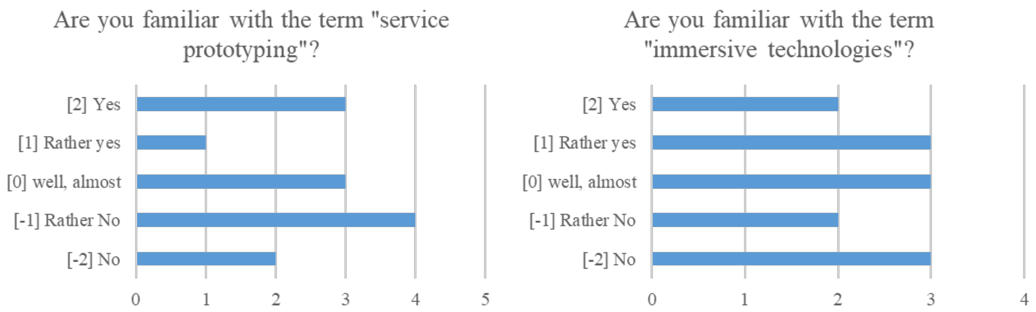

Figure 4.11 Familiarity with Service Prototyping, and Immersive Technologies

The participants were also asked before the presentation and the focus group if they were familiar with service prototyping, and their answers were diverse as shown in Fig. (4.11). 21% of the stakeholder felt that they are familiar with the term service prototyping, 7% of them felt that they are rather familiar with the term, 21% felt that they are almost familiar with the term, while 38% of them were rather unfamiliar with the term SP, and even 14% of them were unfamiliar with the term. The stakeholders were mostly technology affine and they were interested in the impacts of immersive technologies on service prototyping and development as whole. The stakeholders rated their familiarity with immersive technologies, and 15% of them were familiar, 23% were rather familiar with the term, and 23% were almost familiar, while 15% were rather unfamiliar with the term, and even 23% were unfamiliar with the term immersive technologies (including VR, AR, MR).

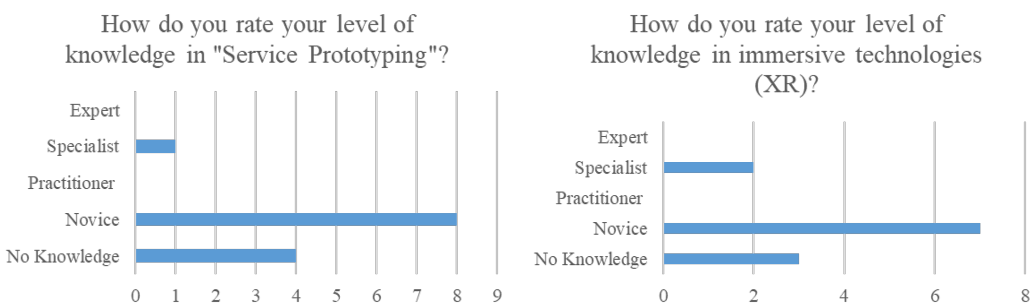

Figure 4.12 Level of Knowledge of Service Prototyping and XR

The stakeholders also rated their level of knowledge in service prototyping, as they were few of them that had previous experience with our service prototyping workshops, or working in service prototyping at Liebherr. 8% of the stakeholders were specialist in service prototyping, while 62% of them were novices and 30% of the participants had no knowledge about service prototyping. The stakeholders also rated their knowledge level in immersive technologies, including VR, AR and MR, as displayed in Fig. (4.12) above. 15% of them were specialist in immersive technologies, while 53% of them were novices and 32% of them had no knowledge on any immersive technology.

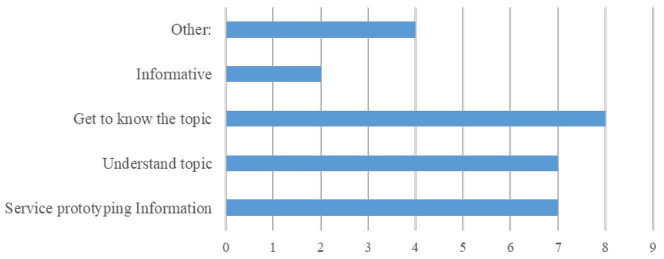

Figure 4.13 What do you expect from this workshop and focus group discussion?

The stakeholders of the focus groups were most interested in getting to know more about service prototyping, to understand the topic more and to get more information about service prototypes. Other comments as shown in Fig. (4.13) were "*how can I use service prototyping for my job?*" or "*how can I leverage service prototyping for my markets?*", and "*how can I use service prototyping for training concepts?*". Other stakeholders added that they would like to have tips and recommendations for application, and the cost benefit and also what kind of reasoning they should leverage to use service prototypes.

4.6.2. Feedback Survey Results

The stakeholders filled out a survey after the discussion was finished, this survey was created to gauge the stakeholder's acceptance of the SP forms mentioned, and also to ask for their evaluations concerning the applicability in a real industrial service environment.

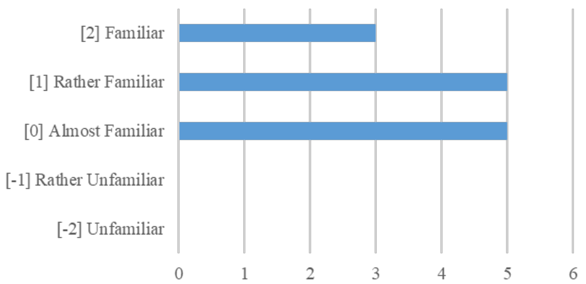

Figure 4.14 How familiar are you with "Service Prototypes" after the workshop?

The rating of the stakeholder's familiarity with the term service prototyping is displayed in Fig. (4.14). 24% of the stakeholder felt that they are familiar with the term service prototyping which increased from 21%. 38% of them felt that they are rather familiar with the term, which increased from only 7%. 38% felt that they are almost familiar with the term which then turned the 52% of stakeholders that were rather unfamiliar or unfamiliar with the term.

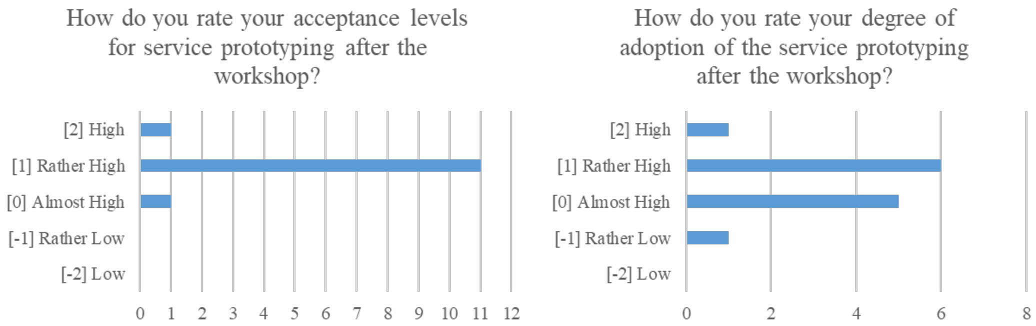

Figure 4.15 The Degree of Acceptance and Adoption after the Workshop

The acceptance of the service prototyping process is a critical aspect of this focus group discussion, as it was important to see the industrial acceptance towards the use of service prototypes. The rating was quite high, as 8% of them described their acceptance level with high, and 84% of them described their acceptance level as rather high, while 8% of them described their acceptance levels as almost high as shown in Fig. (4.15) above. The stakeholder was asked to estimate their degree of adoption to service prototyping in their work process, and 8% of them rated the degree of adoption with high, 46% of them rated it with rather high, 38% of them rated the degree of adoption as almost high, and 8% of them rated the degree of adoption rather low.

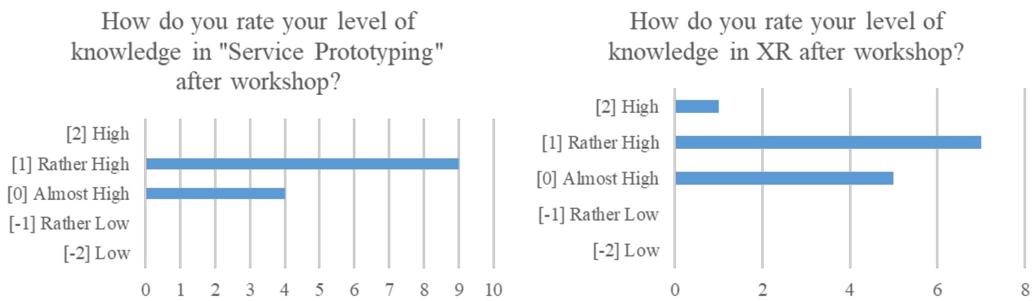

Figure 4.16 Level of Knowledge in Service Prototyping and XR after workshop

The stakeholders self-rated their knowledge level service prototyping after the discussion positively as shown in Fig. (4.16) above, as 62% of them were novices and even 30% had no knowledge about service prototyping before starting the workshop and discussion. 70% of the stakeholders rated their service prototyping knowledge level as rather high, and 30% of the stakeholders rated their SP knowledge level as almost high. This shows a big gain in service prototyping knowledge and information. The stakeholders were then asked to rate their new acquired knowledge level in XR information after participating in the focus group discussion. Before starting the focus group discussion 53% of them were novices and 32% of them had no knowledge on any immersive technology, but after 8% of the stakeholder rated their immersive technologies knowledge level as high, and 54% of them rated it as rather high, while 38% of them rated it as almost high.

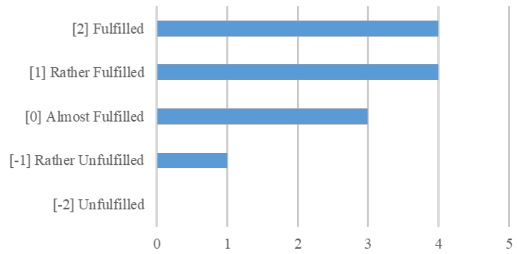

Figure 4.17 Were your expectations for this workshop fulfilled?

At the end of the survey there was a question to ask if the stakeholders' expectations were met in the workshop and discussion as shown in Fig. (4.17), and if they felt that the time was well spend. 30% of them felt that their expectations were fulfilled, 30% of them felt that were rather fulfilled, and 22% of them felt were almost fulfilled, while 8% of them expectation were rather unfulfilled. The workshop was done to not only evaluate the experiment results, but also introduce the SP and XR concepts.

4.6.3. Focus Group Discussion Results

These are some of the comments that they left on the other comments section in their survey, as (a) "*Good presentation, very pleasant and open atmosphere, thank you!*", (b) "*How do you perform service prototyping projects?* ", (c) "*Do not lose sight of the cost-benefit ratios.*", (d) "*Costly solutions without user benefits have no acceptance.*", (e) "*Thank you so much! If possible, I would also like to receive the final results of the work. All the best!*".

Table 4.40 List of Verbal comments for the discussion

Open ended Question	Comments
To what extent are you ready to use service prototypes?	Service Prototyping is one of the future focuses of Liebherr
	Without rapid service prototypes, feedback does not work
	Fascination plays great role in XR due to the immersive experiences
	Acceptance difference between beginners and professionals
	Service prototyping sharing results with the stakeholder
	Searching for potential for issues with customers through service prototyping
	Very useful for me and my work
	Benefit for training in the service sector
	Risk free training on the job, training through experience

What do you think of the results of the research study?	Image says more than a thousand words, and video says more than a thousand images
	VR and AR stay in mind longer
	In real situation implementation would be possible
	No matter what form, the main thing is making a SP
	The more complex the task, the more complex the video or SP
	Simply prototype to test better than start point
	MR / AR disadvantage is when, incorrect info or unsurpassed passages are displayed
	Effort to have clean data for immersive application
How do you assess the effects of Experiencing a service that does not exist yet?	Experience is totally important, buying decision made about experience, so after belly feeling
	Insight into New Product / Service
	Experience is at utmost importance for service
	Early feedback, early mistake makes a better experience afterward
	Make service ideas tangible and visible
	Conservative customers / stakeholders must be convinced
	Service prototyping helps to make service imaginable
How do you assess the effects of Communicating a service idea that does not exist yet?	Expectations awaken by prototype, which could be negative or positive in some cases
	Grasping and touching through prototyping
	Increase acceptance and enthusiasm
	Good ideas expire if not shown
	Make experience with pictures easier to understand
	Prototype timing is important
	Questions gauge the expectation and attitude of stakeholders
	Can be utilized to not be Fixed on only one idea, and in reality is different
How do you assess the effects of Evaluating a service that does not exist yet?	In any case, SP has to be represent the idea clear, as if miss interpreted differently than thought as communicated could lead to errors
	Take development fears away
	If I have SP, then can discuss constructive with customers
	It is important to have the target group rated for usability
	Could be used to review potential customer needs and wants
	Great potential in marketing and promotion
How do you assess the effects of Learning a service that does not exist yet?	As with e-learning, there are two groups, one needs someone to learn and one uses technology to learn
	If not done, then other options may expire
	Learning with stakeholder on concepts, agreeing or disagreeing with it
	Pick up feedback Target audience pay attention
	Learning by doing
	Important to learn the service features and features beforehand
	According to experience, the easier and the easier the better
	Make digital service products tangible through SP
Do you see benefits for using service prototypes?	Training on job very important (no matter which one)
	Time savings through service prototyping
	Optimization potential through iterations with continuous agile development
	Closer to market requirements, needs, and wants
	Better understandable, less barriers
	Stay on the safe side with VR
	To speed up development and cost savings

	Many advantages as effectiveness, Get feedback fast
How do you see the use of service prototypes in service development at Liebherr?	Many advantages, at Liebherr in the future
	We will become more agile and dynamic, and increase man power
	Digital offers are now differentiating, and SP makes development easier
	From paper to AR we have something for sure
	Try everything, no mistakes at the end
	Reduction in diagnosis and maintenance
	Simulate maintenance, and training, optimize by using XR
	Experienced prototypes try and test
	Instead of instructions and guide functions, which can be done with tablet or mobile phone with illustrations
	"Must do" instead of "would be done"

In Tab. (4.40) above is a list of the most important feedback in the focus group discussion. These were discussed in the three focus group discussions guided by open ended questions, all these comments were made verbally in German and then was translated afterwards into English. The sentiment of the comments was positive, and showed that almost all the participants had a higher level of technical adoption for service prototyping and immersive technologies. This also showed in their questions and further communication, which still continues until this day.

To summarize the workshop and the focus group discussions, it was a successful workshop and focus group discussion to (1) gauge the industrial technical acceptance and adoption of service prototyping and immersive technologies, (2) benchmark Liebherr service development process, (3) increase knowledge level of the employees of service prototyping and immersive technologies, and (4) to foresee what a major big company like Liebherr think of the experiment and the results of the experiment. Liebherr also showed great interest in service prototyping processes and tools, as they even hired an employee only for service prototyping in their service development department. This employee is responsible for cross co-collaboration between different departments to facilitate creating service prototypes for all their future developed services. Liebherr also recognized the importance of immersive technologies, and using XR to improve service development, innovation and delivery. Liebherr hired also another employee only responsible for immersive technologies service application and projects. The workshop also showed that service prototyping has a high industrial technical acceptance degree, especially in a big and large cooperation like Liebherr, which is an excellent sign. It showed also the high adoption degree of service prototyping, as Liebherr saw the advantage of using service prototyping to develop new services. Liebherr also is cooperating with the Furtwangen University on several industrial use-cases, where the students work with the employees of Liebherr for several smaller projects involving service prototyping or immersive technologies.

Table 4.41 Comparison of SP Forms based on the Evaluated SP Attributes Impacts (Extended from Abdel Razek et al., 2018a)

SP Type	PSP	MSP	VRSP	ARSP	MRSP
Fidelity	L	M	H	H	VH
Resolution	L	M	VH	H	H
Effort	L	M	VH	H	H
Interactivity	L	M	VH	H	H
UX	L	M	H	H	VH
L= Low, M=Medium, H=High, V H= Very High					
Green= Positive (higher), Yellow = Neutral (Equal), Red = Negative (Lower)					

The results enabled us to compare SP forms based on the evaluated SP attributes as shown in Tab. (4.41) above. The comparison is based on the overall results of the experiment, and industrial focus group findings. The fidelity of the prototype can impact the functionality built into the prototype, as CSP is suited best for initial prototyping processes and ISP for later development of the prototype. The resolution of the prototype can affect the resemblance of the prototype to the final design of the service, as CSP is suited best for using in earlier stages of development, while ISP best utilized in the later stages of development. The effort represents the organizational resources that every organization wants to invest in exploring, evaluating and communicating service ideas, where CSP requires less effort and can be best suited when the ideas are still in the earlier stages and to save costs while ISP can be suited when the idea is already selected and enough organizational resources are available for the service prototyping process. The interactivity of the prototype is decided with the degree of interactivity required in the prototype, as such CSP is more appropriate for when a limited interactivity prototype is needed and ISP is more suitable for prototyping more complex service interactions. The experience of the prototype is a vital attribute as it is based on perceptions and responses from the use or anticipated use of a service prototype; where CSP offers a lower degree of UX and is suited for the earlier stages as the experience is not important while ISP is more suited where UX is important for prototyping process.

4.7. Summary

PSP was the lowest rated SP survey wise, and also the least efficient method as it was the slowest. MSP was not as bad as expected it was actually more efficient than VRSP, and had less error and explanation requests as well. VRSP had the best rated service prototyping experience, but was not as efficient as ARSP and MRSP. ARSP was efficient, but not as effective as it required many explanation requests, which might have been due to the fidelity and resolution of the prototype. MRSP was fastest, rated the highest, and was the most efficient and effective. The sentiment was positive in the VRSP, then MRSP, ARSP, while the sentiment was positive to neutral in MSP, and negative in PSP. The comments from the experiment participants were instrumental in understanding more the impacts of using immersive technologies in service prototype.

The most important aspect of choosing an appropriate SP form is that selection has to be attuned to the SP purpose (implicit complexity) and activity (objective) set by the service stakeholders. There are difficulties in using VR / AR even for a simple task, few also faced cyber sickness as well. MRSP and ARSP were the most efficient methods to deliver the information (according to duration needed to complete the task and the survey ratings). MRSP was the favorited for more than 70% of the participants (from verbal discussions with the participants after the experiment sessions), which lead to believe that MRSP would be the most optimal solution. ARSP was given the highest UX rating by the participants in France, but VRSP was given the highest UX rating in Germany (aside from MRSP). AR usage without training might not be as efficient as using any another conventional form. Combining multiple SP forms might be the most optimal method (CSP + ISP). CSP seems more appropriate for early stage service development, and depends on the service complexity and degree of interactivity in the later stages. ISP seems more appropriate for complex and multidimensional service scenarios that might require interaction, and can be utilized in the later stages of service development.

What was apparent after the industrial workshop and focus group that Liebherr confirmed that there is a huge interest in SP. They even hired two employees for service prototyping and immersive technologies projects, as they are responsible for using service prototyping and immersive technologies to improve service offerings in the company and innovate new service development. We are also working closely with the Liebherr with several student projects on service prototyping and immersive technologies. They are now implementing service prototyping in development of new services in their company. The focus group discussions then were conducted to gauge the industrial technical acceptance and adoption degree of service prototyping and immersive technologies, while receiving their evaluations and feedback on the model, experiment and results. The stakeholders were positive towards service prototyping and its forms, they also added that they currently hired two employees, one for service prototyping and the other for immersive technologies service applications. The stakeholders also had a high acceptance and adoption ratings for service prototypes, and immersive technologies after the workshop and focus group discussions. There were also several industrial request to present the research results, and even was asked to present the findings of the experiment in the international conference for immersive fire fighters. This shows that there is a huge interest from the industry and even not only from the industrial sector, but also from other service sectors.

5. Discussion

5.1. Introduction

The discussion chapter explains and summarizes the main research objective, methods and results. The overall goal of this thesis is to gauge the impacts of immersive technologies on service prototypes with a set of experiments and focus group discussions in order to create a guide for further industrial implementation. The extensive literature review led us to the find a literature gap, where there was a lack of empirical investigation on service prototypes and especially immersive service prototypes. This identified gap also helped in shaping the research approach used in this thesis through mixed qualitative and quantitative methods approach in order to have a better understanding of the impacts and the reasons behind these impacts. To categorize and better understand these impacts a service prototyping research model and instrument were constructed, and the 'service prototyping experience' construct was elaborated. The construct, model and instrument investigated the impacts by comparing immersive service prototypes with conventional ones; by using an experiment and a survey to see the differences in terms of performance, experience, acceptance and feedback. The prototypes used in the experiment were constructed to engage the participants in learning and performing, as to create a representation of an industrial service training experience. The instrument main objective is to investigate the impacts of using immersive technologies (XR) on service prototyping.

For the time constraint of the dissertation, only three immersive service prototypes, and two conventional ones were selected for the experiment, and there was also only one company in the industrial benchmarking. These two CSP forms were chosen as they are currently used in service training processes and similar learning processes according to our literature research. The three types of ISP forms were selected because it makes sense to see which one would perform better in such a task, and what would be their respective impacts. This led to investigating the performance, experience, and adoption degree differences. The research instrument consists of bipolar survey in order to evaluate the immersiveness, real world dissociation, service prototyping experience and acceptance constructs, divided upon 15 semantic scale questions with rating justification elements, where the participant can write their feedback freely. The research was conducted by using mixed methods in order to get the most accurate depiction of the impacts of immersive technologies on service prototypes. Mixed methods was also used as there was a lack in empirical quantitative and qualitative investigation in service prototypes, and their performances. The experiment was successful in showing that not all immersive technologies offer the same advantages in regard to the performance, experience and enjoyment; as many of the participants' feedbacks and evaluations were positive after using ISP. The collected data amount in total was over 500 unique sets of data, including durations, errors, explanation requests, bipolar ratings, rating justifications and participants' comments.

The experiment was conducted with 133 participants experimenting with PSP, MSP, VRSP, ARSP and MRSP. The MRSP experiment was conducted with 30 participants after the main SP experiment due to the delay to receive the Microsoft Hololens equipment. The baseline experiment showed us that by any form it would have been better than nothing at all, which shows the importance of prototyping and communicating in service development and design. The prototype in paper form (PSP) is an outdated type of communication, but still is widely used in communication, prototyping and learning processes worldwide. Obviously, PSP was the slowest, least rated, least interactive, and had the worst service prototyping experience compared to the other SP forms. The prototype in Virtual Reality form (VRSP) brings a great way to risk free training and a great learning environment for absorbing knowledge for longer information retention. The prototype in video Mock-up form (MSP) offers a cost effective method for simple prototyping processes, but could be lacking interaction due to the 2D format of videos, or by using 3D models or artifacts to supplement it, might bring that extra advantage that it needs. The prototype in Augmented Reality form (ARSP) offers the best ratio cost/benefit and from performance and experience, as it could be used with less expansive personal devices (e.g. tablet or smartphone) for a minimum initial investment. The prototype in Mixed Reality form (MRSP) offers the best service prototyping experience through enough immersion and accuracy. The MSP form was by far the best CSP in the effectiveness, efficiency, and experience, while offering a neutral medium where it is easy to digest, understand, and apply to complete the task. MRSP was the best SP form overall as it offered the best possible performance, experience and had the highest adoption degree.

One of the main objectives is to aid service developer, designers and researchers in selecting the most appropriate SP form for each service process, which could be a complex task. The most important aspect is to identify the dependency links between immersiveness and the real world dissociation, service prototyping experience and efficiency. This was done through the statistical analysis of the experiment data, as we have analyzed these dependency links. The statistical analysis was only done on the SP forms with more than 100 participants, which means that another analysis was done especially for MRSP. The objective was to conduct all the SP form experiments at the same time, but due to the delay in the Hololens device acquisition process this was not possible. The experiment results were enlightening, especially in showing that the hypotheses were validated, and the research questions answered, but we felt an industrial view on the experiment and research results would be beneficial. The results of the experiment were then presented and discussed in an industrial service environment in order to gauge the acceptance and adoption degree of an industrial service organization. The focus group workshops and discussions were successful, as service prototyping and immersive technologies acceptance was high, and the stakeholders' sentiment was positive. The organizational acceptance was also felt, as the company hired two new employees to handle service prototypes and immersive technologies in the span of the service prototyping workshops that was done in the past two years.

5.2. Limitations, Reliability, and Validity

The experiment was done in an academic setting, where replication could be challenging as the diversity of the participants from the three campuses is random, and heterogeneous group, so if the experiment was conducted with a homogenous group, other findings might arise. The statistical validation of the model was done with more than 100 participants, which was sufficient; however, having more participants would have been more significant. Nonetheless, as the experiment session duration was about 1 hour, it would have taken over 1000 hours, which would have been challenging to finish in only 3 years. A baseline experiment was conducted in Germany with 30 volunteer students to establish a benchmark for the observation metric, as it was far too challenging to attract real professionals. The baseline experiment revealed why it is important to use a SP, but as all the participants were students, their experience and knowledge levels are limited, which might be reflected in their performances and feedbacks. Some of the participants were also my students, and their first immersive experience were either in my classes or in the experiment, which might have given them a more positive attitude to rate ISP survey higher, and CSP lower as they were fascinated by it.

The SP experiment participation ratio between Germany with 53% and France with 48% of the total number of participants was properly balanced. The gender participation ratio was around the 70% male, and 30% female, but as the experiment was on volunteer basis, we could not choose who wants to participate in the experiment. Regarding the occupation ratio, it was 70% of student and 30% of professionals. This might be also considered as a limitation, but as mentioned before the experiment is on volunteer basis, and the number of professionals participating was relatively high considering they had to spend one hour on the experiment. As for the age slice of the participants, most of the participants are then of younger age, in fact only 34% of the participants were over the age of twenty-five, which might be taken as a limitation as the younger participants might be more digitally affine than the older ones, but as it is an academic setting the volunteers were mostly students and young colleagues that were interested in testing new technologies and processes. MRSP extension on the SP experiment was conducted fully in Germany with 30 participants mostly students, as it was challenging to attract more professionals for another experiment at the same location. Most of the participants in the extension experiment were under the age of 25 years old, but there was nothing to do about this as they were all volunteers.

The experiment was conducted with the 103 participants with only PSP, MSP, VRSP, and ARSP (Hololens issue). Due to the fact that the MRSP extension experiment was only conducted with 30 participants, this could mean that if we test with more than 100 participants we might get a different result. The experiment could have been run singularly, meaning the experiments would have been divided into 6 separate experiments, one for each SP form, and then each of the experiment would have required around 20 minutes each, but we would have had to experiment with 100 participants each. This means that doing the experiment 600 times, which would have taken several years to complete as we would have to attract every year around 100-150 participants from the students at the institutes. The participants of MRSP experiment were also only students, which limits the knowledge difference aspect were we have differences in performance due to knowledge, experience, or know-how. The issue with MRSP is that it requires an MR device, in this case a Hololens, which is costly, as such AR would be the more affordable solution for cases that will be used by higher number of users, as it could be used on their work mobile device or even personal one. The Experiment could have been stronger if it was extended to include simulation service prototypes, and verbal service prototypes, to fully compare CSP and ISP, and to be able to compare the three ISP with three CSP. The issue was that this would made the experiment approximately two hours, which would have been impossible to get 100 in one year, as I was barely able to get 100 participants in the span of over a year in three university campuses, and while the experiment duration was only one hour. The data was rich, but the study needed a longer period to research all the SP forms, and all aspects of immersive technologies impacts in several case studies.

The knowledge absorption duration or the time needed for learning through each SP form was approximated in the pre-tests as it was seen as more efficient to see how long will each of the professions and genders of the expected participants, and use that in the final analysis. This decision was due to the fact that many of the participants have never used VR before, and it was expected that some participants would want to stay longer in the VR environment as they enjoyed it. The learning duration was also averaged for the PSP and MSP, as we clocked how long is it to read the paper instructional manual in multiple knowledge levels and in different languages and used it as our knowledge absorption duration, as for the videos, they are combined of three minutes so it was also considered as the knowledge absorption duration. Other limitations that could be due to the use of a tablet for taking their feedback, as some participants were not comfortable to type on the table touch keyboard, as no one was complaining in the pre-test, but only during the experiment it was highlighted as such a keyboard was provided for the rest of the experiments. Pretty painful for the participants that they had to fill the same questionnaire for each sequence, which means 4 times in total. Some participants also were left an empty space or comment that refers to another question in the justifications area. A lesson learned here is to limit as much as possible that the participants have to fill out the same questions several times.

A couple of industrial participants participated in the experiment, however it is very challenging to recruit people from the industry for one hour, unless the experiment design serves the company's particular context. The results of the SP experiment were presented during an industrial workshop, as it was not possible to ask the employees to complete the experiment by themselves as it would have taken a longer time, and also it would have cost the company extensively, it was decided only to present to them the experiment's process and results to have an open ended discussion. As an observer and researcher conducting a study a certain subjectivity is accounted; but we try to be unbiased so other researchers might have other subjectivity and might come to other results. The main hurdle with implementing MRSP widely is the cost of the device, as the MR Hololens device costs between 3500 and 5000 € depending on the version to purchase the device. There are also other costs for using MR, as you will need around 100€ monthly for software subscriptions and the development costs of programming. There are several other devices on the market but they are still in the development stage and most organizations want to have a partnership with a well-established company, especially in this field.

Reliability of the research means if this research can be transferable to other service contexts, and if other researchers can do the same study and come with similar findings (Trochim, 2006). The research was constructed with the idea of transferring the results to similar service prototyping research streams. The research model and instrument were created to investigate the immersive technologies impact on different forms of service prototypes. Also to compare the performance of ISP and CSP, while gauging the user experience and acceptance of using immersive technologies in service prototyping. There are four main threats to reliability (Murphy and Davidshofer 1988), the (a) general characteristics of the participants, (b) specific characteristics of the participants, (c) aspects of the experiment situation and (d) chance factors. Taking the participants' errors into consideration, we have designed the experiment to be conducted on different sequences so that each SP form is used in a cycle with the other forms, each of them as the starting SP form to eliminate any participant bias in starting with the same SP form every time.

The experiment was also conducted in different times of the day, as to eliminate any deviations due to conducting the experiment at a specific time of the day, where the participants could be still not fresh at the start of the day or too tired at the end of the day. The experiment was also conducted in three different academic campuses, two in France and one in Germany, as the participants have different genders, professions, ages, and backgrounds. The participants' bias is considered as the participant's ratings might be over positive or negative due to the observation of the researcher to the evaluation process, but in this study the participants were able to give their feedback on the Jaxber App, as they also gave their ratings and feedback on the app on the mobile tablet in a separate room as the observer as to eliminate the bias effect.

Due to the ratio of students and professionals in the experiment, which could be considered as a level of knowledge bias. The level of experience bias is almost eliminated as most of these participants didn't know the observer and didn't have any information on the research before the start of the experiment. The researcher error is based on the researcher's experiment setup and interpretations quality, where the most errors in the research design might occur. The experiment was setup to be conducted in different sequences, as to eliminate any participant bias, and also was conducted on the span of over one year as to eliminate any kind of researcher error from being too tired or not concentrated while observing the research. The research bias is based on human responses and interpretations and as we all humans make mistakes it is challenging to eliminate all human errors from research; as measure errors act as random variables across a large number individual (Murphy and Davidshofer 1988). The research findings were both measured in the cases of the participants' ratings and efficiency metric, and evaluated in regards the comments that the participants left in each of these ratings; which leads to interpreting all the findings together to create a complete picture of the research results. The experiment data collection was done with an App, which made it easier to combine the subjective and objective aspects of the research, as the researcher has to subjectively but neutrally evaluate the results to explain why are these results reliable and could be transferred into other research streams. The research was carefully design to eliminate these four mentioned reliability threats as explained before, as such these four errors didn't occur in this study.

The instrument reliability concerns its use in other contexts or research. The research instrument was based on an actual research instrument used before in other experiments (Pallot et al., 2017; Dupont et al., 2017; Krawczyk et al., 2017; Topolewski et al. 2019), as it was demonstrated that the model and instrument are used in similar immersive technologies and user experience research. The research instrument was used for experiment in evaluating the five different SP forms in the experiment, as it showed a consistent performance and rating in all the forms, and also showed positive feedback from the participants, which shows parallel-form reliability of the instrument. Internal consistency is when properties that measured the same constructs show the same tendencies, this is shown from the statistical analysis and from the participants' instrument ratings (Cortina, 1993). While a reliable experiment might provide useful valid information on the application, however an experiment that is not reliable cannot possibly be valid (Murphy and Davidshofer 1988).

The construct validity of the research, is when we clarify if the research measures what it claims to measure (Brown, 1996; Polit and Beck, 2008), which discusses the construct, internal, external and pragmatic validity of this study. We selected this research methodology as no other similar investigations that compares multiple immersive and conventional service prototypes were found. As the research topic is a novel one, we decided to use a mixed methods approach to not only have the quantitative evaluations results but also the qualitative explanations of these results, and interpreting on the overall findings. The research strategy was to create a framework, model and instrument, which aim to validate the hypotheses through the conducting of a comparative experiment. The experiment was created to include the immersion experience, user experience, service prototyping experience and user intention to adopt, where the triangulation of the participants' ratings, feedback and performances results all lead to the same findings. The experiment was conducted in an academic setting as such it is valid in the same academic context; it can be also valid in the industrial learning or training context as they will have the same attitude towards learning as in an academic setting. I wanted to research the impacts of immersive technologies on service prototyping, as no one else was doing it as an investigation, so we decided to investigate by using mixed methods as it would give us the impacts in performance, experience, and acceptance and the reason behind it. Internal validity of the model, statistical analysis, what are the casual links between the variables (Liebert and Neale, 1973), which is considered the relationship between dependent (IX, RWD, SPE, SPX, ItA) and independent constructs (PX, EX, CX). The assumption that there is a relationship between these constructs was based on the fact that it was used in other similar studies, and based on the work of one of the thesis supervisors. Because of lack of reflective indicators or a global item we did not perform "redundancy analysis", but instead we compared the loadings and cross-loadings. We expected the loadings to be larger than the cross-loadings, as we expect items to load stronger on their respective construct than on any other construct, as such the items converge is sufficient.

This experiment was conducted by using a sample of the academic population, so a replication in academic environment might probably get the same results, but as for an industrial 1:1 replication might have limitations due to the fidelity and resolution of the prototype, which might offer limited usability for professionals. The findings of the experiment can be generalized in the academic settings, and in industrial utilization in only an instructional guiding and learning setting. The experiments' participants were all volunteers, so there were no selection criteria as such a random group of volunteer participants participated in the experiment, this is shown from the demographic results of the participants. The SP experiment sample size of the 103 participants (n=103) was representative, as the experiment was conducted in three different locations, with three different target groups, engineers, technologists, and IT students and even some professionals from these fields participated in the experiment as well. The national research council advises that a model can be validated only relative to some application area, where a model that is valid for one application might be invalid for some other applications (National Research Council, 2012). Therefore, the results of the study are valid in the maintenance prototyping and in the learning based industrial services, the results might be valid for other applications but it has not been validated nor tested.

There are several threats to validity as the intentional or unintentional bias in research design, the researcher's expectations, outcomes definition, and confounding variables (Wortman, 1983). The experimental design was created with regards to the user experience and service prototyping framework, to eliminate any kind of unintentional bias this was constructed and previewed in two different conference to collect feedback on the research design before starting with the experiment. The researcher expectations were always kept in check, and in neutral form, as it was perceived that if the expectations are communicated unintentionally to the participants non-verbally it might illicit the ratings of the participants, but this could be also negated as the researcher was neutral throughout the experimentation, and also the participants were not only asked to rate their experience and acceptance but also to justify why did they give that rating. The participant's performance was measured so that there are not unintentional effects on the performance. The outcomes were defined as to have as broad as possible to avoid outlining a predicted outcome that is too narrow or limited. The immersive technologies impacts were observed and interpreted, so that the root causes for the immersiveness impacts were due to the observed and measured variables, which eliminates the covariates errors. The external validity concerns itself with the validity from a perspective driven viewpoint, when the practical feasibility and industrial acceptance are in questions (Pearl and Bareinboim, 2014). The workshops and focus group discussions was conducted at the EMTech (Earth Moving Technologies Division) at Liebherr GmbH, involving industrial stakeholders participating in a workshop, and evaluating the service prototyping process, the SP experiment and its results.

5.3. Responding to the Research Questions and Hypothesis

The main research question is to investigate the impacts of using immersive technologies in service prototyping, which splits the study to gauge the impacts of immersiveness on the real world dissociation, service prototyping experience, and efficiency. Our hypotheses were that the higher the degree of immersiveness, the higher the dissociation to the real world, the SPX, and the efficiency. The results of the quantitative and qualitative results show that SPX is positively influenced by IX, and that IX also influences the efficiency, acceptance and real world dissociation in different ways, depending on the degree of immersion and interactivity. This also verifies the research instrument that makes it possible to assess the experience, efficiency and real world dissociation aspects during the experiments. The instrument can be reused in the experiment where more SP forms are compared against each other. The results of the study are solid, as it shows not only the impacts in regards of the performance, but also the user experience and acceptance aspects as well.

The immersive technologies impacted service prototyping positively, as such improving the efficiency, enhancing the experience, and having a higher user acceptance rating as well. The MRSP was the most efficient and effective, and also the highest in terms of user experience and acceptance ratings, but also the other SP forms had their advantages and their drawbacks as well. The MSP efficiency was unexpectedly high, and even the PSP as the participants were most negative and their feedback and sentiment was negative as well, but they managed to complete the task with less errors than the other forms, except MRSP. The younger participants were really annoyed by the fact that they have to read a one sheet of paper or that they have to watch two videos of combined time of three minutes, which shows that the younger the participant the shorter their attention span. Some of the older participants were more annoyed with the immersive technologies as due to cyber sickness, or that they felt that it was "*overkill*" or "*unnecessary*", but the majority had a positive sentiment and for most of them it was the first time to try an immersive technology. Some of the differences in performances and ratings between gender and professions couldn't be explain from simply analyzing the data, a wider study is needed to investigate these difference in depth.

The participants' attitude in the experiment was also an indication on the success of each of the SP forms. The participants had a happier demeanor using ISP than when they were using CSP. Participants using MRSP were the happiest (83%), and followed by VRSP (63%) and then ARSP (40%). This indicates that the participants were happier using and applying any ISP form, and would favor using it over CSP if they have the choice. The percentage of frustrated participants using PSP (4%) was equal to ARSP (4%), but surprisingly lower than that of MSP (6%) and MRPS (7%). This might indicate that PSP needs less time to adapt as paper is an established method of learning, and when the new technologies are used some might feel unease using them. Participants using VRSP were least frustrated (3%), which might be due to the fact that VR environment is a lot of fun, and gives a high experience. Some participants also faced some cyber sickness when using VR and MR, which might also explain the percentage of frustrated percentage. Participants using AR were also frustrated by the fact that they need to adjust the AR mobile device to be able to see the necessary steps and some didn't have the proper training for using AR.

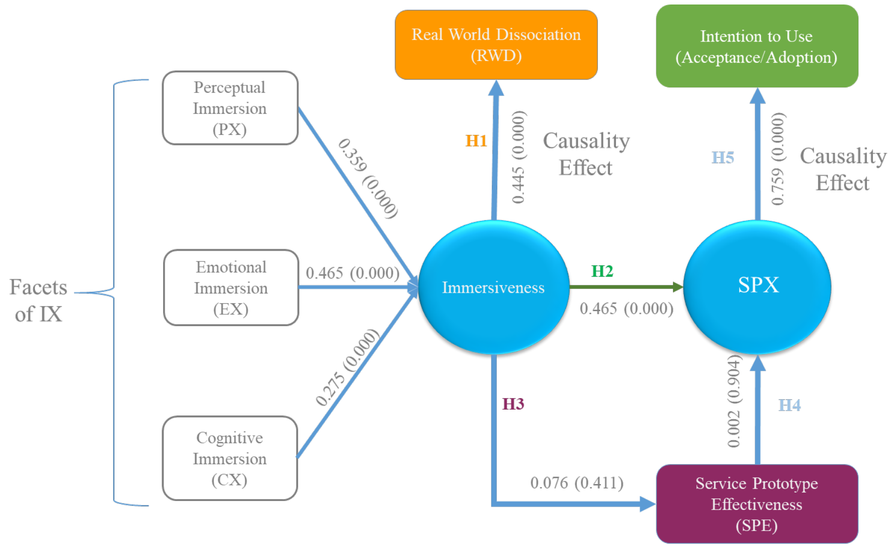

Figure 5.1 Service Prototyping Constructs and Model

From our statistical analysis the effect of immersiveness on RWD and SPX are confirmed, but the effect of immersiveness on SPX is considerably stronger than effect on RWD, and the directions of relationships for all constructs, which is the signs of coefficients, are positive as expected. The statistical analysis also showed that RWD is affected by different factors than the immersiveness as it only explains parts of RWD, and the data analysis showed also that the effect of immersiveness on SPE is confirmed. The overall experiment survey ratings consist of the constructs ratings from each of the SP forms used for all of the 103 participants that participated in the experiment. The most significant path is the SPE to SPX to ItA, which also explains that the effectiveness of the prototype is directly related to eXperience and also tied to the intention of accepting and adopting a prototype.

The first hypothesis proposes the higher the degree of immersiveness, the higher the dissociation to the real world. It was shown that the impact of IX on RWD is positive and significant, which supports the research hypothesis H1. This hypothesis is confirmed as the stakeholders will more immersed then their sense of time, surroundings and external factors will diminish with the increase in immersiveness. The second hypothesis proposes the higher the degree of immersiveness, the better the Service Prototype eXperience. Considering the research hypotheses about the predecessors and their significance stating that IX is predecessor of SPX is supported since in the valid model this path is significant. This means that stakeholders will have a more satisfying SPX that will increase the chances of convincing them to adopt it, or re-use it, and even recommend it to others. The third hypothesis proposes the higher the degree of immersiveness, the more effective the service prototyping process. It is worth to add, that IX has rather low impact on RWD since coefficient of determination but still IX positively affects SPE with high coefficient of determination that support this hypothesis. This indicates that ISP will positively impact on the effectiveness of the prototype. The fourth hypothesis that proposes the higher the effectiveness service prototyping process, the better the Service Prototype eXperience. Considering the research hypotheses about the predecessors and their significance, SPE is predecessor of SPX are supported since in the valid model this path is significant. This means that the participant will enjoy the service prototyping process more if they are more successful to accomplish the task without any help and mistakes and in the shortest duration possible. The fifth hypothesis that proposes the better the Service Prototype eXperience the higher the degree of stakeholders' acceptance and adoption. IX also positively affects SPE, here with high coefficient of determination, which supports this research hypothesis. This shows that as the SPX positively impacts the stakeholder's convincingness to adopt, willing to re-use, and the degree of recommendations to others.

The participants seem to have rated the MRSP, VRSP and ARSP immersiveness construct with highest ratings compared to all CSP forms, which confirms our hypothesis that there are immersive service prototypes offers a higher perceptual, emotional and cognitive experiences than conventional ones. The higher the immersiveness the higher the real world dissociation as in the case of VRSP, which confirms our first hypothesis of the higher the IX the higher the RWD. The second hypothesis was the higher the immersiveness the higher the service prototyping experience, where this is confirmed in both the MRSP, VRSP and ARSP, as they had higher IX and SPX ratings than PSP and MSP. The third hypothesis concerned the service prototyping experience, where we hypothesized that the higher the immersiveness the higher the efficiency. This could be confirmed as the SPX of MRSP had the highest experience rating followed by the VRSP. This shows that MR offered the highest experience for the participants, which also has the highest immersiveness rating. The fourth hypothesis constitutes that the higher the service prototype effectiveness the more satisfying the service prototype experience, and this could be confirmed also in the case of the MRSP, as its SPE and SPX ratings are the highest.

This shows that the participants found MRSP effective and also enjoyed using the SP form. ARSP had also a high SPE rating; however, VRSP had a higher SPX than ARSP although it had a lower SPE. The fifth hypothesis considers that the more satisfying the service prototype experience the higher the intention to adopt, which is also confirmed in the case of MRSP, as the participants rated SPX and ItA highly. The comparison of the results of the SP forms in regards to performance, and experience in each of the SP forms (See Tab. 4.35). If we only focus and analyze the first sequence of each SP form, to be able to precisely gauge the immersiveness as the participants will not have any experience with any SP form, making the first contact and experience the most vital to capture their performance without learning effect, and ratings without the bias of using another SP forms. The ratings represented in the IX, RWD, SPE, SPX, and ItA constructs, and the performance epitomized in the average task duration, errors calculations, explanations requested calculations, and participants' attitude can be (See Tab. 4.34).

The participants in each location behaved differently to the difference SP forms, this could be due to the fact that each experiment location was situated in a university or academic institute campus, where the volunteer participants are from different backgrounds but similar educations. This was unexpected, but as it was found that the campus with more focus on immersive technologies rated the technologies in a more critical manner and gave extensive feedback, but many of them were more interested in the technology not the application or in that case the prototyping idea itself. While the other campuses that concentrate more on engineering, IT and industrial solutions had ratings and feedback varied between positive and few negative. There were few participants whom were overtly negative while being bearish on the technology and process. While the rest that were positive on the technology and process and understood the advantage of prototyping and immersive technologies application and even had some constructive ideas for extensions or new ways to explore. This showed also in the results as the participants from the more engineering campuses had better performance in efficiency and effectiveness, while rating CSP higher than the immersive technology based campus. These metamorphoses of educational background and experience in the experiment was expected but not the extent that was noticed in the comparison between the campuses performance and rating results. This shows that experience and background could be a factor in not only the usage of the immersive technologies, but also its degree of adoption.

5.4. Outcomes Summary

The participants of the baseline experiment had insightful comments, even many of them had recommend to use one or all the SP forms that was used in the experiment without prior knowledge of them, which might indicate that these solutions might have been also the most appropriate ones. The participants in each of the experiment location behaved differently to the diverse SP forms, this could be due to the fact that each experiment location was situated in a university or academic institute campus, as the volunteer participants are from different backgrounds but similar educations. This showed unexpectedly in the ISP ratings results as it was shown that the campus with more focus on immersive technologies rated the technologies critically and gave informative feedback, while the other campuses ratings and feedback varied from very negative to very positive.

Table 5.1 Immersive SP Benefit and Drawbacks

Benefits	**Drawbacks**
Effectiveness (faster task completion duration from ISP)	Cybersickness (especially when using VR HMDs and less when using MR Hololens)
Efficiency (less errors and explanation request in ISP)	Higher costs (HMD costs, Hololens costs, Software costs)
More Satisfying eXperience (Higher SPX rating in ISP)	Initial adapting and learning process (Beginners might find it challenging to use VR and AR without training)

Higher Acceptance and Adoption (ISPs ItA average ratings were much higher than CSPs)	The benefit to cost ratio has to make sense for higher management (Industrial focus group discussion)
Risk free training and learning processes (SP Experiment Comments and Feedback)	
Makes it easier to understand (SP Experiment Comments)	
A better way of collaborating, exploring, and evaluating service ideas (Industrial focus group discussion)	

The results of the study show that there are many benefit and drawbacks for using ISP over CSP. The benefits and drawbacks of immersion are already well documented in the literature. The summary of the benefits and drawbacks are shown in Tab. (5.1) above. The benefits can be summarized in the (1) effectiveness of the users completing a specific task, (2) efficiency of the user in completing a specific task, (3) the higher experience provided when completing the task, (4) the higher acceptance and adoption degree of using immersive service prototypes over conventional ones, (5) the ability to have a risk free environment for training for a specific task, (6) the improved learning process induced from using ISP, and (7) the ability to collaborate in an enhanced manner.

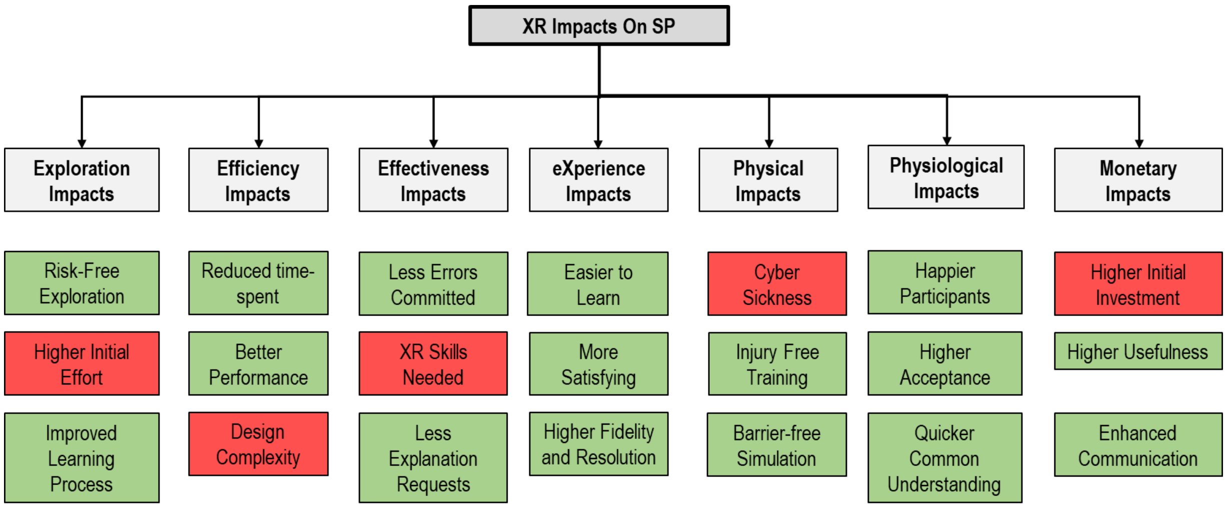

Figure 5.2 XR impacts on SPs

The XR impacts structure was inspired by the prototype benefits work done by Medlej et al. (2017). The initial adapting to XR technologies could be challenging at first, as it requires some sort of introduction to the technology and effort to learn how to develop, implement, apply and even use. Cost-benefit ratio could be an issue due to higher costs, as there are initial, devices, technology and training costs associated with XR. However, it was noticed from all the personal contact with industrial companies that industrial companies are recognizing the advantages of using XR in their processes, especially in the service sector. The tendency to choose and use XR in representing and experiencing service was also observed.

The potential benefits of using XR in service prototyping (as represented in green in Fig. 5.2) in an industrial context can be summarized as: (1) improve service idea exploration with stakeholders, (2) enhance the ability to evaluate service idea through an enhanced experience, (3) expand the communication mediums between the stakeholder to improve visibility and understanding, (4) risk free training for internal service stakeholders even before the service really exist, (5) using it to improve on learning process and increase knowledge absorption, and (6) create a better way of collaborating new service ideas for exploring, evaluation and communication. There were also several drawbacks (represented in red in Fig. 5.2) as: (1) higher initial effort in creating the XR field, simulation or animation, (2) using XR also increases the design complexity, which might make the service development process take longer, (3) XR knowledge and skills are required to develop and use XR service prototypes, (4) cybersickness might occur to few users while using a XR device, and (5) the initial investment in devices, hardware, and software might be high compared to conventional methods. This research can be used as a guide for future industrial application, for the selection of SP forms depending on the different attributes.

5.5. Comparing to Recent Studies

This study and its results could be compared to other SP studies, and immersive assembly studies as well. The SP studies covered multiple facets of service prototyping. (1) exploring the definitions of service prototyping (Blomkvist and Holmlid, 2010), (2) improving service processes (Oh et al., 2013; Fukuhara et al., 2014), (3) testing Product-Service Systems (Exner et al., 2014), (4) utilizing it in a VR simulation (Kwon et al., 2015), (5) experimenting an AR assembly guide (Bode, 2019), (6) testing service processes (Peng et al, 2017), (7) evaluating service prototypes by using walkthroughs (Arvola et al., 2012; Boletsis et al., 2017), (8) influencing transformational change (Kuure et al., 2014 ; Boletsis, 2018), and (9) use service prototyping for a mobile AR app (Satti et al., 2019). The studies found in the literature varied from quantitative studies, and qualitative studies, while most of the studies found were qualitative. The immersive service prototyping studies where authors compared different forms of prototyping was also found recently (Satti et al., 2019; Bode, 2019), however no study was found that compared 5 different SP forms with each other. Also there was no study found that used mixed methods to verify their results, and explain their quantities results, or to validate their qualitative results.

Table 5.2 Service Prototyping Studies

Studies	Research Approach	Findings	Reference
Service Prototyping Definition	Qualitative (expert interviews)	According to the interviewed service design experts, it might be challenging for service prototyping to be successful at the moment; but there is potential in the not yet fully formed application of service prototyping.	Blomkvist and Holmlid 2010

Service Walkthrough	Qualitative (case study)	Suggested that service walkthrough can be utilized to evaluate service prototypes. It also reveals information about user's practical and experiential issues.	Arvola et al. 2012
Car self-sales service	Qualitative (usability use case)	Introduced a VR 3D service scene that automatically or semi-automatically models on a 3D screen in response to the participant's actions. Self-service processes, service activities, and service scenes represented in VR.	Oh et al. 2013
SINCO Methods	Qualitative (interviews, and use case data)	Suggested that service prototyping can be an influential tool in transformational change, and in encouraging facilitation and team work. The co-creation prototyping approach enables a technology-aided learning process and supports experiential learning.	Kuure et al. 2014
PSS Lifecycle Testing	Qualitative (case study)	Suggested that a comparison to other possible prototyping approaches is missing. Introduced the idea of using paper-based and other low fidelity prototyping techniques combined with service engineering validation aspects allowing an early, fast, low cost and iterative testing of PSS.	Exner et al. 2014
Service Processes Optimization	Qualitative (case study experiment)	Confirmed that managers and employees were able to understand their ordinary processes, make plans for improving their processes by using the service prototype suite. Improved their observed service processes as there was an increase of the stay ratio of a waiting staff in dining areas and the number of additional orders.	Fukuhara et al. 2014
S-Scape Service Prototyping	Qualitative (case study)	Suggested that 3D VR based test-bed is an effective tool at the stage of service prototyping. Introduced practical methods for service prototyping in actual duty-free shop. Proved validity and practicality of the service prototyping methods through target service analysis rather than optimal alternative selection.	Jung Bae 2014
Evaluating Servicescape Designs	Qualitative research by using case study, and user feedback	Aimed to evaluate the servicescape design of a Duty-free Shop in a systematic manner to visualize various options for the servicescape design. Supported the relationship between servicescape design, customer perception, and the VR-based laboratory experiment effectiveness for evaluating servicescape design.	Kwon et al. 2015
3D Multiple Medical Imaging System	Quantitative (consultation scenario survey with 30 participants)	Showed that the participants (doctors) are satisfied with the 3D app system. Suggested that the system can be a helpful health technology for future healthcare.	Peng et al 2017
Virtual Body-storming Cognitive Walkthrough	Qualitative (case study)	Showed that the virtual body-storming method can be used for prototyping services that include human interaction and spatial aspects.	Boletsis et al. 2017
Prototyping Service Journey	Quantitative (42 participants survey after experiment)	Found that the performance of the VR service walkthrough method is similar to that of the service walkthrough method in communicating the service concept but in an immersive way that fosters constructive feedback	Boletsis 2018
Mobile AR App Evaluation	Mixed methods approach (questionnaires, physiological sensors, and performance evaluation)	Introduces the User Experience Measurement Index, and the results of using a mixed method UX evaluation approach for evaluating a Mobile AR App prototype using various methods and sensors.	Satti et al. 2019

Evaluation of an AR Assembly Guidance	Quantitative (comparative experiment in an industrial setting)	Indicated that an AR guidance system is excellent, and it would be accepted by new users based on the user experience they offered and the subjective meaningfulness and quality of feedback they produced.	Bode 2019

A table with all the relevant SP studies was constructed to give an overview on the research approach and findings of these mentioned studies as shown in Tab. (5.2) above. Blomkvist and Holmlid (2010) informs through their qualitative in-depth interviews study that using SP in organizations showed potential but still might prove challenging to implement. Our study aims to increase the awareness of definitions of different service prototyping forms, and to define the service prototyping experience as well. Arvola et al. (2012) suggests over qualitative case studies that using immersive technologies evaluate service prototypes reveals more information about practical and experiential user issues, which confirms with our findings as well. Other researchers took also qualitative approach and proposed that a 3D VR based test environment prototype is an effective tool for service prototyping (Jung Bae, 2014; Kwon et al., 2015), which also confirms with our results and consideration on VRSP. Some qualitative studies also suggested that service prototyping can be a powerful tool for organization transformational change and could be used as a strong peer-to-peer learning and communication process as suggested by Kuure et al. (2014), which also confers with our characterization of service prototyping as a powerful communication tool. Exner et al. (2014) conducted a qualitative case study that suggests that a comparison to other possible prototyping approaches is missing, and that a combination of low and high fidelity techniques would be a cost beneficial way to test a product-service-system. Fukuhara et al. (2014) conducted a qualitative study by using MR for service process optimization, which resulted in confirming that stakeholders were able to understand their ordinary processes, make plans for improving their processes as they used the MR visualization, which also confirms with our experiment results.

Peng et al. (2017) conducted a quantitative study by using VR service prototype in consultation; which shows that stakeholders were satisfied with the prototype, and this suggested that it can be a helpful for future utilization in the field, this was also confirming to the results we had in our experiment and study. Boletsis et al. (2017) and Boletsis (2018) conducted two qualitative studies to evaluate the user experience and quality of feedback by using VR and AR prototypes, the research suggests that the AR prototype could be considered to be suitable for prototyping services that include human interaction and spatial aspects (Boletsis et al., 2017), while the VR prototype gave a performance similar to that of the conventional one, but communication of the service concept in such an immersive way fosters constructive feedback (Boletsis, 2018). Bode (2019) examines the evaluation of an AR assembly guidance system in an assisted manufacturing context with a quantitative experiment comparative user study. The majority of the other research results suggested that AR based guidance systems are excellent, and would be accepted by new users in the industry, which also confirms our knowledge of the industrial acceptance as seen in the focus group interview or the acceptance from the professionals in the experiment.Table 5.3 XR Assembly Studies Description

XR Assembly Studies	Findings	Reference
Comparing VR and AR, engineering drawing, and paper assembly plan as a training tool for assembly tasks	VR and AR were found to out-perform the 2D engineering drawing	Boud et al. 1999
Comparing blueprints, non-immersive desktop, and an immersive VR environment to examine the effectiveness of the learned skills	On average participants using immersive and non-immersive VR outperformed the ones using blueprints by 50% of assembly completion time	Banerjee et al. 1999
Comparing task completion in a VR environment and a real environment	VR can be compared to a similar experimental task in real environment if it involves only measuring movement ranges	Whitman et al. 2004
Compared AR assembly guiding system with a printed manual, computer assisted instructions using a monitor and using a HMD	AR reduced the assembly task error rate by 82%	Tang et al. 2004
Comparing performance of an AR-based method using a monitor and a HMD	AR-based method can provide an efficient way for assembly guidance	Yuan et al. 2008
Comparing AR assembly guidance with a paper manual and a verbal expert tutorial	AR is more suitable for complex tasks, where in simple task the performance didn't differ significantly	Wiedenmaier et al. 2009
Comparing between desktop VR, desktop stereo VR and a paper-based approaches in regards to performance, completion times, and accuracy	The complexity significantly impacts the performance in regards to the completion time, and that the representation benefits the accuracy.	Strobel and Zimmerman 2011
Comparing AR prototype guiding system against a paper based	The AR system yielded better results, and the beginner assemblers' learning curve of was reduced and task performance was increased	Hou et al. 2013
Comparing VR training and traditional physical training on the effectiveness for learning transfer	Physical training outperformed virtual training; however, after two weeks the VR trained participants improved their assembly completion durations	Carlson et al. 2015
Evaluating MR potential for delivering assembly instructions, by using a proof of concept prototype	The Hololens is promising, but still areas require improvement before it is ready for factory assembly application	Evans et al. 2017
Evaluating MR guidance system for manufacturing assembly	The guidance system performs well in a real manufacturing scene	Teng et al. 2017
Solving 3D burr puzzles comprised of virtual and physical training elements, with VR, paper and video based instructions	There were no significant differences between VR training and the best performing physical training in performance	Murcia-Lopez and Steed 2018
Comparing role of different visual cues in immersive VR setting and a non-immersive environment in regards to user's performance performing manual assembly	Immersive VR training might be faster and more accurate than training on a 2D screen for specific tasks	Dwivedi et al. 2018
Comparing VR training or a traditional paper instructional manual for assembly	VR users were on average slower and less successful at completing the task	Barkokebas et al. 2019
Comparing an AR with a traditional paper instructions systems in terms of effectiveness and usability	AR guidance is a far better choice than the traditional one, and it had also a high user acceptance	Bode 2019
Examining the impact of AR assembly guidance on four visualization technologies	AR instructions have a strong visual stimulation ,resulting in longer task related attention span, and increased the information effectiveness and quality	Wang et al. 2020

Compared MR Hololens assembly guide with desktop, tablet and tablet AR instructions in regards to completion time, error count, and score	The use of MR led to a time saving of 16% over the tablet AR, and had lower error rate as well. However MR had a lower UX rating than the Tablet AR one	Hoover et al. 2020

The XR assembly studies were also scarce as shown from the literature review results (see Figure 2.7), where most of the studies involved AR technology for either assembly guidance or interactive instructional manual. Several studies compared between different forms of instructional manuals, comparing traditional (paper, video) with immersive ones. A list of the most relevant studies is listed in Tab. (5.3) above. Boud et al. (1999) compared different training tools for assembly tasks (VR, AR, engineering drawing, and paper assembly plan); and found that VR and AR out-performed the 2D engineering drawing. Our results also confirm the results of this study, as VRSP and ARSP out-performed PSP. Banerjee et al. (1999) compared the effectiveness of blueprints, non-immersive desktop, and an immersive VR environment to increase assembly skills; and found that immersive and non-immersive VR outperformed blueprints by a decrease of 50% in the assembly completion time. Our study also confirms with this study, as we saw a decrease in assembly time in the ARSP and MRSP compared to the PSP and MSP. Whitman et al. (2004) compared the experience of task completion by using VR and real environments and found that the experience can be compared if it involves limited movement ranges. Our study also agrees with this study, but as the technology evolved so much in the recent years, we can even say it gives a better experience than the real environment when using high end HMDs and haptic devices. Tang et al. (2004) compared AR assembly guiding system with a printed manual, where it was shown that AR reduced the assembly task error by 82%. Our study showed that ARSP task completion error rates were actually higher than the PSP, but the MRSP had a much better error rate than the other SP forms. Yuan et al. (2008) compared the performance of an AR-based assembly method, which showed that it can provide an efficient way for assembly guidance. Our study confirms with this one, as the results showed that ARSP was efficient in completing the task. Wiedenmaier et al. (2009) compared AR assembly guidance with a paper manual and a verbal expert tutorial, where the results showed that AR is more suitable for complex tasks. Our study shows that using an SP even for a simple task can effect greatly the performance and experience, and that ARSP was also the second most efficient after MRSP.

Strobel and Zimmerman (2011) comparing performance (completion times, and accuracy) of desktop VR, desktop stereo VR and a paper-based approaches, which showed that the task complexity significantly impacts the performance. Our study also agrees with the study as it was observed from the participants' that they thought that ISP is more suited for more complex tasks. Hou et al. (2013) comparing AR prototype guiding system against a paper based, as it showed that the AR system yielded better results, with reduced beginner learning curve and increased performance. Our results also confirm that AR offers a great way for beginners to learn and it also showed that there is an increase in performance compared to the conventional forms. Carlson et al. (2015) compared the learning transfer effectiveness of VR training and traditional physical training, where actually physical training outperformed virtual training; but after two weeks the VR trained participants improved their assembly completion durations. Our results show that the participants that used VRSP had a longer level of knowledge retention than the other participants, but as we didn't have any physical form we can't confirm the other parts of the results. On one hand, Evans et al. (2017) evaluated MR potential for delivering assembly instructions, result showed that Hololens is promising however still require improvement before it is ready for industrial application. On the other hand, Teng et al. (2017) evaluated MR assembly guidance system, as it performed well in a real industrial scene. Our research confirms also the MR could be well used in an industrial assembly process, and with small improvements it would be ready for industrial application. Murcia-Lopez and Steed (2018) compared assembly performance while solving a 3D puzzle by using VR, paper and video based instructions but found were no significant differences between VR training and the best performing physical training in performance. Dwivedi et al. (2018) compared user's manual assembly performance in immersive VR and a non-immersive environment in regards to the role of different visual cues, which showed that immersive VR training might be faster and more accurate than training on a 2D screen for specific tasks. These results confer with our results as well, as the participants using ISP performed better than the participant using CSP.

Barkokebas et al. (2019) comparing VR training and paper instructional manual for assembly, showed that VR users were on average slower and less successful at completing the task. Our results paint a different picture, as VRSP performed better than when using PSP, and committed less errors while doing it. Bode (2019) compared the effectiveness and usability of AR and traditional paper instructions systems in an assembly industrial setting, as it showed that AR guidance is a far better choice and a higher user acceptance. These results are confirmed also from our results, as participants using ARSP had a better performance, experience and acceptance than while using PSP. Wang et al. (2020) examined the impact of AR assembly guidance, and they found that AR instructions have a strong visual stimulation resulting in longer task related attention span, and increased the information effectiveness and quality. These results also match our results with the use of ISP and especially MRSP, which is a more visual version of the ARSP. Hoover et al. (2020) compared the completion time, error count, and score of MR Hololens assembly guide with desktop, tablet and tablet AR instructions, where the use of MR led to a time saving of 16% over the tablet AR, and had lower error rate as well. These results also seem to confirm with our results however the time saving led by MRSP over ARSP was only 3%.

5.6. Contribution to the Body of Knowledge

This study differs from the other studies as it uses both the qualitative and quantitative research methods as all other similar studies either used qualitative or quantitative methods. The quantitative results of the experiment are statistically valid as it was conducted with more than 100 participants, in comparison to the quantitative use cases found in the literature whom had much less participants. This study was the first investigation to have a comparison of five different forms of service prototypes, and also a benchmark experiment to compare not only the performance in regards to the efficiency and effectiveness, but also the immersiveness factor, the user experience and user acceptance. The study has also industrial application and will be utilized as a guide for future industrial experimentation. We had several discussions with college researchers who were interested in our research, and we had also several industrial workshops and discussion, which reflected the industrial interest in service prototyping. We also have been invited to publish several chapters in service centric academic books, and we published a new book on multidimensional service prototyping. We have also published several conference papers, and journal papers, which had relative success from number of reads, and citations. We feel that the research in the service prototyping aspects and application is still in the growing phases. This study adds to the literature a concrete depiction of the immersive technologies impacts on service prototypes and the user experience. The study also offers service researchers a service prototyping framework and model, which could be further utilized and optimized. This research aims to increase awareness of immersive service prototyping forms and their impacts, advantages, and drawbacks.

Table 5.4 Relevant Service Prototyping Research Domains

SP Domains	References
Process optimization	Exner et al. 2014 ; Arvola et al. 2012, Fukuhara et al. 2014
Design improvement	Kwon et al. 2015 ; Peng et al. 2017
Methodology	Blomkvist and Holmlid 2012; Kuure et al. 2014, Blomkvist 2014, van Husen et al. 2016
Training	Jung Bae and Seong Leem 2014, Boletsis et al. 2017
Comparisons	Arvola et al. 2012, Peng et al. 2017, Boletsis 2018, Bode 2019, Satti et al. 2019

We have identified several service prototyping research domains that are relevant for our research. These SP research domains are shown in Tab. (5.4) above with the most relevant publications in each of the domains. This study adds to the literature as it was the only study to use both quantitative and qualitative mix methods research approach, and use a comparative experiment with more than 100 participants to validate the proposed model. The results confirm with the literature found, as all of the qualitative and quantitative studies came to similar conclusions and findings. The study was also the first study to compare five different SP forms in regards to performance, eXperience, intention to accept and adopt, and user attitude. The study also added to the body of knowledge new definitions (see Table 2.15 for full definitions).

The study also characterizes service prototypes into two forms: Conventional Service Prototypes (CSP), Immersive Service Prototypes (ISP). The study results indicated that SP forms impacts SP attributes, purposes and activities, which can be seen in the effects on the following attributes. (1) In regards of the fidelity attribute, the CSP tend to have low to medium level of fidelity, while ISP had a high to very high level of fidelity. This indicates that ISP could deliver a higher level of service detail and functionality built into the prototype. (2) Considering the resolution attribute, CSP tends to have a low to medium level of resolution, while ISP tend to have a high to very high level of resolution. This indicates that ISP will offer a higher degree of resemblance of the prototype to the final service design. (3) Looking at the effort attribute, CSP tends to have low to medium level of effort, while ISP has a high to very high level of effort. This shows that ISP uses more organizational resources to complete, explore and implement the prototype than CSP does. (4) When considering the interactivity attribute, CSP tends to have low to medium level of interactivity, while ISP has a high to very high level of interactivity. This indicated that ISP has a higher degree to which the user can interact with the prototype in a freer and a more fluid manner. (5) In regards to the UX attribute, CSP tends to have a low to medium UX level, while ISP has a high to very high level of UX: This indicated that ISP offers a higher perceptual, emotional, and cognitive experience than CSP, and also has a higher level of response to the anticipated use of a prototype.

5.7. Contribution to Industrial Practices

The participants of the industrial workshop and focus group were also interested in learning more about service prototyping and its applications in their corresponding projects. The asked questions about how to use service prototyping for developing service prototypes, introducing new services into new markets, and applying service prototyping for training concepts. They also wanted to get more tips for the application and use of immersive technologies in their service project, especially about the evidencing and reasoning to why to use them. Another big part of their questions was about costs, whether initial costs of the hardware, software and training. The participants also indicated that they have higher technology adoption degree of service prototyping and immersive technologies after the industrial workshop and focus group discussion. The comments of the participants (see Table 4.37) were also a great insight to the focus of industrial organizations and their acceptance of service prototyping and immersive technologies.

The impacts at Liebherr can be directly seen, as they hired two new employees, one for service prototyping processes and another for immersive technologies projects. This shows that a large company like Liebherr can adjust in agile manner in innovating their service development and delivery process to adapt with new processes and technologies. They are using and implementing service prototyping for developing new services, even a manager at Liebherr mentioned that "*Service Prototyping is one of the* *future focuses of Liebherr*". Liebherr also thinks that SP is efficient and effective for method for developing new industrial services, one employee even mentioned "*Early feedback, early mistake makes a better experience afterward*". Liebherr are also working closely with the Furtwangen University on collaborative industrial service prototyping and immersive technologies students' projects. Every semester we have a service prototyping or immersive technologies collaborative project that engages the students and the employees of Liebherr in collaborating on completing a project to be used later by the company in developing, implement and delivering new industrial services.

Table 5.5 Service Prototyping Purpose, Activity in Relation to SP Forms

Purpose	Activity	Task	SP	Fidelity	Resolution	Effort	Interactivity	UX
Exploration	Brainstorming	Collecting Ideas	CSP	Low-Med	Low-Med	Low-Med	Low-Med	Low
			ISP	High	High	High-V High	High	High
Evaluation	Testing	Decision Making	CSP	Low-Med	Low	Low	Low-Mid	Low-Mid
			ISP	High-V High	High-V High	High-V High	High-V High	High-V High
	Demonstrating	Feasibility Analysis	CSP	Low-Med	Low-Med	Low-Med	Low	Low-Med
			ISP	High-V High	High-V High	High-V High	High-V High	High-V High
Communication	Learning	Training	CSP	Low	Low	Low-Med	Low-Mid	Low-Mid
			ISP	High-V High	High-V High	High-V High	High-V High	High-V High
	Interacting	Informing	CSP	Low	Low	Low	Low-Med	Low-Mid
			ISP	High	High	High-V High	High-V High	High-V High
	Integrating	Decision-making, Training	CSP	Low-Med	Low-Med	Low-Med	Low-Med	Low-Med
			ISP	High-V High	High-V High	High-V High	High-V High	High-V High
	Planning	Time Management	CSP	Low	Low	Low	Low	Low
			ISP	High-V High	High	High-V High	High-V High	High-V High

As there are different effects for each of the SP forms, there is a best suited form for every service purpose and activity but also depending on each organizations' requirements, needs, and attributes as shown in Tab. (5.5). The table shows the following grading where Low represents lower capability of the specific attribute, Med represents medium capability of the specific attribute, and High represents high capability of the specific attribute The study illuminated the XR impacts on the industrial application of service prototyping including of: (1) exploration impacts (risk free exploration, improved learning process, better collaboration), (2) efficiency impacts (faster durations, higher usefulness, better performance), (3) effectiveness impacts (less errors, less explanation requests), (4) eXperience impacts (better learning, more satisfying, higher acceptance), (4) physical impacts (cyber sickness, injury free training), (5) physiological impacts (happier participants, easier to understand), and (6) monetary impacts (higher investment cost, higher usefulness on the long run, training costs).

The impacts on work practices could be summarized into: (1) the use of service prototyping supports the service development process, where the results add to knowledge for selecting and using service prototype forms, (2) it is important to know when to implement which service prototype form as immersive service prototyping processes may require more organizational resources but they also produce a better representation of the future service, (3) according to the organizational purpose, and objective different forms are to be implemented conferring to the desired fidelity, resolution, and effort, (4) exploring service ideas with service stakeholders is vital in the service development process, and by using ISP stakeholders can have a better eXperience, (5) SP supports the exploration, evaluation and communication of service ideas; through the use of service prototyping process instead of just learning about it in the traditional service design processes, (6) communicating service concepts to internal stakeholders can be improved greatly by using service prototyping as they can be integrated in service training even before the service exists, and (7) The results showed that using ISP in assembly process whether in training before the assembly guidance or learning by doing on the job is beneficial.

6. Conclusion

6.1. Concluding Remarks

The purpose of this study has been fulfilled in recognizing, assessing and categorizing the impacts of XR technologies (VR, AR and MR) on service prototyping and prototypes. The research objectives have been tackled with research questions, hypotheses, and model. The lack of empirical studies on ISP and also on comparing CSP and ISP as well as model was revealed by the literature review. The SP research model and hypotheses were elaborated and validated through statistical analysis. Regarding the findings, the UX survey results show that participants preferred ISP forms rather than CSP forms, which confirm our expectation. Furthermore, findings also display that there are still some challenges in using immersive technologies like cybersickness that cannot be simply ignored and neglected. Results also reveal that the more appropriate SP solution could reside in combining two, or eventually more, SP forms depending on the service complexity and strategy, as ISP and CSP offer different benefits while bringing some unavoidable drawbacks and different costs as well as outcomes. Nonetheless, it appears that, due to investment costs, CSP forms might be more appropriate for the early stage of service co-creation when describing a new service idea. However, if the initial investment is already budgeted for another service and the XR devices are already there, then co-creation by using ISP could induce more and better ideas and feedback from the service stakeholders. Ideally speaking, ISP forms could be considered more suitable for the later stages of less complex services or at the earlier stage for more complex services that require multiple dimensional prototyping. Beyond the findings, one could conclude that the best approach could be a combination of both CSP and ISP forms for the service prototyping and development process as it adds many beneficial elements, like an improved experience, an enhanced understanding and a higher degree of acceptance, to the process. On one hand, CSPs might be more appropriate for non-complex or short service scenarios in order to save costs and time in the prototyping process. On the other hand, ISPs necessitate a significant financial investment for buying the necessary immersive equipment and personal effort for implementing immersive prototyping solutions while they are more appropriate for multi-dimensional service processes.

Lately, several recent studies on ISP in the context of assembly in the industrial service sector (2019 and 2020) were identified and compared in terms of results in the discussion chapter. Other recent studies also demonstrate the service industrial interest with ISPs starting to be used in several industrial and manufacturing organizations as it gives to the service stakeholder many benefits: (1) anticipating the degree of satisfaction of their user experience of the service while it does not yet exist; (2) evaluating the performance of the service, even before it exists; (3) identifying the potential drawback of the service; (4) bringing more feedback from service stakeholders, and (5) contributing through improvement in the overall experience. Clearly, it is likely to use CSPs in the early stage for roughly presenting a new service, combination with ISPs used to experience the whole service scenario before it even exists, optimize the service process, and evaluate user interactions. In brief, the ability to foresee a new service scenario requirement, experience, and outcomes before it gets created or implemented is vital in creating the best service experience. A vital aspect in selecting the most appropriate SP form for the task is that it has to be adjusted to the purpose and activity set by service stakeholders and in the appropriate fidelity, resolution, and effort levels. This dissertation could be used as a guide to help researchers, and service designers in selecting service prototyping form for their service communication processes. This work could be considered as explorative study, as it is the first study to compare several conventional and immersive prototypes while using a mixed approach of qualitative and quantitative research methods. This study also represents the state of art in the immersive and conventional service prototypes research.

6.2. Future Work

The next step is to continue onto the research on service prototyping industrial applications, and continue in exploring new industrial applications. We are currently working on extending the SP model to include smart service prototyping, and include the data dimension into the service prototyping dimensions. I am continually improving the SP forms definitions, processes, and applications according to the latest research results; and will continue experimenting with the different SP forms to create an extensive study on the forms that are most appropriate for each service application. The objective is to introduce and familiarize service prototyping to a wide range of industrial organizations, where it will be applied in real service creation while it could be studied for further development. The work on service prototyping continues also through my current role within the service competence center at the Furtwangen University, as the project work is funded by the Baden Württemberg Ministry of Research and Education. My role is to use our lab and our knowledge in service prototyping, especially immersive ones, to demonstrate the added value of smart services against normal one. The research involves interacting with industrial SMEs in the region to support them in innovating their service offerings and introduce the benefit of using service prototyping and immersive technologies. There is also a research project planned with industrial and academic partners to use service prototyping for an industrial AR assembly guidance system. This funded project will span over 4 years and will include constructing a XR service prototyping Lab at the Furtwangen University.

This work is also continuing in the direction of industrial applications, as more focus will be on the implementation side, and less on the theoretical side. A suggestion for future research is to investigate the effects of other emerging technologies like smart and remote technologies on service prototyping and the stakeholders' capability to explore, communicate, and evaluate. The research on applying service prototyping for development of industrial services is increasingly indicating industrial interest and acceptance. Service prototyping is a novel process that serves the purpose of creating an experience of a service before it exists, which opens a lot of possibilities for service development. The co-creative process of service prototyping allows the service designers, service operators and customers to get together and work towards finding the most appropriate method to deliver the service.

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Appendix 1: résumé en Français

1. Contexte

Le prototypage n'est pas quelque chose de nouveau ; selon Budde et al. (1992), le prototypage est une approche systématique pour transformer des idées, des ébauches et des concepts en un prototype qui permet d'anticiper et de simuler son scénario d'utilisation tout au long du processus de développement du système. Le prototypage n'est pas limité à des objets spécifiques comme un produit, un processus ou un service, mais peut être étendu à tout autre objet comme un jeu par exemple, pour aboutir à un prototype de jeu. Selon Mogensen (1994), les prototypes ont plusieurs facettes : (a) ils servent à clarifier la conception, les exigences et les problèmes afin que les concepteurs et les ingénieurs puissent modifier le prototype jusqu'à ce que la conception finale soit atteinte, car les prototypes suggèrent ce à quoi l'avenir pourrait ressembler ; (b) leur valeur respective ne réside pas seulement dans le processus d'apprentissage qu'ils fournissent mais aussi dans l'expérience qu'ils créent pour que les parties prenantes apprennent par une expérience ; (c) ils peuvent servir de pont entre l'analyse et la conception car ils fournissent des idées sur ce qui pourrait être changé et ce qui pourrait rester.

Un intérêt naissant pour le développement de prototypes de services se manifeste dans les secteurs industriels manufacturiers et dans le milieu universitaire. Les technologies immersives pourraient avoir un impact significatif en explorant et en Co-créant des prototypes de services avec les parties prenantes, en permettant la collecte d'observations et de commentaires importants pour créer et affiner une idée de service, ou pour l'améliorer après y avoir été immergé. Un processus de Co-création de prototypes de services immersifs pourrait aider les ingénieurs et les concepteurs à tirer parti d'une expérience plus complète, ce qui permettrait d'améliorer le retour d'information pour le brainstorming ou la sélection d'une idée de service. L'évaluation d'une nouvelle conception de service en immergeant les parties prenantes au lieu de leur fournir une représentation en 2D ou un service conventionnel permet de mieux comprendre le service, car elles pourront en faire l'expérience au lieu de se contenter de le voir. Cela pourrait être vital pour la prise de décision, car les ressources en matière de services sont rares et chaque centime économisé sur les coûts est un centime gagné ; créer un service après avoir évalué son prototype de service pourrait non seulement augmenter les chances de succès du service mais aussi accroître les profits et améliorer l'image de l'entreprise.

Nous travaillons sur les impacts des technologies immersives sur le prototypage de services, où nous menons une étude comparative sur différentes formes de prototypes de services. Le prototypage de services comporte des éléments de conception et d'ingénierie de services, mais il est principalement axé sur l'innovation de services. Cette étude comprend des expériences et des entretiens avec des groupes de discussion, où sont étudié les performances, l'expérience et le degré d'adoption de chaque prototype de service. Les prototypes de services visent à transformer les idées de services intangibles en expériences réelles. Les technologies immersives peuvent permettre aux parties prenantes d'un processus de prototypage de services d'avoir une expérience plus complète grâce à l'immersion. La motivation académique est ici de mesurer les impacts de ces technologies immersives utilisées dans le processus de prototypage de services. Pour être en mesure de comprendre ces impacts, une enquête est nécessaire pour comprendre la réflexion et l'évaluation des parties prenantes sur l'expérience du prototype de service avec l'utilisation des technologies immersives. Cette enquête se concentre sur les performances, l'expérience et le degré d'adoption des prototypes de services immersifs et conventionnels. La motivation derrière cette étude industrielle empirique est d'aider les organisations à être capables de comprendre les formes et les outils de prototypage de services, sans avoir besoin d'un investissement initial ou de recherches approfondies. L'espoir est que cette recherche serve de base à de futures recherches universitaires et applications industrielles.

Les objectifs de cette thèse sont les suivants : (1) Identifier les défis à relever par l'utilisation des technologies immersives dans le cadre du prototypage de services ou des prototypes de services ; (2) Catégoriser les différentes formes de prototypes de services ; (3) Identifier les facteurs ayant un impact sur l'expérience, les performances et l'adoption des SP ; (4) Comparer les différentes formes de prototypes de services ; (5) Évaluer les impacts des technologies immersives dans le cadre du prototypage de services en termes de bénéfices et d'inconvénients. La principale question de recherche concerne l'étude des impacts de l'utilisation des technologies immersives sur un processus de prototypage de service dans un contexte d'innovation de service. Les principaux objectifs de la recherche sont (a) d'identifier les facteurs d'impact des différents prototypes de services, et (b) d'évaluer ces impacts par rapport à l'utilisation de formulaires de prototypage de services conventionnels, c'est-à-dire le prototypage de services sur papier.

Fig. 1 Aperçu de la recherche

2. Analyse de l’état de l’art

Il y a actuellement une transition dans l'industrie, poussée par différentes tendances, telles que : la numérisation, l'industrie 4.0, l'intelligence artificielle et la servisation. L'assemblage est une tâche que l'on retrouve dans la plupart des processus industriels et de fabrication. Baines et autres (2009) définissent la servisation comme les capacités d'innovation de l'organisation pour augmenter la valeur ajoutée en passant de la vente de produits à la vente de systèmes de services. Cette transformation est également sensible dans le montant des investissements de recherche en matière de numérisation et de servisation. Les flux de publications de recherche pertinents pour notre enquête sont les suivants (1) études de recherche sur les services ; (2) études sur les rayons X ; (3) prototypage de services ; (4) expérience immersive des services ; (5) les rayons X dans la formation industrielle ; et (6) les rayons X dans l'assemblage de maintenance.

Le service est un terme général qui peut être interprété comme allant de l'obtention d'un repas dans un restaurant à l'entretien ou à la formation. Shostack (1977) a été l'un des premiers à décrire un service en le caractérisant selon quatre éléments (IHIP) : *Intangibilité*, *Hétérogénéité*, *Inséparabilité* et *Périssabilité*. Dans l'ISO (2015), le service est défini comme "*les moyens ou méthodes que les organisations utilisent pour fournir, généralement intangibles bien qu'ils puissent également inclure des éléments tangibles, des résultats que les clients apprécient et souhaitent obtenir*". Selon Simo et al. (2012), toute entreprise fait faillite après l'introduction de nouveaux services, en raison de leur complexité et de leur nature immatérielle, Le prototypage favorise alors la participation des parties prenantes au développement du service. Cela peut être dû au manque d'utilisation des nouvelles technologies, comme les technologies immersives. Afin de déterminer la meilleure solution technologique possible pour la valeur ajoutée des services, les technologies immersives ont été sélectionnées car elles répondent aux exigences d'une solution de représentation plus complète pour le prototypage de services.

Selon Pallot et al. (2013a), le concept d'immersion peut prendre une forme physique, cognitive ou collective selon l'objectif et la caractéristique. Le prototypage immersif est un processus de prototypage innovant qui utilise des technologies pour immerger les acteurs dans un but précis. Selon Dupont et al. (2016), l'immersion est considérée comme la perception d'être physiquement présent dans une réalité immersive. Les technologies immersives offrent la possibilité d'interagir et de communiquer avec des environnements immersifs, où un ou plusieurs des cinq sens sont sollicités. Pallot et Richir (2016) ont défini l'"*immersivité*" comme "*l'état d'être profondément engagé, reconnu comme une immersion tactique et sensorimotrice ; ou entièrement absorbé dans la résolution d'un problème, considéré comme une immersion stratégique et cognitive ; ou lire une histoire captivante ou regarder un film passionnant,* *considéré comme une immersion narrative ou émotionnelle*". L'utilisation de prototypes de services immersifs présente des avantages avérés, comme l'exploration et l'apprentissage avec un prototype de VR, qui consiste à apprendre en aucun risque (Pallot et Richir, 2015). Davis et al. (2012) estiment que la compréhension des causes de la cybersanté est une étape nécessaire pour rendre l'environnement virtuel plus utilisable. Selon Richir et Pallot (2017), la principale implication de l'immersion due au phénomène d'illusion (faux 3D) est qu'elle provoque une fatigue cérébrale et visuelle qui entraîne une expérience immersive inconfortable.

Selon Budde et al. (1992), "*le prototypage n'est pas un jeu, mais une technique systématique permettant de traduire directement des idées, des projets et des concepts en logiciels, de les simuler et de les utiliser dans le processus de développement du système*". Il existe plusieurs formes de prototypage, allant de simples prototypes en papier (Snyder, 2003) à des prototypes complexes immersifs (Kim et al., 2008). Booth et Kurpis (1993) parlent du prototypage comme de "*l'utilisation de représentations*", tandis que Blomkvist et Holmlid (2010) affirment que le prototypage est "l'utilisation de prototypes pour explorer, évaluer ou communiquer dans la conception". Selon Ries (2011), le prototypage permet un effet d'apprentissage accéléré grâce à la rapidité accrue de la mise en œuvre, contrairement aux longs cycles d'analyse et de développement. Sämann et al. (2016) ont identifié trois objectifs pour l'utilisation du prototypage dans le développement de services, à savoir (1) les exigences monétaires, (2) les exigences non monétaires et (3) la mise en œuvre technique. Hippel (1989) a été le premier à mentionner le terme "*prototypage de service*s" dans la publication Transférer le prototypage de produits et de services aux utilisateurs : un avantage du processus d'innovation ? Blomkvist et Holmlid (2011) suggèrent également que les prototypes de services puissent être utilisés pour l'exploration, l'évaluation et la communication. Blomkvist (2014) le décrit comme l'utilisation de prototypes pour explorer, évaluer ou communiquer en matière de conception. La plupart des définitions sont quelque peu lacunaires car elles représentent pour la plupart une version statique et monodimensionnelle du prototypage de services, où l'accent est mis uniquement sur des artefacts physiques et des situations futures relativement peu spécifiques conduisant à une réflexion abstraite sur le service développé. Ensuite, pour pouvoir créer une définition inclusive du prototypage de services qui soit plus dimensionnelle et plus large, nous avons dû prendre en considération d'autres définitions du prototypage de services provenant de publications antérieures.

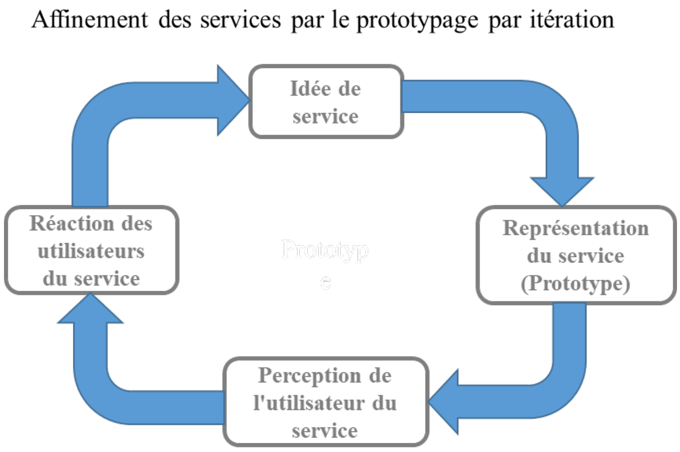

Fig. 2 Compréhension actuelle d'un processus de prototypage de services

Nous considérons que les prototypes de services conventionnels sont les formes de prototypage qui utilisent des méthodes conventionnelles pour représenter et afficher le prototype. Les CSP n'étant pas explicitement mentionnés dans la littérature, une recherche a été effectuée sur des termes de recherche alternatifs pour l'analyse documentaire. Les CSP conventionnels sont classés en quatre catégories : (1) Prototypes de services basés sur la parole (VSP), (2) Prototypes de services basés sur le papier (PSP), (3) Prototypes de services basés sur la maquette (MSP) et (4) Prototypes de services basés sur la simulation (SSP). Les documents publiés qui traitent explicitement des impacts du prototypage de services immersifs ou de l'expérience de prototypage de services immersifs se sont avérés insuffisants, car il y a très peu d'informations sur le sujet. Plusieurs nouvelles conventions et conférences ont été créées pour étudier les technologies immersives, et un grand nombre d'animateurs et de consultants utilisent le prototypage de services dans leurs initiatives et ateliers. Le terme "Immersive Service Prototypes" n'était pas mentionné dans la littérature avant notre précédente publication (Abdel Razek et al., 2018a). Les SP immersifs sont classés en trois catégories : (1) Prototypes de service basés sur la réalité virtuelle (VRSP), (2) Prototype de service basé sur la réalité augmentée (ARSP), et (3) Prototype de service basé sur la réalité mixte (MRSP).

La définition standard convenue de l'UX comme étant celle de l'Organisation internationale de normalisation (ISO FDIS 9241-210) : "*L'expérience de l'utilisateur est la perception et les réponses d'une personne qui résultent de l'utilisation ou de l'utilisation prévue d'un produit, d'un système ou d'un service*". Dans un contexte de service, McCrudy (2006) décrit l'UX comme les interactions entre les parties prenantes du service et le service, l'organisation, créant une réaction. Selon Wu et al. (2009), les UX sont classés en deux catégories, à savoir La qualité de service (QoS) et la qualité d'expérience (QoE), ils ont également modélisé la QoE comme une construction multidimensionnelle des perceptions et des comportements des utilisateurs. Wu et al. (2015) ajoutent que la présence dépend de facteurs de QoS, tels que : latence, fréquence de trame ou calibrage optique. Dans le cas d'une expérience immersive, Pallot et al. (2013) proposent une extension des modèles de Wu, pour prendre en compte l'interaction sociale dans le contexte d'un environnement immersif. Nous considérerons la définition ISO de l'UX comme la définition standard, car aucune table de définition des UX n'a été créée.

Dans l'état actuel des connaissances, le prototypage immersif de services a surtout été utilisé dans des scénarios de services orientés vers l'utilisateur avec des interactions complexes dans divers secteurs comme la fabrication, les soins de santé, l'automobile, la restauration et la vente. Nous avons également identifié jusqu'à présent seulement 75 articles publiés via une recherche Google scholar qui combine les mots "*immersive*" et "*prototype de service*". Il ne restait plus que 5 articles publiés après les avoir filtrés dans la recherche avec l'expression "prototype de service immersif". La plupart de ces articles publiés étaient principalement théoriques et n'avaient pas fait l'objet d'une validation quantitative. Il n'a été trouvé aucune étude portant sur l'impact des technologies immersives sur les prototypes de services. En résumé, nous avons constaté qu'il n'existe aucune définition disponible pour les ISP (y compris VRSP, ARSP et MRSP) et les SPX, et qu'il y a un manque d'études quantitatives empiriques sur les SP dans la littérature. Il y avait également un manque de recherche sur les impacts de la XR sur le prototypage de services dans la littérature. En outre, il y a un manque d'études empiriques sur les formes de ISP.

Pour mieux comprendre les impacts de ces technologies immersives (XR), il est utile de différencier les formes de SP en deux catégories principales, les prototypes de services conventionnels (CSP) et les prototypes de services immersifs (ISP). Plusieurs articles ont été publiés au cours des trois dernières années (Abdel Razek et al., 2017 ; 2018, 2019) concernant les formes de prototypage de services, et une étude comparative entre les prototypes de services immersifs et conventionnels. Les premiers résultats montrent qu'il existe une différence significative entre certaines formes de prototypage de services immersifs et les formes conventionnelles. Les différences sont mesurées en termes de performance, d'expérience et de niveau d'acceptation. En combinant tous ces points mentionnés ci-dessus avec les connaissances trouvées sur l'immersivité et l'expérience de l'utilisateur (Pallot et al., 2013, Pallot et al., 2017, Eynard et al., 2016, Dupont et al., 2017), nous pouvons suggérer que les prototypes de services sont destinés à aider les parties prenantes des services dans les processus complexes de services, du développement aux tests et au lancement. L'ISP a également pour but d'explorer, d'évaluer et de communiquer les processus de service et les comportements des parties prenantes à travers l'expérience utilisateur, et plus particulièrement l'expérience immersive.

Pour combler le manque de littérature, un modèle et un instrument de recherche ont été construits et appliqués à l'expérimentation sur des prototypes de services immersifs et conventionnels. Cette expérimentation a été conçue pour explorer et caractériser les impacts de la radioscopie sur les prototypes de service, en comparant différentes formes de radioscopie. La comparaison montre ensuite s'il y a une différence significative entre les formes de SP, et révélera les impacts de l'utilisation de la XR sur la SP. Les participants à l'expérience ont utilisé chacune des différentes formes de SP, puis ont rempli une enquête après chaque utilisation. Cette enquête est un questionnaire bipolaire qui permet aux utilisateurs d'exprimer leur appréciation sur des propriétés spécifiques tout en donnant leur avis sur chacune des évaluations données. L'expérience et l'acceptation sont également subjectives pour chaque utilisateur, car elles sont couvertes par l'enquête bipolaire. La performance de chaque participant a été mesurée en enregistrant la durée d'exécution de la tâche, le nombre d'erreurs et les demandes d'explication. Pour étudier les impacts de l'utilisation de la radio sur les prototypes de services, nous avons dû prendre en compte les différentes formes de SP.

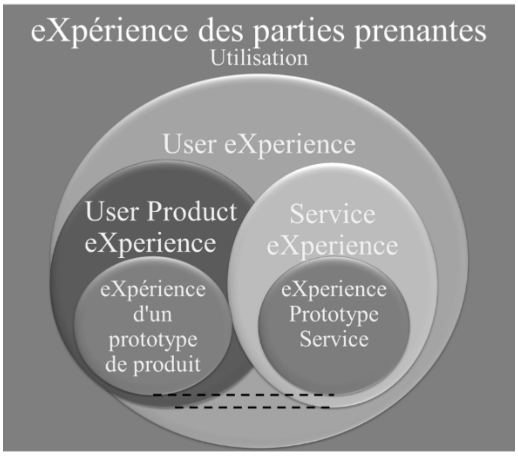

Fig.3 Représentation graphique des relations d'expériences (extension sur Abdel Razek et al. 2018a)

Comme il existe plusieurs définitions de l'expérience" qui sont valables et largement utilisées, une définition est générée à partir des définitions les plus pertinentes pour représenter au mieux l'expérience qui résulte de l'innovation de service, et en particulier par le biais du prototypage de services. La liste de nos définitions utilisées dans la thèse est présentée dans l'onglet. (1) ci-dessous.

Tab.1 Définitions utilisées dans le mémoire

Concept	Définition	Références
Service Prototyping	Un processus de développement de services qui utilise des représentations de services, ou des parties de ceux-ci, afin d'explorer, d'évaluer et de communiquer une idée, une conception ou un concept de service avant même que le service n'existe.	Abdel Razek et al. 2017
Service Prototype (SP)	Le prototype de service peut être considéré comme une version expérimentale de l'idée de service, qui permet d'évaluer les performances et l'expérience du service, avant même que le service n'existe, afin de Co-créer le service d'une manière itérative agile.	Abdel Razek et al. 2018a

Service Prototype eXperience (SPX)	Les connaissances retenues par l'utilisateur et son expérience individuelle, ses impressions et ses observations dans le cadre d'un processus de prototypage de service, qui comprend ce qui est perçu ou ressenti Les moments spécifiques qui conduisent à la création d'une expérience de service complète. $\sum_{n=1}^{\infty}(SPX1 + SPX2 + \cdots + SPXn) = SPX, \quad Optimally \sum_{n=1}^{\infty}(SPX) \cong SX$	Définition non existante (étendue sur Abdel Razek et al.2018a)
Conventionnel Service Prototype eXperience (CSPX)	Les prototypes de services qui sont lancés en utilisant des méthodes conventionnelles comme la parole, le papier, la maquette et la simulation sont utilisés pour inciter les parties prenantes à explorer, évaluer et communiquer des idées de services ou des parties de ceux-ci.	Définition non existante Abdel Razek 2020
Immersive Service Prototyping	L'utilisation d'une idée de service réelle ou fictive pour permettre aux parties prenantes d'anticiper l'expérience dans un environnement immersif.	Définition non existante (étendue sur Abdel Razek et al.2018a)
Immersive Service Prototype eXperience (ISPX)	Des prototypes de services basés sur l'immersion qui permettent aux parties prenantes d'utiliser la VR, la AR ou la MR pour les inciter à explorer, évaluer et Co-créer une idée de service.	Définition non existante Abdel Razek 2020
Virtual Reality Service Prototype (VRSP)	SP basé sur la VR illustrant une réplique virtuelle d'une idée de service ou de parties de celle-ci permettant aux parties prenantes d'être immergées dans un environnement virtuel interactif en utilisant un HMD de VR.	Définition non existante (étendue sur Abdel Razek et al.2018a)
Augmented Reality Service Prototype (ARSP)	SP basé sur la AR superposant une idée de service, une représentation, ou des parties de celle-ci, pour augmenter l'environnement réel de l'acteur avec des informations virtuelles en utilisant un appareil mobile.	Définition non existante (étendue sur Abdel Razek et al.2018a)
Mixed Reality Service Prototype (MRSP)	SP basé sur la MR qui reflète une idée de service ou des parties de celle-ci, pour engager les parties prenantes en interagissant avec des hologrammes (représentation d'objets virtuels) et des informations dans leur environnement réel en utilisant un dispositif de MR Hololens.	Définition non existante (étendue sur Abdel Razek et al.2018a)

Le modèle de recherche SP comprend la partie Immersion du modèle d'expérience utilisateur de l'environnement immersif et collaboratif (ICE) et les facteurs de Pallot et al. (2017) et Dupont et al. (2018) qui ont été développés pour étendre les environnements virtuels immersifs (IVE) plus traditionnels. Ce modèle a été conçu pour pouvoir répondre aux questions de la recherche et tenter de valider l'hypothèse tout en évitant que trop de questions ne submergent la bonne volonté des répondants. Le modèle de recherche SP comprend l'IX et le SPE ayant un impact sur le SPX, et son effet causal sur l'intention d'adopter le service proposé. L'expérience immersive (IX) pourrait être décrite comme la combinaison des immersions perceptuelles, émotionnelles et cognitives d'un utilisateur (Pallot et al., 2017). Selon Pallot et al. (2017), nous pouvons prenne en compte 5 aspects : (1) l'immersion perceptuelle (PX) mesurée en évaluant l'intuition du prototype, il est établi comme l'engagement sensoriel de l'utilisateur et l'interactivité du prototype, qui signifie l'engagement interactif de l'utilisateur. (2) l'immersion émotionnelle (EX) est évaluée sur la base du degré d'attractivité du prototype pour l'utilisateur, (3) l'immersion cognitive (CX) qui est évaluée sur la base du niveau d'intérêt du prototype et de l'engagement cognitif de l'utilisateur par rapport au prototype, et (4) l'efficacité du prototype de service (SPE) est représentée par la convivialité du prototype illustrant la présence de l'utilisateur, le niveau d'agrément du prototype et enfin l'utilité perçue du prototype pour l'utilisateur.

Les effets de causalité sont alors mesurés par trois facteurs distincts de UX. Le premier effet occasionnel pourrait être dû à l'utilisation des dispositifs à rayons XR, car le temps d'immersion semble différent de celui d'un état normal. Cela se traduit par la conscience qu'à l'utilisateur de son environnement et par sa réactivité à des facteurs ou événements extérieurs. Les effets causaux du prototypage de service dépendent des objectifs du prototype de service, de la manière dont l'apprentissage de l'utilisateur est affecté. L'utilisateur doit être capable d'accomplir la tâche après avoir utilisé le prototype. L'immersion de l'utilisateur lors de l'utilisation d'un prototype de service immersif pourrait affecter l'utilisateur car il observera et évaluera le prototype en le vivant au lieu de se contenter de le voir. L'utilisateur pourrait alors conclure, s'il est convaincu, d'adopter le prototype de service immersif, ou s'il est disposé à le réutiliser dans un autre contexte, voire à le recommander à d'autres pour une utilisation ultérieure. Les facteurs de causalité peuvent être résumés en deux constructions : (a) la dissociation du monde réel (RWD) qui est basée sur le sens du temps, le sens de la présence et la réactivité à l'environnement ; (b) l'intention d'adopter (ItA) représentée par la conviction de l'adopter, la volonté de le réutiliser et le degré de recommandation à d'autres. Pour pouvoir disposer d'une description exhaustive de l'impact de l'immersion, il faut que l'instrument de recherche comporte plusieurs questions pour chaque construction élevée, et une question pour chaque propriété de UX.

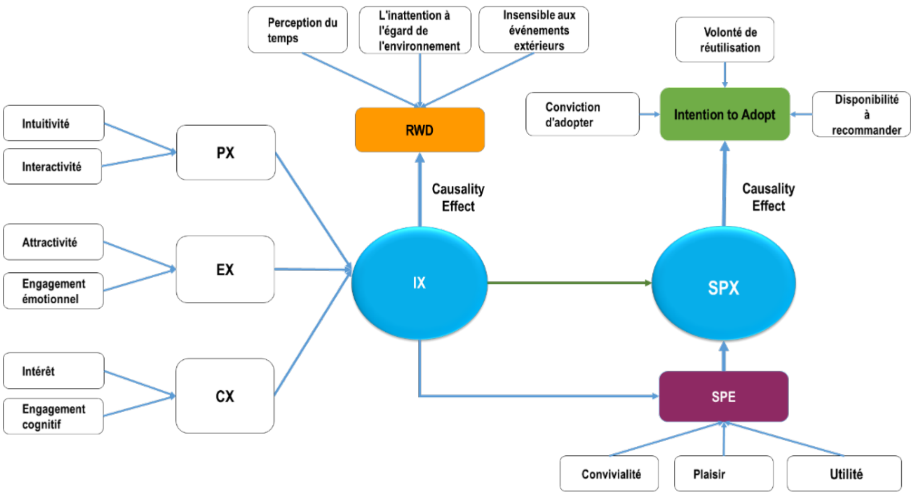

Fig. 4 Modèle de recherche détaillé sur les PS

Une vue plus détaillée des relations de construction et du modèle de recherche proposé pour la SP est présentée dans la figure (4) ci-dessus. L'immersion de l'utilisateur lors de l'utilisation d'une SP a pu être observée et évaluée en voyant si l'utilisateur est convaincu d'adopter la PS, ou s'il est prêt à la réutiliser dans un autre contexte, ou même à la recommander à d'autres pour une utilisation ultérieure. Les facteurs de causalité peuvent être résumés en trois constructions : l'expérience de prototypage de services (SPX), l'efficacité de prototypage de services (SPE) et la dissociation du monde réel (RWD). La SPE affecte AR la capacité à atteindre l'objectif, à avoir moins d'erreurs et moins de demandes. La dissociation du monde réel affecte la distorsion de la sensation du temps, le degré d'attention à l'environnement et aux facteurs externes. La SPX sera affectée par l'immersivité et la SPE. Ces 15 propriétés UX, qui sont transformées en questions d'évaluation bipolaires basées sur une échelle sémantique à deux antonymes, comme "Peu attrayant" et "Attrayant" ou "Inutile" et "Utile". Chaque question à notation bipolaire (quantitative) comporte une question ouverte (qualitative) où le répondant peut fournir sa motivation et/ou les raisons justifiant le niveau de notation donné.

Ce chapitre de revue de la littérature vise à donner une meilleure compréhension des domaines de recherche liés à la psychologie scolaire, et à interconnecter ces domaines de recherche sous une forme cohérente. Toutefois, l'analyse documentaire est un processus continu qui s'étend sur tout le cycle de la thèse de doctorat afin d'identifier les publications plus récentes qui sont pertinentes et même de permettre une comparaison avec des études récentes. Les principaux axes de publication de cette thèse sont les "services", l'"immersion", le "prototypage", l'"acceptation ou l'adoption" et l'"expérience". L'assemblage par rayons X dans le secteur des services industriels est apparu comme l'application principale de cette étude. Le manque d'études empiriques consacrées à la comparaison des différentes formes de SP constitue une lacune évidente dans la littérature, malgré le fait que 2 études empiriques aient été récemment identifiées (une publiée en 2019 et une en 2020). Il a été démontré qu'il y a un manque d'études empiriques transversales viables sur le prototypage de services immersifs qui se limite actuellement à la AR. Les théories pertinentes identifiées et les modèles existants ont servi de base à l'élaboration d'un cadre de recherche visant à mieux comprendre les impacts de ces technologies immersives (XR) sur le prototypage de services. Les questions de recherche ont guidé l'analyse documentaire vers l'élaboration d'un modèle approprié sur la SP et pour découvrir les impacts de la XR sur les formes de PS. Il y a également un manque de caractérisation de l'expérience de prototypage de services dans le corpus de connaissances ; c'est pourquoi une définition de la SPX est proposée pour expliquer l'expérience des parties prenantes dans un processus de prototypage de services. Un modèle de recherche sur la SP est proposé, basé sur l'effet causal de l'IX sur le RWD de l'utilisateur et de la SP sur l'intention d'adoption.

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3. Questions et hypothèses de recherche

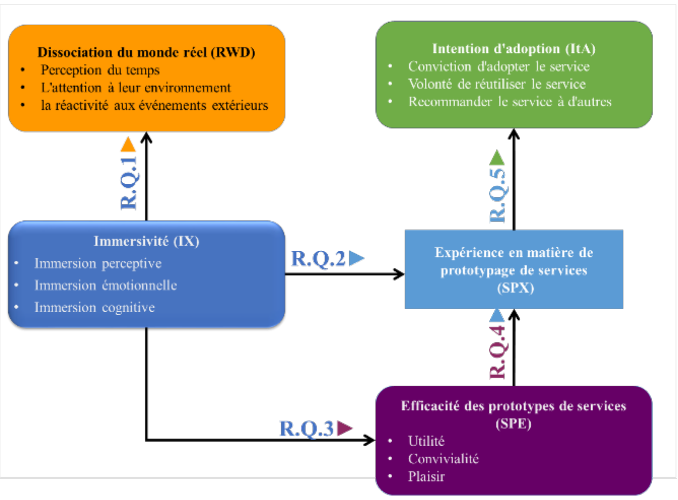

Fig. 5 Un modèle simplifié de recherche sur les SP construit une relation

La première sous-question porte sur l'impact de l'immersion sur les parties prenantes sur la dissociation du monde réel en termes de temps, d'attention et d'environnement. Cela nous aidera à déterminer si les technologies immersives affectent la capacité à être conscient des facteurs externes lorsqu'on est immergé. La première hypothèse propose que lors de l'utilisation d'un prototype de service, plus le degré d'immersion est élevé, plus la dissociation par rapport au monde réel est importante. Plus les parties prenantes seront immergées, plus leur sens du temps, leur environnement et les facteurs externes diminueront avec l'augmentation de l'immersivité. La deuxième sous-question concerne l'examen des impacts de l'immersion sur l'expérience du prototype de service des parties prenantes, et la manière dont elle affectera le SPX. Cela englobera la possibilité d'adoption, de réutilisation et de recommandation future de ce type ou processus de prototypage de service. La deuxième hypothèse propose que, lors de l'utilisation dans un prototype de service, plus le degré d'immersivité est élevé, meilleure est l'expérience du prototype de service. Les parties prenantes disposeront d'un SPX plus satisfaisant qui augmentera les chances de les convaincre de l'adopter, ou de le réutiliser, et même de le recommander à d'autres.

La troisième sous-question porte sur les impacts de l'immersion sur les qualités ergonomiques et hédoniques du prototype de service en termes d'efficacité (d'un prototype de service). Cela permettra de comprendre quel type d'impact les technologies immersives peuvent avoir sur l'efficacité du prototype. La troisième hypothèse propose que lors de l'utilisation d'un prototype de service, plus le degré d'immersivité est élevé, plus le processus de prototypage de service est efficace. La quatrième sous-question porte sur les impacts de l'efficacité et de l'efficience du prototype de service sur les parties prenantes SPX. Cela nous aidera à déterminer si les technologies immersives ont un impact sur les SPX des parties prenantes. La cinquième sous-question porte sur l'impact de l'échange de services sur l'intention d'utilisation des parties prenantes en termes de degré d'acceptation et d'adoption. Cela nous aidera à identifier si les technologies immersives affectent l'intention d'utilisation et, par conséquent, le degré d'adoption. La quatrième hypothèse propose que plus le processus de prototypage des services est efficace, plus le SPX est efficace. En effet, le participant appréciera d'autant plus le processus qu'il réussira mieux à accomplir la tâche sans aide ni erreur et dans la durée la plus courte possible. La cinquième sous-question porte sur les impacts du SPX sur l'intention d'utilisation des parties prenantes en termes de degré d'acceptation et d'adoption. Cela nous aidera à déterminer si les technologies immersives affectent l'intention d'utilisation et, par conséquent, le degré d'adoption. La cinquième hypothèse propose que lors de l'utilisation d'un prototype de service, plus le SPX est bon, plus le degré d'acceptation et d'adoption par les parties prenantes est élevé. Comme l'utilisateur sera plus immergé que la conviction des parties prenantes d'adopter, de vouloir réutiliser, et le degré de recommandations aux autres avec l'augmentation de l'immersivité, ce qui conduit à un meilleur SPX.

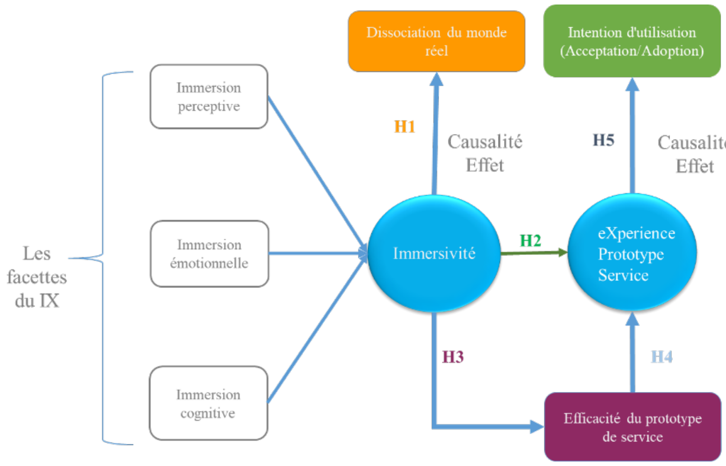

Fig. 6 Le modèle de recherche proposé pour la SP

L'enquête commence par la création d'une base de référence pour les performances, car il est essentiel de découvrir la différence de performances lors de l'utilisation ou non de prototypes de service. L'expérience de SP a été menée avec les cinq différents formulaires de SP, où l'expérience, l'acceptation et la performance du participant sont mesurées (enquête bipolaire, durée d'achèvement de la tâche, calcul des erreurs, calcul des demandes d'explications) et évaluées (justification des questions de l'enquête, expression du visage dans l'attitude). En raison de l'indisponibilité de la technologie MR (Microsoft Hololens), cette partie de l'expérience n'a pas été exécutée en même temps que les 4 autres formulaires SP. Afin d'explorer les impacts des technologies immersives, trois approches seront utilisées pour collecter les données : (1) enquête bipolaire exploratoire avec justification de la notation après l'achèvement de chaque tâche ; (2) performance des participants tout au long des expériences ; et (3) retour d'information et justification de la notation des participants. L'expérience de validation vise à valider le modèle et l'instrument de recherche, par la comparaison de prototypes de services immersifs et conventionnels dans une expérience, puis à l'évaluer dans un cadre industriel.

L'expérience de validation de la SP a été conçue pour engager les participants sur le plan perceptif, émotionnel et cognitif. Les modes d'emploi sur papier sont assez courants dans l'industrie pour l'entretien des machines ou même pour des utilisations plus personnelles comme l'assemblage de meubles Ikea. Ce type d'instructions basées sur des dessins peut être considéré comme une partie du processus de service. La notice d'instructions présente aux participants, par exemple, les étapes et les éléments nécessaires au montage ou au démontage de meubles spécifiques. C'est pourquoi, pour concevoir notre expérience, nous avons imaginé un service d'assistance aux personnes qui doivent monter ou démonter un élément mécanique constitué de plusieurs pièces de la manière la plus confortable, la plus efficace et la plus fiable possible. Dans ce cas, les acteurs du service exploreraient, tout au long du processus de prototypage du service, différentes alternatives de service par l'utilisation de différentes formes (PSP, MSP, VRSP, ARSP, MRSP) de prototype de service que les participants expérimenteront et fourniront un retour d'information sur les aspects mentionnés ci-dessus (immersivité, dissociation du monde réel, efficacité, expérience et intention d'accepter et d'adopter). Les participants ont dû remplir quatre enquêtes bipolaires au cours de chaque session d'expérimentation individuelle. Chaque question bipolaire présente une échelle sémantique avec des valeurs de notation allant de -2 à 2. Le questionnaire commence par la sélection du formulaire de SP qui a été rempli. Les participants ont tous été assignés à des cycles de SP différents, afin d'éliminer les biais liés à l'exécution de la tâche avec le même formulaire de SP au début ou à la fin d'un cycle. Le cycle d'expérimentation consiste en la combinaison des formulaires SP utilisés dans un ordre spécifique. Le cycle de SP que le participant commence avec changement chaque ensemble de participants pour éliminer également les biais.

Plusieurs études du domaine de la recherche sur l'assemblage industriel sont similaires, comme des études comparant différentes formes de conseils ou de formation en matière d'assemblage. Boud et al. (1999) ont comparé les temps de réalisation de l'assemblage des méthodes d'assemblage immersives (VR, AR) et conventionnelles (dessin, plan). Banerjee et autres (1999) ont comparé l'efficacité des compétences acquises en utilisant des plans, un bureau non immersif et un environnement immersif. Tang et autres (2004) ont comparé des systèmes de guidage d'assemblage en utilisant la AR, un manuel imprimé et des instructions assistées par ordinateur dans le cadre d'une expérience. Wiedenmaier et autres (2009) ont comparé le guidage d'assemblage à l'aide d'un AR, d'un manuel imprimé et d'un tutoriel verbal d'expert dans le cadre d'une expérience. Strobel et Zimmerman (2011) ont comparé la VR de bureau, la VR stéréo de bureau et une approche basée sur le papier en ce qui concerne la performance, les temps de réalisation et la précision. Murcia-Lopez et Steed (2018) ont comparé la VR, les instructions sur papier et sur vidéo dans le cadre d'une expérience. Barkokebas et autres (2019) ont comparé les performances d'une formation en VR ou d'un manuel d'instruction traditionnel sur papier dans le cadre d'une expérience. Bode (2019) a comparé la VR à des systèmes d'instructions sur papier en termes d'efficacité et de facilité d'utilisation dans un cadre industriel. Hoover et autres (2020) ont comparé le temps d'exécution, le nombre d'erreurs et le score du guide d'assemblage de MR Hololens avec les instructions d'AR de bureau, de tablette et de tablette dans un cadre expérimental.

Cette étude examine l'impact des technologies immersives sur les prototypes de services, mais dans un cas, une étude uniquement quantitative ne donnera pas une image complète car elle pourrait montrer les statistiques mais pas le raisonnement. D'autre part, une étude uniquement qualitative pourrait être bénéfique pour trouver les raisons de l'impact, mais cela serait également insuffisant car elle se fera sur une base limitée de participants et ne pourra pas être interprétée à une plus grande échelle. Les méthodes mixtes semblent être la méthode de recherche la plus appropriée pour remettre en question une telle étude exploratoire multidimensionnelle (Johnson et Onwuegbuzie, 2014). Pour valider le modèle, une expérience est nécessaire pour tester l'hypothèse. Pallot et Pawar (2012) ont utilisé des méthodes mixtes pour l'étude de l'expérience immersive, et ont également été utilisés par Krawczyk et al. (2017) et Topolewski et al. (2019) pour une étude similaire de l'expérience immersive. La technique des méthodes mixtes permettra de valider les résultats en utilisant la triangulation des données qualitatives et quantitatives, en utilisant les données qualitatives pour explorer et interpréter les résultats quantitatifs grâce au retour d'information recueilli et aux parties prenantes du questionnaire intégré quantitatif et qualitatif prévu (Greene et al., 1989 ; Morse, 1991 ; Morgan, 1998 ; Tashakkori et Teddlie, 1998 ; Creswell et al., 2003). En utilisant le modèle de triangulation validant le modèle de données où les deux séries de données sont collectées en même temps à partir de l'enquête en utilisant un questionnaire intégré quantitatif et qualitatif. L'enquête a été menée sur l'application Jaxber car elle offre un moyen facile de collecter les données des participants sur leurs appareils numériques ou sur nos propres tablettes fournies. Les observations et les données sur les attitudes ont également été directement saisies et tapées dans un fichier Excel. Les données collectées sont ensuite corrélées avec les observations observées au cours des expériences afin de valider le modèle.

L'instrument de recherche consiste en 15 questions d'évaluation bipolaire dans une enquête avec une échelle sémantique pour tenter de vérifier le modèle, où l'utilisateur doit justifier cette évaluation dans l'espace de justification afin de comprendre la motivation derrière l'évaluation soumise. Ces éléments de justification intégrés dans le questionnaire bipolaire permettent aux participants d'exprimer librement leurs commentaires sur les notes qu'ils ont soumises sous forme de texte. Ce questionnaire a été créé en anglais, afin d'être utilisé dans des études publiées, puis a été traduit en allemand, qui a été utilisé dans les expériences réalisées à l'Université de Furtwangen, et en français, qui a été utilisé à l'ENSAM des campus de Laval et d'Angers. Ces questions ont été soigneusement sélectionnées pour couvrir les facettes de l'expérience de la psychologie scolaire, les facettes de l'efficacité de la psychologie scolaire et les facteurs de dissociation du monde réel comme discuté dans la publication précédente (Abdel Razek et al., 2018b). Au cours des expériences, la performance des participants a été évaluée dans l'accomplissement de la tâche en mesurant le temps nécessaire à chaque participant pour accomplir la tâche de démontage et d'assemblage, en plus de la durée d'absorption des connaissances qui a été estimée dans l'expérience de pré-test. Les participants ont été observés lorsqu'ils accomplissaient la tâche afin de noter les commentaires verbaux des participants, d'observer leurs réactions au cours de l'expérience, et de capturer leurs observations pendant l'expérimentation. La durée nécessaire à chaque participant pour terminer la tâche a été mesurée, les erreurs et les explications demandées ont également été calculées. Les observations produites à partir de la performance des participants et de leur attitude pendant l'expérience seront utilisées comme interprétations des résultats de l'enquête. L'objectif est, après avoir validé quantitativement le modèle et l'instrument, de faire évaluer l'expérience et les résultats d'un point de vue industriel.

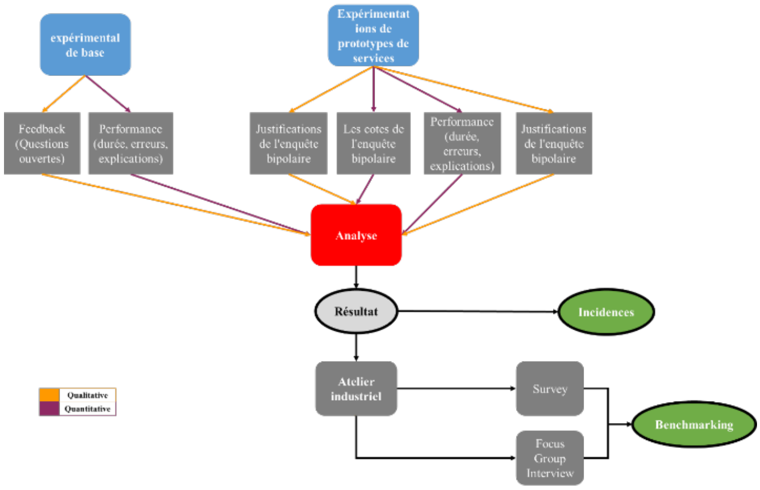

Fig. 7 Aperçu simplifié de l'enquête

Les tâches ont été chronométrées à partir du moment où le participant commence la tâche de démontage ou de montage jusqu'à la fin de chacune de ces tâches. La durée nécessaire à l'accomplissement de la tâche comprend la durée d'absorption des connaissances constituée par les deux vidéos des processus de démontage et de montage. Les demandes d'explication étaient la seule façon pour le participant d'obtenir des instructions ou des conseils pour accomplir la tâche, car tous les participants sont autorisés à demander des explications lorsqu'ils en ont besoin. Au cours de l'expérience, un chercheur a observé les actions et les réactions des participants ; même lorsqu'ils étaient immergés dans la VR, l'observation de ce qu'ils faisaient été confié à un moniteur. Les interactions de chaque participant sur l'utilisation de l'ARSP ont été faites à travers la tablette et l'application de VR. L'observation physique a également été faite pendant qu'ils utilisaient la PSP et la MSP et pour voir s'ils avaient besoin d'un soutien quelconque. La durée de chaque tâche a été enregistrée et les attitudes, commentaires, demandes d'explication et erreurs ont été notés. L'enquête démographique consistait en 10 questions à choix multiples, dans lesquelles les participants ont consigne leurs informations. L'enquête bipolaire de 15 questions que les participants ont rempli après chaque utilisation d'un formulaire SP et l'achèvement de la tâche d'assemblage a été construite pour évaluer (1) leur immersion ou l'expérience immersive (IX), (2) la dissociation du monde réel (RWD), (3) l'efficacité du prototype de service (SPE), (4) l'expérience du prototype de service (SPX), et (5) l'intention d'acceptation et d'adoption du prototype de service (ItA). L'enquête a été construite avec un questionnaire bipolaire qualitatif quantitatif intégré avec une échelle sémantique, où chaque question bipolaire a un élément pour justifier la notation sous forme de texte libre. L'enquête a permis à chaque participant de justifier la note qu'il a donnée, car ces justifications donnent un aperçu de l'utilisation. Le sentiment des participants a également été déduit de la formulation utilisée dans leurs commentaires.

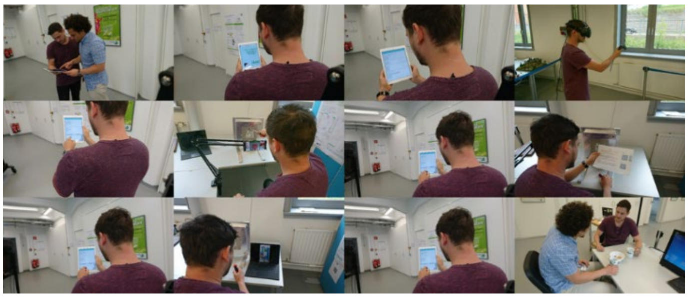

Fig. 8 Protocole d'image expérimentale

Ces tâches physiques sont guidées par les différents formulaires d'instruction : (1) PSP comprend toutes les étapes nécessaires et l'explication de chaque étape à travers le dessin CAO de chaque partie de l'objet métallique en trois parties (Vidéo : https://youtu.be/YcQ6fn9KN_c) ; (2) MSP contient une vidéo de réplication des processus d'assemblage et de désassemblage pour montrer à l'utilisateur comment le faire correctement (Vidéo https://youtu.be/JQTmSKRnqcQ) ; (3) VRSP pour immerger l'utilisateur dans un HTC Vive HMD pour explorer et interagir avec les instructions dans un environnement virtuel (Vidéo https://youtu. be/j7Oai6jqKO4) ; (4) ARSP utilise un dispositif à tablette pour superposer les instructions de chaque étape de désassemblage et d'assemblage directement sur la construction métallique physique (Vidéo https://youtu.be/37ZXbGF1npI) ; et (5) MRSP qui utilise un MR Hololens pour projeter une instruction holographique pour chaque processus de désassemblage et d'assemblage en projetant les étapes nécessaires sur la pièce métallique (Vidéo https://youtu.be/QgSxmYYNR_I). La première expérience avec les formulaires de SP se traduit par une expérience des parties prenantes qui induit des réactions et un retour d'information de l'utilisateur recueilli et analysé en même temps que mes observations. Ces prototypes de formulaires de service auront des réactions et des retours d'information différents de la première fois des utilisateurs. Un cycle de formulaires a donc été conçu pour que chaque formulaire SP soit utilisé comme premier formulaire afin d'éliminer les biais.

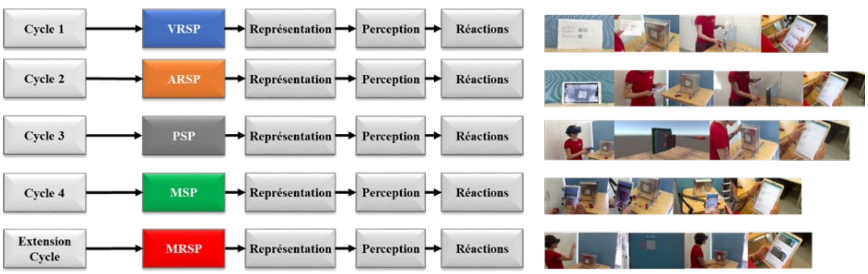

Fig. 9 Processus d'expérimentation de la PS

L'expérience implique les participants dans deux CSP au cours desquels ils lisent un dépliant, regardent une vidéo et utilisent deux ISP et les participants interagissent avec des objets dans un environnement de réalité virtuelle ou dans un environnement de réalité augmentée. Tous les participants utilisent ces CSP pour effectuer les tâches de démontage et d'assemblage en utilisant le support de chacune des différentes formes de CSP. L'élément mécanique à désassembler/assembler est composé d'une construction métallique en trois parties dont les composants imbriquent. La construction métallique en trois parties comporte plusieurs vis et boulons à plusieurs endroits, qui doivent être dévissés/vissés : L'attitude des participants a été observée pendant l'exécution des tâches de démontage et de montage, lorsque chaque participant réagit dans la situation stressante lois de l'accomplissement de ces tâches. Les lois de observations faites au cours des deux sessions d'expérimentation ont été notées et enregistrées sur une feuille Excel comme suit : (1) chronométrage de la durée des tâches de démontage et de montage ; (2) comptage du nombre d'erreurs ; (3) comptage du nombre de demandes d'explication ; et (4) saisie de l'attitude des participants (expressions faciales) pendant la réalisation des deux tâches (y compris 3 options d'attitude) : (a) Bonheur signifie que l'observateur pourrait détecter un sourire ou des expressions faciales positives ; (b) Neutre signifie que l'observateur ne peut pas décoder l'expression faciale du participant ; (c) Frustré signifie que l'observateur pourrait voir que le participant est triste ou à une expression faciale négative).

Chaque participant devait expérimenter chacun des prototypes de formulaire de service, exécuter la tâche et donner son avis en remplissant une enquête bipolaire. L'enquête contenait quinze questions bipolaires à l'échelle sémantique, chaque question représentait une propriété UX, et chacune de ces trois propriétés constituait une construction inférieure, et chacune de plusieurs constructions inférieures constituait une construction supérieure. L'échelle sémantique des notes allait de [-2], représentant très faible, [-1] faible, [0] modéré, [+1] fort et [+2] très fort. La durée totale de la session d'un participant était d'environ une heure pour accomplir les deux tâches quatre fois en utilisant les quatre différentes formes de prototype de service et en répondant également à l'enquête. Cette enquête est composée de questions bipolaires avec un espace de justification pour que chaque utilisateur puisse développer sa réponse, ce qui permet de collecter, d'analyser et d'interpréter les données en même temps. Les données de ces ré posent aux questions bipolaires seront intégrées dans les résultats quantitatifs et les données de la partie justification des questions seront intégrées dans les résultats qualitatifs. Les données collectées ont été regroupées en plusieurs ensembles de réponses ; le premier ensemble de résultats est constitué des données démographiques des participants ; le deuxième ensemble de résultats concerne l'enquête bipolaire à laquelle les participants ont répondu ; enfin, le troisième ensemble de résultats reflète les mesures d'observation. Après les expériences SP, il y aura des tests futurs dans un contexte industriel, avec des acteurs industriels ; il s'agit de tester le modèle validé, affiné dans un scénario réel, pour constater l'impact dans un contexte industriel. J'ai également organisé un atelier industriel dans une organisation industrielle (Liebherr Gmbh) pour démontrer les facettes et les applications de la SP.

L'objectif de l'atelier industriel et du groupe de discussion est d'évaluer l'acceptation industrielle du processus de prototypage de services et l'utilisation du prototype de service dans un cadre industriel.

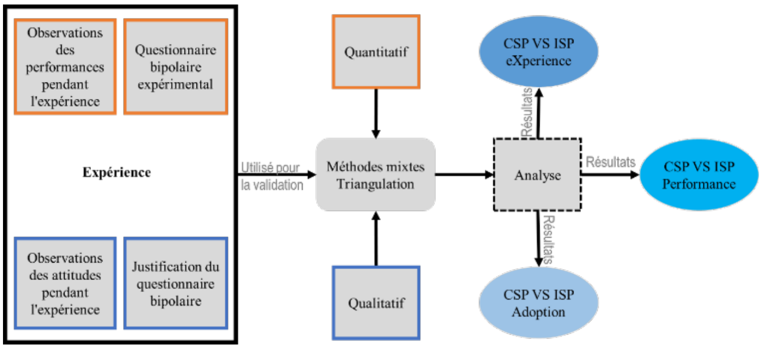

Fig. 10 Résumé des méthodes

Dans la figure (10) ci-dessus, nous résumons les méthodes et les résultats attendus sous forme de graphique pour une meilleure compréhension des méthodes et des résultats. Comme le montrent les expériences de base, les expériences de validation et les entretiens avec des groupes de discussion industriels, les données collectées combinées à mes observations au cours de l'expérience seront utilisées pour valider le modèle et l'instrument. La validation se fera par triangulation pour permettre la preuve par vérification croisée de plus d'un ensemble de données. Puisqu'il s'agit d'un nouveau courant de recherche en matière d'innovation de services et de technologies immersives. Ensuite, une expérience pour vérifier cette recherche conceptuelle exploratoire, selon un ensemble prédéterminé de formes de PS, dans un cas d'utilisation de service spécifique qui peut être également évolutif et réalisable.

4. Contributions

L'expérience a été créée pour engager dynamiquement les participants en commençant par (a) répondre à une enquête démographique, (b) puis en procédant à plusieurs prototypes de service conventionnels et immersifs et à une construction mécanique en quatre parties ; ils utiliseront les prototypes pour effectuer les tâches de démontage puis d'assemblage, ils (c) répondront à une enquête bipolaire sur ce qu'ils ont utilisé et fait. L'objectif de l'expérience de base est de prévoir l'impact de la non-utilisation d'un SP pour soutenir l'accomplissement de la tâche. L'expérience de base a été menée avec trente étudiants participants, la durée moyenne de l'expérience étant de trente minutes par participant. Plusieurs tests ont été effectués pour établir la durée nécessaire à la maitrise des connaissances pour chaque forme de SP, et pour améliorer la méthodologie et la mise en place globale de l'expérience. L'objectif principal de l'expérimentation pour les psychologues scolaires est de montrer les différences entre les différentes approches de psychologues scolaires et de vérifier le modèle et l'instrument de recherche. L'expérience principale a été menée avec quatre formes de PS, VRSP, ARSP, PSP et MSP ; cette expérience a duré en moyenne une heure par participant, avec un total de 103 participants de différents horizons. L'expérience de SP a été menée sur différents cycles, ce qui signifie que chaque groupe de participants a commencé avec une forme de SP différente, afin d'éliminer les biais dus aux connaissances latentes de l'utilisation de toute forme de SP. L'expérience d'extension a été menée uniquement avec le MRSP car le dispositif Hololens (MR) n'était pas disponible en même temps que les autres dispositifs de VR et de AR. Cette expérience d'extension a été menée pour comparer les performances, l'expérience et l'acceptation de la MRSP avec les quatre autres formes de SP. L'expérience d'extension a également été menée avec trente participants, chaque session d'expérimentation ayant duré environ vingt minutes.

L'expérience de base a réussi à montrer que même pour un processus aussi simple, la communication est cruciale pour mener à bien la tâche avec succès et efficacité. Les participants ont pu terminer les tâches d'assemblage, mais ils ont dû faire face à de nombreux défis et problèmes au cours du processus, visibles dans les commentaires, ainsi que dans les mesures de performance. Le participant le plus rapide a été l'un des deux participants à terminer la tâche sans aucune erreur et sans demander d'explications, terminant la tâche en seulement quatre minutes et quarante-trois secondes. Le participant le plus lent a terminé la tâche en dix-neuf minutes et trente-sept secondes, avec huit erreurs et quatre demandes d'explication. La durée moyenne d'exécution de la tâche était d'un peu plus de onze minutes, et la moyenne des erreurs commises et des demandes d'explication était de 4,3 par participant. Celui qui a commis le plus grand nombre d'erreurs a également demandé le plus d'explications, ce participant a eu une durée d'exécution de la tâche de quatorze minutes et quarante et une secondes avec onze erreurs et neuf demandes d'explication.

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Le participant ayant le plus d'erreurs et de demandes d'explication à ce commentaire : "le positionnement et l'ajustement des pièces étaient le plus grand problème", il a ajouté qu'il "recommanderait une vidéo de la tâche en cours d'exécution pour la", et il termine les commentaires en ajoutant qu'il "ne comprenait pas comment cela pouvait être réalise car, très difficile à visualiser sans un manuel ou un guide". Les commentaires auxquels le participant le plus lent a répondu pour la question la plus difficile étaient "Je ne savais pas comment ri où enlever les pièces en premier ? Et que faire ensuite ?", et c'est ce qu'il a répondu à la question de recommandation "Un guide sur la AR aurait été utile pour les instructions étape par étape", et la dernière chose que le participant a ajouté dans la section des autres commentaires était que "la AR fonctionnerait mieux dans un environnement industriel". Le participant le plus rapide avait une expérience antérieure de l'assemblage mécanique, acquise au cours de ses études techniques précédentes, et il a mentionné qu'il avait "fait un processus similaire dans ses études pratiques". En réponse au plus grand défi auquel il était confronté, il a répondu à la question de recommandation que, selon lui, "du papier avec un simple dessin" suffirait, et il a ajouté dans la section des autres commentaires que "la MR serait meilleure pour la compréhension". Une comparaison des performances et de l'expérience a été faite pour constater s'il y a des différences entre les participants en fonction de leur sexe. Les commentaires des participants montrent qu'ils souhaitaient bénéficier d'un soutien ou d'une orientation quelconque, ce qui montre que même de simples dessins, images ou animations en 3D auraient fait une grande différence. Les participants ont également indiqué qu'un guide étape par étape est nécessaire, même pour des processus simples. Ils ont également ajouté que les appareils MR offrent l'avantage supplémentaire de travailler en mains libres, ce qui serait plus approprié pour des tâches d'assemblage similaires. Ils ont également fait valoir que visualiser la conception finale ou même les étapes successives sans aucun support est un défi. Un participant a ajouté qu'il avait eu une réalisation totalement différente de la conception avant de terminer la tâche, montrant que même pour une tâche aussi simple, la confusion est inévitable lorsqu'aucune communication n'a lieu.

Tab. 2 Résumé des résultats de l'expérience de base

Observations	Moyenne	Femme	Homme
Durée d'achèvement des tâches (DAT) [min:sec]	11:09	11:21	11:04
Erreur d'utilisation moyenne par participant (EA)	4.3	3.63	4.55
Taux d'opportunité d'erreur (EOR)	21.50%	18.13%	22.73%
Taux de fréquence des erreurs (EFR)	90%	87.50%	90.91%
Intensité des erreurs (EI)	11	10	11
Taux moyen des demandes d'explication (XA)	4.33	4.63	4.23
Taux d'opportunité des demandes d'explication (XOR)	21.67%	23.13%	21.14%
Taux de fréquence des demandes d'explication (XFR)	93.33%	87.50%	95.45%
Intensité des demandes d'explication (XI)	9	9	9
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)			

Vérifier l'association de l'Immersivité (IX) aux variables de l'Efficacité du prototypage de services (SPE), de la Dissociation du monde réel (RWD), de l'Expérience du prototypage de services (SPX), et. Intention d'adopter (ItA). IX est une construction d'ordre supérieur qui est formée par les 3 variables de l'expérience d'immersion, perceptuelle (PX), émotionnelle (EX) et cognitive (CX). Ces variables sont mesurées par les questions de l'enquête représentées dans 2 propriétés UX chacune. Le RWD est formé par les trois propriétés mais est causé par la IX, dont la première hypothèse est que la IX a un impact positif sur le RWD. La deuxième hypothèse est que le IX est un prédécesseur (effet de causalité) du SPX, le SPX est formé par le IX et le SPE. La troisième hypothèse est que IX a un impact positif sur la SPE, qui est formée par trois propriétés de l'enquête. La quatrième hypothèse est que la SPE est un prédécesseur (effet de causalité) de la SPX, où plus la SPE est élevée, plus la SPX est élevée. La cinquième et dernière hypothèse est que la SPX a un impact positif sur l'ItA, car l'intention est formée par trois propriétés de la UX. Le modèle développé tente de vérifier les constructions inférieure et supérieure du modèle, en utilisant une construction formative où les questions (Q1 → 15) forment la construction de IX, RWD, SPE et ItA. Comme la séquence de départ du prototype avec lequel le participant a commencé (variable Seq.) pourrait affecter les mesures, une partie de tous les répondants est regroupée pour l'analyse, en outre elle sera vérifiée séparément en quatre groupes donnés par la variable Seq. En considérant l'analyse dans 5 cas différents, comme nous avons examiné (a) tous les répondants, (b) la séquence 1, (c) la séquence 2, (d) la séquence 3, et (e) la séquence 4. Le modèle a été validé statistiquement (Pour une vue détaillée de la validation, veuillez-vous référer au document principal de la thèse).

Tab.3 Décomposition de l'enquête expérimentale SP

Haute construction	Moyenne Construction	Construire plus bas	Enquête	Propriétés
Service Prototype eXpérience (SPX)	eXpérience immersive (IX)	eXpérience perceptuelle (PX)	Q1	Intuitivité
			Q2	Interactivité
		eXpérience émotionnelle (EX)	Q4	Attractivité
			Q6	Engagement émotionnel
		eXpérience cognitive (CX)	Q7	Intérêt
			Q8	Engagement cognitif
	Dissociation du monde réel (RWD)		Q10	L'intemporalité
			Q11	Attention
			Q12	Réactivité aux événements extérieurs
	Efficacité des prototypes de services (SPE)		Q3	Convivialité
			Q5	Plaisir
			Q9	Utilité
Intention d'adoption (ItA)			Q13	Conviction d'adopter
			Q14	Volonté de réutilisation
			Q15	Disponibilité à recommander

L'expérience principale de SP a mobilisé 103 participants, tandis que dans l'expérience complémentaire de MRSP, seuls 30 participants se sont portés volontaires, ce qui ajoute à un total de 133 participants l'ensemble des expérimentations de SP. La durée totale des premières sessions d'expérimentation des SP était d'environ une heure par participant, y compris le temps pour (a) le briefing, (b) l'expérience, (c) l'expérimentation et (d) le retour d'information. Au cours de l'expérience, des observations ont été faites sur l'attitude, les interactions et les réactions des participants aux outils et aux dispositifs utilisés, même lorsqu'ils étaient immergés dans la VR. Le sentiment du participant est basé sur l'émotion de son retour d'information sous la forme de la justification des évaluations en texte libre.

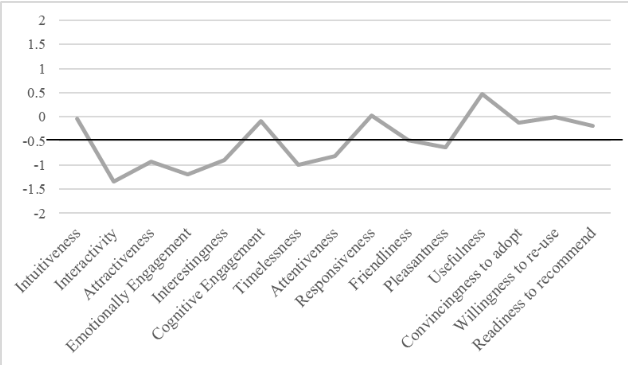

Fig. 10 Courbe des résultats quantitatifs de l'enquête PSP

Le prototype basé sur le service papier (PSP) est la forme la plus familière de prototype, car tous les participants auraient utilisé un manuel d'instruction sur papier pour quelque chose, même dans leur vie quotidienne, comme l'assemblage de meubles IKEA ou la fabrication d'un gâteau au four. L'absorption des connaissances se fait avant les tâches de démontage et de montage. Les participants ont utilisé un manuel d'instruction conventionnel sur papier pour les guider dans les étapes à suivre pour accomplir la tâche. Le participant le plus rapide a mis cinq minutes et quarante-neuf secondes, les plus lentes dix minutes et trente secondes, et la moyenne sept minutes et quinze secondes. La plupart des participants ont pu terminer la tâche dans l'intervalle d'une minute et vingt secondes, ce qui en fait la forme de SP la moins cohérente utilisée du point de vue de la durée. L'attitude des participants pendant l'exécution de la tâche a également été observée. Les observations montrent que 86% des participants étaient neutres ou désintéressés lorsqu'ils ont complété la tâche en utilisant la PSP, tandis que 10% étaient visuellement heureux ou satisfaits, et 4% étaient frustrés ou en colère pour une raison quelconque.

Tab. 4 Observations PSP Différence entre les sexes et les professions

Observations	**Moyenne**	**Femme**	**Homme**	**Professionnels**	**Étudiants**
TCD (min:sec)	07:15	07:20	07:15	07:14	07:16
EA	0.08	0.1	0.07	0.04	0.09

EOR	0.39%	0.50%	0.35%	0.20%	0.45%
EFR	5.83%	5%	5%	4%	7%
EI	2	2	2	1	2
XA	0.11	0.2	0.08	0.14	0.09
XOR	0.53%	1%	0.40%	0.70%	0.45%
XFR	9.90%	15%	8%	11%	9%
XI	2	2	1	2	1
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Les participants ont attribué à l'enquête PSP la note la plus basse parmi toutes les formes de PS, et ont attribué une note négative à presque toutes les propriétés de l'enquête. Cela pourrait être un signe important que les participants pensent que le papier est dépassé et qu'il constitue désormais une forme de communication redondante ou une méthode archaïque de transmission d'informations d'un endroit à l'autre. Ce problème pourrait également être dû au fait que la brochure d'instruction de la PSP a été créée en anglais, puis traduite en allemand et en français, ce qui a également été le cas pour l'enquête. Les résultats de l'enquête PSP ont été les plus faibles parmi tous les autres formulaires SP, comme mentionné précédemment, ce qui pourrait être dû à différentes causes. Afin de pouvoir clarifier ces raisons, il est nécessaire d'approfondir les constructions et leurs notations. L'évaluation des participants pour les constructions PSP montre que le papier est une forme de communication dépassée et non écologique, qui manque également de facteurs d'immersion, ce qui conduit à un déficit dans l'expérience d'utilisation. La seule construction qui a obtenu une note supérieure à la note moyenne de l'enquête est l'intention d'adopter le papier, car celui-ci est toujours bien accepté comme forme de communication par un grand nombre de participants. Les différences dans les notes pourraient être dues à plusieurs facteurs, comme le fait de considérer les deux identificateurs démographiques pour prévoir s'il y a une différence significative entre eux.

Tab.5 Enquête PSP sur les différences de classement selon le sexe et la profession

UX (-2 →+2)	Moyenne	Femme	Homme	Professionnels	Étudiants
IX	Faible (-0.75)	Faible (-0.85)	Faible (-0.73)	Faible (-0.57)	Faible (-0.82)
RWD	Faible (-0.59)	Faible (-0.57)	Faible (-0.6)	Faible (-0.31)	Faible (-0.71)
SPE	Faible (-0.22)	Faible (-0.32)	Faible (-0.56)	Faible (-0.41)	Faible (-0.23)
SPX	Faible (-0.48)	Faible (-0.61)	Faible (-0.45)	Faible (-0.31)	Faible (-0.55)
ItA	Faible (-0.1)	Faible (-0.45)	Faible (-0.01)	Neutre (0.08)	Faible (-0.173)
Vert = supérieur (positif), Rouge = inférieur (négatif)					

Le sentiment des participants est globalement négatif, seule l'évaluation de l'utilité des biens étant positive. La valeur moyenne du sentiment PSP était de -0,36, ce qui est dû au sentiment négatif des propriétés d'interactivité, d'attractivité et d'engagement émotionnel. Le papier n'offre aucun type d'interactivité, à l'exception d'un sentiment négatif, mais comme les participants sont pour la plupart des étudiants, ils sont aussi plus sensibles à la technologie et à l'environnement, ce qui pourrait être un facteur important dans ce sentiment négatif. La PSP en tant que prototype n'a pas été conçue pour être visuellement attrayante en tant que telle. Le sentiment exprimé par les participants à la question de savoir si le prototype est attrayant était également négatif, ce qui pourrait être attribué à la nature d'une brochure d'instruction ne comportant que des instructions textuelles et des schémas mécaniques pour les pièces utilisées dans la tâche. La PSP ne s'est pas rapprochée de la plupart des participants, car elle manquait d'éléments narratifs et n'avait pas de dessins susceptibles d'évoquer des émotions. Les participants ont mentionné dans leurs commentaires qu'ils avaient le sentiment que la PSP était un "manuel d'instruction typique" sans "interaction" et certains ont même mentionné qu'ils "ne pouvaient pas lire et visser en même temps". Ils ont également estimé que la PSP était "ennuyeuse" et ne contenait que des "informations factuelles". Les participants ont également trouvé que la PSP n'avait "rien de spécial" et l'ont trouvée "moins attrayante" car "la lecture prend du temps". Cependant, ils ont également mentionné qu'ils étaient "concentrés sur la tâche" car elle est "facile à comprendre". Ils ont également ajouté qu'ils l'utiliseraient "mais si c'est la seule option" et seulement "en fonction de la situation", ils pourraient la recommander.

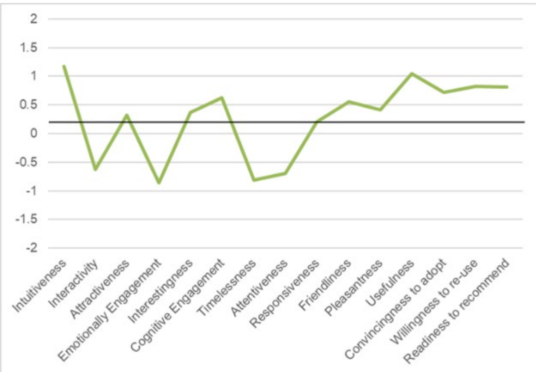

Fig. 11 Courbe de notation de l'enquête MSP

Prototype de service basé sur une maquette (MSP) où les participants regardent deux vidéos, une pour le démontage et une pour le montage, et procèdent ensuite à l'accomplissement de la tâche. Les participants ont fait preuve de constance dans leurs performances en accomplissant la tâche tout en utilisant le MRSP. Plusieurs participants ont également commenté verbalement la facilité avec laquelle ils ont pu reproduire la tâche après l'avoir regardée, mais d'autres participants se sont plaints d'avoir oublié les étapes après avoir regardé les vidéos. Les participants ont pu terminer la tâche en un temps relativement plus élevé que la moyenne, car elle était plus rapide que la PSP. Cette différence de performance pourrait être due au fait qu'ils n'ont eu qu'à reproduire la tâche telle que vue dans les vidéos, alors que dans le cas de la PSP, ils ont dû d'abord lire et comprendre la notice d'instructions. Le participant le plus rapide pour accomplir la tâche a pris quatre minutes et trente-neuf secondes, le plus lent en huit minutes et cinquante-sept secondes et la moyenne en six minutes et une seconde. La plupart des participants ont accompli la tâche dans l'intervalle de quarante-sept secondes entre cinq minutes et trente-trois secondes et six minutes et vingt secondes. Cet écart est le plus faible de toutes les formes de PS, ce qui montre la cohérence de la PSM en tant que forme de communication. Il y a eu plusieurs aberrations à la hausse, ce qui est nettement plus que les autres formes de SP, ce qui montre que certains participants ont trouvé difficile de reproduire un processus après l'avoir observé directement à deux reprises (démontage unique, montage unique). Les participants se sont montrés assez neutres tout en accomplissant la tâche en utilisant la MSP, comme le montre leur attitude tout au long de l'expérience. 82 % des participants étaient neutres ou impartiaux dans l'utilisation de MSP, tandis que 12 % étaient visuellement heureux, et seulement 6 % étaient frustrés ou donnaient des signes visuels de malheur.

Tab. 6 Observation du MSP Différences entre les sexes et les professions

Observations	Moyenne	Femme	Homme	Professionnels	Étudiants
TD (sec)	06:01	06:05	06:01	05:49	06:06
EA	0.14	0.2	0.12	0.14	0.13
EOR	0.68%	1.00%	0.60%	0.70%	0.65%
EFR	10.68%	15%	9.64%	14.00%	9.33%
EI	2	2	2	1	2
XA	0.14	0.15	0.13	0.11	0.15
XOR	0.68%	0.75%	0.65%	0.55%	0.75%
XFR	11.65%	5%	13.25%	11.00%	12%
XI	3	3	1	1	3
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Les notes de la MSP sont les plus élevées parmi les formes de SP conventionnelles, et sont positives dans presque toutes les propriétés de l'enquête. Cela pourrait indiquer que les participants pensent que la vidéo a un bon usage et pourrait être utilisée comme une bonne forme de communication. Le principal défi de la création de la vidéo était d'essayer de transmettre l'information sans aucun son, car cela aurait signifié qu'il y aurait eu trois versions différentes de chaque vidéo pour couvrir les trois langues utilisées dans l'enquête. Les participants ont évalué positivement la MSP dans son ensemble, où la plupart des propriétés ont été jugées positives. Cependant, l'interactivité, l'engagement émotionnel, le sens du temps et le sens de l'environnement ont tous été notés négativement. Ces évaluations négatives pourraient être dues au fait qu'une vidéo n'est pas immersive si elle n'est pas en 3D ou si elle ne comporte pas une forte intrigue pour immerger le spectateur. De plus, la vidéo ne déforme pas l'heure et n'interrompt pas, de sorte que les participants l'ont peut-être moins bien notée que les autres propriétés. Les participants ont évalué les propriétés d'intuitivité et d'utilité de manière particulièrement positive, car il est évident que la vidéo offre une reproduction du démontage et du montage qui est intuitive à suivre et à refaire, et qu'elle est également un outil utile pour apprendre de nouvelles informations et qu'elle est largement utilisée.

Tab.7 Différence de notation des MSP en fonction du sexe et de la profession

UX (-2 →+2)	Moyenne	Femme	Homme	Professionnels	Étudiants
IX	Fort (0.17)	Fort (0.17)	Fort (0.17)	Fort (0.33)	Fort (0.11)
RWD	Faible (-0.43)	Faible (-0.58)	Faible (-0.4)	Faible (-0.08)	Faible (-0.57)
SPE	Fort (0.67)	Fort (0.62)	Fort (0.69)	Fort (0.87)	Fort (0.6)
SPX	Fort (0.27)	Fort (0.24)	Fort (0.28)	Fort (0.46)	Fort (0.2)
ItA	Fort (0.79)	Fort (0.82)	Fort (0.78)	Fort (0.86)	Fort (0.76)
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Le sentiment moyen global de la MSP est positif, comme le montre la valeur du sentiment qui est de 0,16. Les participants ont fait des commentaires positifs sur la façon dont la vidéo était à la fois intuitive et utile, et que la plupart d'entre eux étaient également positifs à l'égard du concept d'acceptation. Les participants ont également montré un sentiment négatif dans les justifications de la propriété d'engagement émotionnel, ce qui pourrait être dû au fait que la vidéo n'avait pas d'instructions verbales et également pas de sous-titres avec les instructions. Les participants ont mentionné qu'ils "doivent juste regarder et reproduire la tâche effectuée dans la vidéo", mais il semble que pour certains, elle était "longue, donc vous devez vous souvenir de toutes les étapes". L'interaction de MSP avec les participants est limitée car plusieurs d'entre eux ont mentionné qu'ils "ne peuvent que faire une pause ou revenir en arrière", tandis qu'un des participants a justifié que MSP n'était "pas spécial mais utile" et même "pas passionnant mais informatif". Ils ont également estimé que la MSP était "très passive" et que certains étaient "distraits par les bruits", ce qui suggère qu'ils n'étaient pas immergés. Les participants ont estimé que MSP "manque d'instructions vocales" ou de "sous-titres", sinon ils ont estimé qu'il est "très utile pour les tâches complexes" et "il est facile à partager et à utiliser".

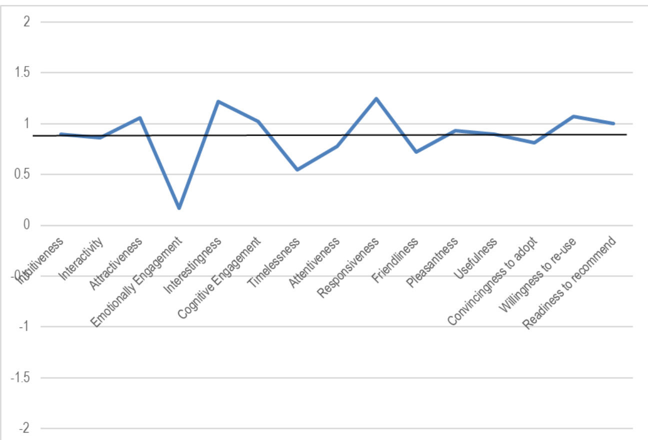

Fig. 12 Courbe des résultats quantitatifs de l'enquête VRSP

L'expérience du prototype de service basé sur la réalité virtuelle (VRSP) a engagé les participants dans un environnement de VR avec une simulation interactive de formation immersive en 3D. La simulation de formation consistait en un manuel d'instruction interactif des processus de démontage et de montage, afin que les participants puissent suivre les étapes de manière immersive et apprendre sans risque. Le participant le plus rapide a pu accomplir la tâche en cinq minutes et cinquante-trois secondes, tandis que le plus lent l'a fait en dix minutes et vingt-quatre secondes ; et la durée moyenne était de six minutes et cinquante-cinq secondes. La plupart des durées des participants se situaient entre six minutes et trente secondes et sept minutes et huit secondes, ce qui montre que la plupart des participants ont achevé la tâche en trente-huit secondes, ce qui montre la cohérence du VRSP. Les participants étaient beaucoup plus heureux après avoir fait l'expérience du VRSP que de toute autre forme de PS, ce qui ressort de leurs expressions faciales ainsi que de leurs commentaires verbaux après coup. 63% des participants étaient visuellement heureux pendant et après avoir terminé la tâche en utilisant VRSP, tandis que 34% étaient neutres ou désintéressés après avoir utilisé VRSP et seulement 3% étaient frustrés ou visuellement affectés après avoir utilisé VRSP. Ces personnes visuellement affectées étaient également les mêmes que celles qui ont eu des problèmes de cyber maladie après avoir utilisé la simulation de VR pour la première fois.

Tab. 8 VRSP : différences entre les sexes et les professions

Observations	Moyenne	Femme	Homme	Professionnels	Étudiants
TCD (sec)	06:55	07:10	06:50	06:40	07:01
EA	0.14	0.3	0.06	0.08	0.13
EOR	0.69%	1.50%	0.30%	0.40%	0.65%
FR	7.77%	20%	6%	8.00%	9.33%
EI	3	3	2	1	3
XA	0.12	0.35	0.07	0.15	0.13
XOR	0.58%	1.75%	0.30%	0.75%	0.65%
XF	8.65%	20%	5%	12.00%	6.67%
XI	3	3	2	2	3
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Le VRSP a été le plus satisfaisant en ce qui concerne UX, et l'attitude des participants était également positive et la plupart d'entre eux ont commenté verbalement à quel point ils l'ont apprécié. Cette évaluation supérieure à la moyenne des participants pourrait être due aux facteurs d'immersion de la VR Immersivité, car la plupart des participants ont trouvé l'environnement de la VR attrayant, intéressant et réactif L'enquête a été créée pour évaluer si les participants ont apprécié l'utilisation du formulaire et pour en savoir plus sur l'utilisation sous forme de commentaires et de justifications. Le VRSP construit des notes moyennes montre que l'ItA était la construction là mieux notée, ce à quoi on pouvait s'attendre puisque la VR a le plus haut niveau d'implication, et en tant que telle, elle aurait pu être intéressante pour les participants. La figure montre que les notes IX, RWD et SPE étaient proches de la note moyenne du VRSP de SPX. La note ItA était supérieure à la note moyenne de l'enquête avec 0,96, ce qui pourrait suggérer que les participants étaient plus qu'heureux d'accepter et d'adopter cette forme de SP. La note RWD était de 0,86, ce à quoi on pouvait s'attendre puisque la VR dissocie l'utilisateur de son environnement. Pour être en mesure de saisir les impacts des immersions, une analyse plus approfondie des différences de performance et de notation des participants dans l'expérience. Les différences peuvent provenir de plusieurs facteurs, mais comme nous pouvons facilement connaître les données démographiques des participants, nous choisissons les aspects liés au sexe et à la profession.

Tab. 9 Résultats de l'enquête VRSP Différences entre les sexes et les professions

UX (-2 →+2)	Moyenne	Femme	Homme	Professionnels	Étudiants
IX	Fort (0.87)	Fort (0.68)	Fort (0.93)	Fort (0.7)	Fort (0.93)
RWD	Fort (0.86)	Fort (0.68)	Fort (0.91)	V. Fort (1)	Fort (0.81)
SPE	Fort (0.85)	Fort (0.69)	Fort (0.9)	Fort (0.74)	Fort (0.9)
SPX	Fort (0.88)	Fort (0.71)	Fort (0.93)	Fort (0.77)	Fort (0.93)
ItA	Fort (0.96)	Fort (0.85)	Fort (0.99)	Fort (0.7)	V. Fort (1.07)
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

La valeur de justification moyenne du VRSP était de 0,54, ce qui constitue un sentiment positif. Les réactions des participants ont été pour la plupart positives, confirmant le résultat positif de l'enquête, ce qui montre que les participants ont attribué une note positive à VRSP et ont également eu un sentiment positif. Le sentiment des participants était positif avec une valeur de 0,54, le RWD était également positif avec 0,53, le SPE avec 0,53, le ItA était positif avec une valeur de 0,55 et le SPX était également positif avec une valeur de 0,54. Les commentaires varient, mais la plupart des commentaires laissés par les participants étaient positifs. Les participants ont mentionné que le VRSP est "très intuitif et explicite", certains l'ont trouvé "convivial parce qu'il est simple" tandis que d'autres l'ont trouvé "peu convivial pour les personnes qui n'ont jamais essayé la VR". Les participants ont également mentionné que le VRSP est "visuellement très attrayant", mais ils ont dit qu'ils "n'avaient aucune émotion envers lui" en l'utilisant et ont même ajouté qu'il est "très utile pour les projets". Les participants n'avaient pour la plupart "aucun sens du temps" et étaient "complètement isolés de la réalité" et ils "le recommandent fortement, surtout pour les tâches complexes".

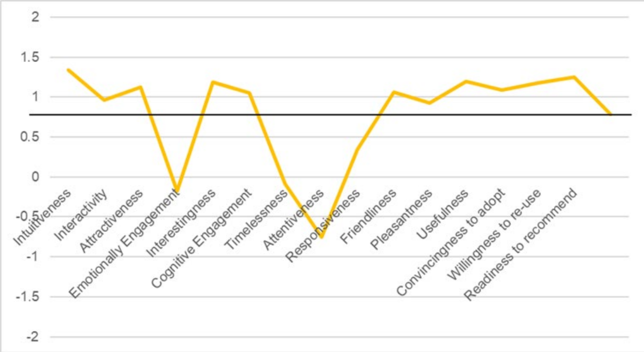

Fig. 12 Courbe des résultats quantitatifs de l'enquête ARSP

Le formulaire ARSP (Augmented Reality basé Service Prototype) est l'un des deux formulaires, ARSP et MRSP, dont les participants ont l'absorption des connaissances en même temps que les tâches de démontage et de montage. Les participants ont utilisé une application AR installée sur une tablette montée sur un bras de bâton fixe pour faciliter l'utilisation, car ils reçoivent les instructions pour la tâche à partir des marqueurs fixés sur la construction mécanique. Le participant le plus rapide a terminé la tâche en une minute et quarante et une secondes, tandis que le plus lent a pris sept minutes et trente-huit secondes ; et la moyenne était de trois minutes et trois secondes. Plusieurs participants ont pris beaucoup plus de temps que la moyenne, ce qui pourrait expliquer que certains participants jouaient avec l'application et le marqueur de la AR, car il s'agissait de leur premier contact avec la AR. Certains participants ont également été confrontés à des difficultés d'identification des marqueurs, car ils n'ont pas pu positionner la tablette correctement, ce qui a entraîné une perte de temps en essayant d'ajuster l'emplacement et la position de la tablette. Les participants étaient pour la plupart heureux lorsqu'ils utilisaient l'ARSP, où 56% des participants étaient visuellement heureux ou satisfaits, tandis que 40% étaient visuellement impartiaux ou neutres, et seulement 4% étaient visuellement frustrés ou malheureux.

Tab. 10 Observation de l'ARSP Différences entre les sexes et les professions

Observations	**Moyenne**	**Femme**	**Homme**	**Professionnels**	**Étudiants**
TCD (min:sec)	03:03	03:09	03:02	02:58	03:06
EA	0.14	0.2	0.12	0.07	0.16
EOR	0.68%	1.00%	0.60%	0.35%	0.80%
EF	10.68%	20.00%	8.43%	7.14%	12%
EI	2	1	2	1	2
XA	0.31	0.35	0.3	0.18	0.36
XOR	1.55%	1.75%	1.50%	0.90%	1.80%
XF	18.45%	15%	19.28%	14.29%	20%
XI	4	4	4	2	4
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

La construction la mieux notée est l'ItA avec une note de 1,17, ce qui est considérablement plus élevé que les autres constructions. Cela pourrait contribuer à l'acceptation du courant principal de la AR et à l'émergence de jeux comme Pokémon Go, qui rendaient la AR cool et amusante. Les guides pédagogiques sur la AR sont également largement utilisés dans l'industrie et certains participants ont pu le voir auparavant et avoir un préjugé favorable à son égard, car il semble que ce soit la solution la plus logique. La note moyenne de l'expérience de prototypage de services est inférieure de 13% à la moyenne, ce qui n'est pas une différence significative, mais cela pourrait être dû aux différences de sexe ou de profession des participants. L'ARSP a été l'une des formes de SP les mieux notées, avec une moyenne de 0,78 affichée avec la ligne noire droite coupant la courbe ci-dessus. Presque toutes les propriétés ont été notées au-dessus de la moyenne, à l'exception de l'engagement émotionnel, de l'intemporalité, de l'attention et de la réactivité qui ont tous été notés en dessous de la moyenne.

Tab. 11 Enquête ARSP UX sur les différences entre les sexes et les professions

UX (-2 →+2)	**Moyenne**	**Femme**	**Homme**	**Professionnels**	**Étudiants**
IX	Fort (0.91)	Fort (0.66)	Fort (0.98)	Fort (0.88)	Fort (0.96)
RWD	Faible (-0.17)	Faible (-0.1)	Faible (-0.18)	Faible (-0.01)	Faible (-0.22)
SPE	V Fort (1.06)	Fort (0.88)	V Fort (1.1)	V Fort (1.03)	V Fort (1.08)
SPX	Fort (0.78)	Fort (0.65)	Fort (0.81)	Fort (0.75)	Fort (0.79)
ItA	V Fort (1.17)	V Fort (1.15)	V Fort (1.18)	V Fort (1.13)	V Fort (1.19)
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Les résultats qualitatifs de l'enquête auprès des participants pour l'ARSP montrent un sentiment positif, puisque la valeur moyenne du sentiment était de 0,5, et aussi que presque toutes les justifications de l'évaluation des propriétés étaient positives, sauf deux propriétés. Le sentiment d'engagement émotionnel était négatif, confirmant également la note négative des participants, car l'AR n'avait pas de lien émotionnel avec le participant. Le sentiment de conscience de l'environnement a également été négatif, ce qui montre que les participants ont eu l'impression d'être distraits de l'accomplissement de la tâche. L'intuitivité et l'attrait des évaluations étaient tous deux positifs, ce qui montre que les participants ont apprécié l'intuitivité des instructions de la AR et qu'ils étaient également attirés par les visualisations. Afin de pouvoir identifier les raisons de ces sentiments positifs dans la plupart des évaluations de l'attractivité, et les sentiments négatifs dans seulement deux d'entre elles, un tableau avec le commentaire de justification le plus mentionné a été construit avec la question de l'enquête également. Les commentaires des participants étaient pour la plupart positifs et montraient l'enthousiasme pour la AR en tant que technologie, et pour l'ARSP en tant que forme de prototypage de service. Les participants ont mentionné à plusieurs reprises qu'elle est "visuellement intuitive" et qu'elle est "facile à comprendre", certains ont également mentionné qu'elle "aide un débutant à résoudre la tâche", et l'ont même qualifiée de "bonne solution à l'avenir si elle est davantage améliorée". Les participants ont également mentionné que l'ARSP "a beaucoup de potentiel" et que "s'il fonctionne correctement", ils "recommanderaient ce prototype à tout le monde".

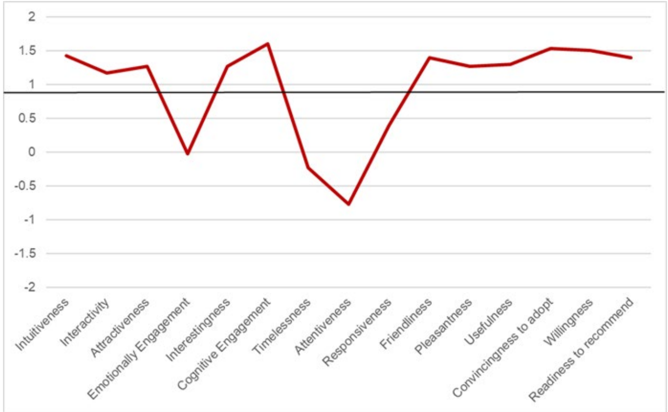

Fig. 13 Courbe des résultats quantitatifs de l'enquête MRSP

L'expérience MRSP (Mixed Reality basé Service Prototype) commence en donnant aux participants les appareils MR Hololens avec le manuel d'instruction holographique. La performance des participants est mesurée en observant la durée d'exécution de leur tâche, les erreurs commises et les explications demandées. Ensuite, ils remplissent le questionnaire sur l'utilisation du prototype en ce qui concerne l'expérience et l'intention de l'accepter et de l'adopter. Le participant le plus rapide à terminer la tâche était de deux minutes et une seconde, tandis que le plus lent était de trois minutes et cinquante et une secondes ; et la moyenne était de deux minutes et cinquante-trois secondes. La plupart des participants ont terminé les tâches entre les deux minutes trente-quatre secondes et les trois minutes onze secondes, avec une moyenne de deux minutes cinquante-deux secondes sur le box plot, ce qui est presque identique à la moyenne calculée. Le temps le plus long pour terminer la tâche en utilisant le MRSP était de trois minutes cinquante et une seconde, tandis que le plus court était de deux minutes et une seconde, et la moyenne de deux minutes cinquante-trois secondes. Le participant le plus rapide a terminé la tâche 30 % plus vite que la durée moyenne, ce qui est également 50 % plus rapide que le plus lent. L'attitude de la plupart des étudiants était positive, car ils étaient vraiment impressionnés par les Hololens et les hologrammes graphiques. 87% des participants étaient visuellement heureux pendant et après l'utilisation du MRSP, tandis que 10% étaient neutres et 3% étaient frustrés ou se sentaient mal à l'aise. Peu de participants ont éprouvé un malaise car ils ont été affectés par la cybersanté, dont on a discuté verbalement avec eux après qu'ils aient terminé la tâche.

Tab. 12 Résultats quantitatifs de l'enquête MRSP Différences entre les sexes

Observations	Moyenne	Femme	Homme
TCD (min:sec)	02:53	03:05	02:46
EA, EOR, EF, EI	0	0	0
XA, XOR, XF, XI	0	0	0
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)			

Le MRSP permet aux participants d'apprendre et d'effectuer la tâche simultanément, ce qui est une manière plus efficace de réaliser la tâche, comme le montrent les résultats de l'expérience de PS, où le ARSP était la forme de SP la plus efficace en ce qui concerne la durée de réalisation de la tâche. Les participants ont évalué positivement la MRSP, en fait la note est beaucoup plus élevée que celle des autres formes de SP et beaucoup plus élevée si on la compare seulement aux premières séquences des autres formes de SP mais ceci est discuté plus loin dans le chapitre. Les participants ont évalué positivement la MRSP dans l'ensemble, avec une excellente note pour presque tous les concepts. Les participants ont évalué l'engagement cognitif avec la note la plus élevée de 1,6, qui est la note la plus élevée, qui provient de la superposition holographique des informations qui se produit directement sur les lunettes, et les yeux sont alors totalement engagés avec ces visualisations. Les participants ont également attribué une note particulièrement élevée à la construction d'acceptation, toutes ses propriétés de construction ayant reçu une note bien supérieure à la note moyenne de l'enquête, ce qui montre que la quasi-totalité des participants sont prêts à adopter le MRSP, à le réutiliser et même à le recommander à d'autres.

Tab. 13 Résultats quantitatifs de l'enquête MRSP Différences entre les sexes

UX (-2 →+2)	Moyenne	Femme	Homme
IX	V. Fort (1.11)	V. Fort (1.09)	V. Fort (1.13)
RWD	Faible (-0.2)	Modérer (0.09)	Faible (-0.37)
SPE	V. Fort (1.32)	V. Fort (1.42)	V. Fort (1.26)
SPX	Fort (0.97)	V. Fort (1.01)	Fort (0.94)
ItA	V. Fort (1.48)	V. Fort (1.36)	V. Fort (1.54)
Vert = supérieur (positif), Rouge = inférieur (négatif)			

Le sentiment moyen des participants était positif avec une valeur moyenne de 0,5, toutes les propriétés ayant un sentiment positif étaient l'intérêt, l'utilité, le degré d'adoption et les propriétés d'engagement cognitif avec un sentiment positif élevé, et le sentiment de temps et de conscience avait un sentiment neutre. Le participant a pu utiliser la MR bien que beaucoup d'entre eux n'aient jamais utilisé une technologie immersive auparavant, un participant a même déclaré "c'est ma première expérience, le temps a passé très vite". Je me suis senti comme Tony Stark", et un autre participant a ajouté "J'utilise la technologie de MR pour la première fois, cela m'a semblé réaliste et excitant". Les participants ont mentionné que la MRSP "montrait les actions étape par étape en tapotant" alors que "parfois il y a un très petit retard dans le temps lorsqu'on tape". Les participants ajoutent également que "chaque étape est animée en détail, de sorte que l'on comprend immédiatement ce qu'il faut faire" et que "c'est si proche de la réalité", mais qu'il y a cependant le problème de l'imprécision du "contrôle des gestes". Les participants mentionnent également que le MRSP "surmonte les inconvénients des instructions ennuyeuses" et qu'"il aidera les nouveaux employés à apprendre des tâches spécifiques en peu de temps". Les participants confirment leur grande acceptation de MRSP en ajoutant que "pour certaines applications complexes, je suis convaincu et prêt à l'utiliser à nouveau" et que "c'est plus intuitif, plus drôle et plus rapide que les autres outils" pensent. Cela montre que les commentaires des participants sont positifs et que leur sentiment est moyen.

Les expériences ont été menées avec succès dans un cadre académique, avec plus de 100 participants. Le modèle de recherche a été validé statistiquement et les hypothèses ont toutes été soutenues. Il y avait des différences dans les résultats des expériences entre les deux pays (France et Allemagne) où les expériences ont eu lieu. Les trois endroits où l'expérience a eu lieu avaient trois domaines principaux d'enseignement et de recherche différents, allant des technologies immersives (Laval), du génie mécanique (Angers), de la gestion des services et de l'informatique (Furtwangen). Par exemple, en France, (1) la PSP du point de vue des UX est la forme la moins satisfaisante, et a eu le plus grand nombre de demandes d'explication, (2) la MSP semble être efficace car elle a eu 0 demande d'explication, et semble avoir une expérience neutre, (3) la VRSP a la deuxième satisfaction la plus élevée en matière de UX, et a été la deuxième plus rapide, elle a eu le moins d'erreurs de calcul, et (4) l'ARSP a eu la plus grande satisfaction en matière de UX et la plus rapide en ce qui concerne la performance. Alors qu'en Allemagne, (1) la PSP a eu la durée moyenne d'achèvement des tâches la plus lente et la note UX la plus négative des participants, (2) la MSP a eu la deuxième durée moyenne d'achèvement des tâches la plus rapide et le moins d'erreurs en moyenne, (3) la VRSP a la note de satisfaction UX la plus élevée, a également été la plus impressionnante pour la plupart des participants, et (4) l'ARSP a subi le plus d'erreurs et de demandes d'explication, et cela a pris plus de temps que prévu car les participants ont joué avec la saisie des marqueurs (à partir des observations).

Tab. 14 Comparaison des observations des formulaires SP

Observations	BSL	PSP	MSP	VRSP	ARSP	MRSP
Durée de réalisation des tâches (min:sec)	11:09	07:15	06:01	06:55	03:03	02:53
Erreur d'utilisation moyenne par participant	4.3	0.08	0.14	0.14	0.14	0
Taux d'opportunité d'erreur	21.50%	0.39%	0.68%	0.69%	0.68%	0
Taux de fréquence des erreurs	90%	5.83%	10.68%	7.77%	10.68%	0
Intensité de l'erreur	11	2	2	3	2	0
Demandes d'explication d'utilisation moyenne	4.33	0.11	0.14	0.12	0.31	0
Explications Demandes Taux d'opportunité	21.67%	0.53%	0.68%	0.58%	1.55%	0

Explication Demandes Taux de fréquence	93.33%	9.90%	11.65%	8.65%	18.45%	0
Intensité des demandes d'explication	9	2	3	3	4	0
L'attitude des heureux participants	2%	10%	12%	63%	40%	83%
Attitude des participants neutres	25%	86%	82%	34%	56%	10%
L'attitude des participants frustrés	73%	4%	6%	3%	4%	7%
Vert = Positif (supérieur), Jaune = Neutre (égal), Rouge = Négatif (inférieur)						

Le participant le plus rapide a utilisé le MRSP, qui représente la manière la plus efficace d'accomplir la tâche, car il était beaucoup plus rapide que les autres formulaires SP, et beaucoup moins d'erreurs et de demandes d'explication. Les participants ont eu tendance à faire moins d'erreurs de manière surprenante en utilisant la PSP, ce qui pourrait suggérer que les participants ont été capables de décoder les instructions de la notice papier et ont effectivement causé en moyenne moins d'erreurs. Les participants ont également demandé moins de demandes d'explication en utilisant la PSP, ce qui montre que l'instruction papier est largement utilisée et que la plupart des participants n'ont pas eu besoin d'éclaircissements supplémentaires sur la tâche, car ils sont utilisés pour extraire des informations du papier plus que tout autre support immergé ou autre.

Tab. 15 La SP établit une comparaison des résultats quantitatifs

UX (-2 →+2)	**PSP**	**MSP**	**VRSP**	**ARSP**	**MRSP**
IX	Faible (-0.75)	Fort (0.17)	Fort (0.87)	Fort (0.91)	V. Fort (1.11)
RWD	Faible (-0.59)	Faible (-0.43)	Fort (0.86)	Faible (-0.17)	Faible (-0.2)
SPE	Faible (-0.22)	Fort (0.67)	Fort (0.85)	V. Fort (1.06)	V. Fort (1.32)
SPX	Faible (-0.48)	Fort (0.27)	Fort (0.88)	Fort (0.78)	Fort (0.97)
ItA	Faible (-0.1)	Fort (0.79)	Fort (0.96)	V. Fort (1.17)	V. Fort (1.48)
Vert = Positif (supérieur), Jaune = Neutre (égal), Rouge = Négatif (inférieur)					

Les participants ont attribué la note IX à la construction la plus élevée dans l'ARSP, puis dans la VRSP, qui n'a pas été aussi exemptée, car elles utilisent toutes deux des technologies immersives et, à ce titre, auront une plus grande immersivité que les deux formes de SP classiques. Les participants ont estimé que l'ARSP est la forme de SP la plus neutre par rapport à la construction RWD car elle offre une superposition des informations sur l'environnement réel en temps réel, de sorte que la notion de temps sera la plus neutre ou comme le "temps réel" et ne sera pas fortement déformée comme la VRSP qui a un facteur de distorsion de la notion de temps élevé. Les participants ont donné la meilleure note à l'ARSP en ce qui concerne l'intention d'accepter et d'adopter, ce qui montre que les participants sont les plus susceptibles d'accepter et d'adopter l'ARSP comme leur forme préférée de prototypage de services. Les participants ont également donné la meilleure note à l'ARSP en ce qui concerne l'efficacité, car cela pourrait être dû à la nature directrice (le faire tout en le vivant) de l'ARSP par rapport aux autres formes de PS. Les participants ont évalué l'expérience du PRSV comme la plus élevée par rapport à toutes les autres formes, ce qui pourrait suggérer qu'ils ont trouvé que c'était la forme de SP la plus interactive et la plus immersive avec une expérience supérieure.

Les justifications du participant concernant le concept d'immersion sont positives pour l'ARSP, la VRSP et la MSP, alors qu'elles sont négatives pour la PSP, ce qui montre que l'ARSP a eu les commentaires les plus positifs concernant les propriétés d'immersion. Les justifications des participants concernant le concept de dissociation du monde réel étaient positives pour la VRSP uniquement, et négatives pour la PSP et la MSP, tandis que l'ARSP avait une valeur neutre, ce qui montre que les participants se sentaient positivement dans l'environnement immersif de la VR. Les participants ont également justifié l'intention d'accepter le concept de manière positive dans le VRSP, l'ARSP et le MSP, tandis que les résultats qualitatifs de la notation PSP étaient négatifs, ce qui montre que les participants n'acceptaient pas la PSP ou du moins qu'ils avaient un préjugé négatif à son égard. Les participants ont justifié positivement l'évaluation de l'efficacité de la SP dans le cas de l'ARSP, de la VRSP et de la MSP, tandis que l'ARSP a été très bien considérée dans les commentaires relatifs à l'efficacité. Le sentiment des participants à l'égard de la SPX était positif dans le cas de la VRSP, de l'ARSP et de la MSP, mais négatif dans celui de la PSP. Le sentiment des participants montre qu'ils ont le plus apprécié l'expérience VRSP.

Tab. 16 SP Comparaison des résultats qualitatifs de l'expérience

Sentiment (-1→ +1)	**PSP**	**MSP**	**VRSP**	**ARSP**	**MRSP**
IX	Négatif (-0.49)	Neutre (0.07)	Positif (0.54)	Positif (0.56)	Positif (0.50)
RWD	Négatif (-0.33)	Négatif (-0.22)	Positif (0.53)	Neutre (-0.03)	Positif (0.31)
SPE	Négatif (-0.26)	Positif (0.37)	Positif (0.54)	Positif (0.70)	Positif (0.56)
SPX	Négatif (-0.36)	Positif (0.16)	Positif (0.54)	Positif (0.5)	Positif (0.5)
ItA	Négatif (-0.21)	Positif (0.52)	Positif (0.55)	Positif (0.69)	Positif (0.64)
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

La comparaison de la séquence SP en position un montre les différences entre les performances de chaque forme SP par rapport à l'expérience de base. La séquence 1 est particulièrement importante pour les observations car elle montre la performance de la première utilisation pour le participant avec chacune des formes de SP ; ce qui élimine tout biais de toute expérience antérieure ou connaissance latente due à une utilisation antérieure de la PS. Les résultats suggèrent que le formulaire MRSP est le formulaire SP le plus rapide à remplir, car il a pris le moins de temps pour accomplir la tâche. La forme de SP la plus lente est la PSP, car elle a pris plus de deux fois plus de temps que la MRSP, qui a duré sept minutes et vingt-sept secondes, mais elle prend quand même moins de temps qu'il n'en aurait fallu si aucune forme de SP n'avait été utilisée, car il a fallu en moyenne 11 minutes et neuf secondes pour achever la tâche sans l'aide de la PS. Les participants ont fait de nombreuses erreurs en accomplissant la tâche sans utiliser de PS, ils ont fait en moyenne 4,3 erreurs par participant, ce qui est assez élevé même en le comparant avec le formulaire de SP avec la plus haute cote d'erreur VRSP avec 0,25. Cela montre que les participants ont fait le plus d'erreurs en accomplissant la tâche après avoir utilisé le VRSP, ce qui pourrait être dû à l'absence d'interactions dans le prototype, mais comme il s'agit d'un prototype, il a fallu ajuster une certaine fidélité et résolution pour que tous les prototypes soient égaux en ce sens.

Tab. 17 Comparaison des observations de la séquence Position 1

Observations	BSL	PSP 1	MSP 1	VRSP 1	ARSP 1	MRSP
Durée de réalisation des tâches (min:sec)	11:09	07:27	05:50	07:10	03:02	02:53
Erreur d'utilisation moyenne par participant	4.3	0.19	0.08	0.25	0.21	0
Taux d'opportunité d'erreur	21.50%	0.96%	0.40%	1.25%	1.04%	0%
Taux de fréquence des erreurs	90%	11.54%	8.00%	17.86%	16.67%	0%
Intensité de l'erreur	11	2	1	3	2	0
Demandes d'explication d'utilisation moyenne	4.33	0.19	0.12	0.21	0.58	0
Explications Demandes Taux d'opportunité	21.67%	0.96%	0.60%	1.07%	2.93%	0%
Explication Demandes Taux de fréquence	93.33%	15.38%	12.00%	10.71%	33.33%	0%
Intensité des demandes d'explication	9	2	1	3	4	0
L'attitude des heureux participants	2%	12%	20%	65%	52%	83%
Attitude des participants neutres	35%	84%	72%	27%	41%	10%
L'attitude des participants frustrés	77%	4%	8%	8%	7%	7%
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)						

Les participants ont montré que même une tâche de démontage et de montage aussi simple pouvait être difficile pour de nombreux participants, dans l'expérience de base, où les participants n'ont pas utilisé de formulaire SP, ils avaient un devis de 4,3 demandes par participant. Si l'on compare le devis des demandes d'explication de base avec le devis le plus élevé du formulaire SP, l'ARSP, qui est de 0,58, il reste 7,5 fois plus de demandes d'explication. Les participants avaient plusieurs questions pendant l'utilisation de l'ARSP, un participant sur deux avait une question pendant l'utilisation de l'ARSP, beaucoup d'entre elles étant dues à la reconnaissance des marqueurs et à la fonctionnalité de la tablette. Afin de mieux comprendre les évaluations des participants à l'enquête, nous avons sélectionné les évaluations de la première séquence de chaque formulaire SP et les avons comparées avec celles de MRSP. Les évaluations des participants ont pu être mesurées au mieux lors de la première utilisation de chaque formulaire SP respectif, car cela permettra de saisir leurs premières impressions après la première expérience.

Tab. 18 Séquence Position One Survey Ratings

UX (-2 → +2)	PSP 1	MSP 1	VRSP 1	ARSP 1	MRSP
IX	Faible (-0.45)	Faible (-0.13)	Fort (0.78)	Fort (0.75)	V Fort (1.12)
RWD	Faible (-0.55)	Faible (-0.61)	Fort (0.65)	Faible (-0.26)	Faible (-0.20)
SPE	Faible (-0.04)	Fort (0.51)	Fort (0.69)	V. Fort (1.11)	V Fort (1.32)
SPX	Faible (-0.27)	Fort (0.07)	Fort (0.79)	Fort (0.69)	Fort (0.97)
ItA	Fort (0.14)	Fort (0.71)	Fort (0.89)	V. Fort (1.09)	V. Fort (1.48)
Vert = supérieur (positif), Jaune = égal (neutre), Rouge = inférieur (négatif)					

Les participants ont attribué à la MRSP la note la plus élevée dans chaque construction, à l'exception de la RWD qui montre que les participants ont le sentiment qu'elle les dissocie du monde réel car elle est la note la plus proche de la note neutre de 0. La note des participants dans la première séquence n'a pas beaucoup changé par rapport à l'enquête globale, si ce n'est que la MSP est plus proche de la Neutreité que de la positivité, et que la PSP est moins négative que dans le total de l'enquête de 50% pour être précis. Cela montre que les participants qui ont utilisé la PSP dans les séquences suivantes ont estimé qu'elle faisait défaut car ils pouvaient la comparer aux autres formulaires de la SP, ce qui pourrait être également le cas pour la MSP.

Afin de mieux comprendre la faisabilité du prototypage de services et l'utilisation des rayons XR dans la création et l'expérimentation du prototypage de services, un atelier a été organisé avec des acteurs industriels. Cet atelier visait à évaluer l'intention des industriels d'accepter et d'adopter les prototypes de service et l'utilisation des rayons X dans le prototypage de service. L'atelier comprenait également une explication de l'expérience de SP et de ses résultats, afin de prévoir s'ils pensent que cela est faisable dans un cadre de service industriel. L'atelier a eu une discussion de groupe avec des questions ouvertes après la présentation de la SP afin de pouvoir recueillir des données à partir de leurs réponses. Pour résumer l'atelier et les discussions de groupe, il s'est avéré fructueux pour (1) évaluer l'acceptation technique et l'adoption par l'industrie du prototypage de services et des technologies immersives, (2) comparer le processus de développement de services de Liebherr, (3) augmenter le niveau de connaissance des employés du prototypage de services et des technologies immersives, et (4) prévoir ce qu'une grande entreprise comme Liebherr pense de l'expérience et de ses résultats. Liebherr a également montré un grand intérêt pour les processus et les outils de prototypage de services, puisqu'elle a même engagé un employé uniquement pour le prototypage de services dans son département de développement de services. Cet employé est responsable de la collaboration croisée entre les différents départements afin de faciliter la création de prototypes de services pour tous leurs futurs services développés. M. Liebherr a également reconnu l'importance des technologies immersives et de l'utilisation des rayons X pour améliorer le développement, l'innovation et la prestation des services. Liebherr a également embauché un nouvel employé responsable uniquement de l'application et des projets de service des technologies immersives. L'atelier a également montré que le prototypage de services a un degré élevé d'acceptation technique industrielle, en particulier dans une grande coopération comme celle de Liebherr, ce qui est un excellent signe. L'atelier a également montré le degré élevé d'adoption du prototypage de services, car Liebherr a vu l'avantage d'utiliser le prototypage de services pour développer de nouveaux services. Liebherr coopère également avec l'université de Furtwangen sur plusieurs cas d'utilisation industrielle, où les étudiants travaillent avec les employés de Liebherr pour plusieurs petits projets impliquant le prototypage de services ou les technologies immersives.

Tab. 19 Comparaison des formes de SP basée sur les impacts des attributs évalués (étendu sur Abdel Razek et al., 2018a)

SP Type	PSP	MSP	VRSP	ARSP	MRSP
fidélité	L	M	H	H	VH
Résolution	L	M	VH	H	H
Effort	L	M	VH	H	H
L'interactivité	L	M	VH	H	H
UX	L	M	H	H	VH
L=Faible, M=Moyen, H=Élevé, V H= Très élevé Vert = plus élevé (positif), Jaune = égal (neutre), Rouge = plus faible (négatif)					

La comparaison est basée sur les résultats globaux de l'expérience et sur les conclusions des groupes de discussion industriels. La fidélité du prototype peut avoir un impact sur les fonctionnalités intégrées dans le prototype, car le CSP est le mieux adapté aux processus de prototypage initial et le ISP au développement ultérieur du prototype. La résolution du prototype peut influer sur la ressemblance du prototype avec la conception finale du service, car le CSP est le mieux adapté aux premiers stades du développement, tandis que le ISP est le mieux utilisé aux derniers stades du développement. L'effort représente les ressources organisationnelles que chaque organisation souhaite investir dans l'exploration, l'évaluation et la communication des idées de service. Le CSP nécessite moins d'efforts et peut être mieux adapté lorsque les idées en sont encore aux premiers stades et pour économiser des coûts, tandis que le ISP peut être adapté lorsque l'idée est déjà sélectionnée et que suffisamment de ressources organisationnelles sont disponibles pour le processus de prototypage du service. L'interactivité du prototype est décidée en fonction du degré d'interactivité requis dans le prototype. En effet, le CSP est plus approprié lorsqu'un prototype à interactivité limitée est nécessaire et le ISP est plus adapté au prototypage d'interactions de services plus complexes. L'expérience du prototype est un attribut essentiel car elle est basée sur les perceptions et les réponses de l'utilisation ou de l'utilisation prévue d'un prototype de service ; lorsque le CSP offre un degré moindre d'UX et convient aux premières étapes car l'expérience n'est pas importante alors que le FAI est plus adapté lorsque l'UX est important pour le processus de prototypage.

5. Conclusion et perspectives

L'objectif général de cette thèse est d'évaluer les impacts des technologies immersives sur les prototypes de services à l'aide d'une série d'expériences et d'entretiens avec des groupes de discussion afin de créer un guide pour une mise en œuvre industrielle ultérieure. L'analyse documentaire nous a permis de constater une lacune dans la littérature, à savoir le manque d'études empiriques sur les prototypes de services et en particulier les prototypes de services immersifs. Cette lacune identifiée a également contribué à façonner l'approche de recherche utilisée dans cette thèse par une approche mixte de méthodes qualitatives et quantitatives afin d'avoir une meilleure compréhension des impacts et des raisons de ces impacts. Afin d'identifier et de mieux comprendre ces impacts, un modèle et un instrument de recherche de prototypage de services ont été construits, et la construction d'une "expérience de prototypage de services" a été élaborée. Le concept, le modèle et l'instrument ont étudié les impacts en comparant des prototypes de service immersifs avec des prototypes conventionnels ; en utilisant une expérience et une enquête pour voir les différences en termes de performance, d'expérience, d'acceptation et de retour d'information. Les prototypes utilisés dans le cadre de l'expérience ont été construits pour inciter les participants à apprendre et à performer, afin de créer une représentation d'une expérience de formation en matière de services industriels. L'objectif principal de l'instrument est d'étudier les impacts de l'utilisation des technologies immersives (XR) sur le prototypage des services.

Pour la contrainte de temps de la thèse, seuls trois prototypes de services immersifs et deux prototypes conventionnels ont été sélectionnés pour l'expérience, et il n'y avait également qu'une seule entreprise dans l'analyse comparative industriel. Ces deux formes de CSP ont été choisies car elles sont actuellement utilisées dans des processus de formation au service et des processus d'apprentissage similaires selon notre recherche documentaire. Les trois types de formes de PSI ont été sélectionnés parce qu'il est logique de voir laquelle serait la plus performante dans une telle tâche, et quels seraient leurs impacts respectifs. Cela a conduit à étudier les différences de performance, d'expérience et de degré d'adoption. L'expérience a réussi à montrer que toutes les technologies immersives n'offrent pas les mêmes avantages en termes de performance, d'expérience et de plaisir ; en effet, de nombreux commentaires et évaluations des participants ont été positifs après avoir utilisé un PSI. Au total, plus de 500 ensembles de données ont été recueillis, y compris les durées, les erreurs, les demandes d'explication, les évaluations bipolaires, les justifications des évaluations et les commentaires des participants. L'expérience a été menée auprès de 133 participants qui ont expérimenté la PSP, la MSP, la VRSP, l'ARSP et la MRSP. L'expérience MRSP a été menée avec 30 participants après l'expérience principale SP en raison du retard à recevoir l'équipement Microsoft Hololens. L'expérience de base nous a montré que, sous quelque forme que ce soit, cela aurait été mieux que rien du tout, ce qui montre l'importance du prototypage et de la communication dans le développement et la conception des services.

Le prototype sous forme papier (PSP) est un type de communication dépassé, mais il est encore largement utilisé dans les processus de communication, de prototypage et d'apprentissage dans le monde entier. Il est évident que la PSP était la plus lente, la moins bien notée, la moins interactive et qu'elle a connu la pire expérience de prototypage de services par rapport aux autres formes de PSP. Le prototype sous forme de réalité virtuelle (VRSP) apporte un excellent moyen de formation sans risque et un excellent environnement d'apprentissage pour absorber les connaissances afin de conserver les informations plus longtemps. Le prototype sous forme de maquette vidéo (MSP) offre une méthode rentable pour les processus de prototypage simples, mais pourrait manquer d'interaction en raison du format 2D des vidéos, ou en utilisant des modèles 3D ou des artefacts pour le compléter, pourrait apporter cet avantage supplémentaire dont il a besoin. Le prototype sous forme de réalité augmentée (ARSP) offre le meilleur rapport coût/bénéfice et de performance et d'expérience, car il pourrait être utilisé avec des appareils personnels moins expansifs (par exemple tablette ou smartphone) pour un investissement initial minimum. Le prototype sous forme de réalité mixte (MRSP) offre la meilleure expérience de prototypage de services grâce à une immersion et une précision suffisantes. La forme MSP est de loin le meilleur CSP en termes d'efficacité, d'efficience et d'expérience, tout en offrant un support neutre où il est facile à digérer, à comprendre et à appliquer pour mener à bien la tâche. La MRSP était la meilleure forme de SP dans l'ensemble car elle offrait les meilleures performances et expériences possibles et avait le plus haut degré d'adoption.

L'un des principaux objectifs est d'aider les développeurs, concepteurs et chercheurs de services à sélectionner le formulaire de SP le plus approprié pour chaque processus de service, ce qui pourrait être une tâche complexe. L'aspect le plus important est d'identifier les liens de dépendance entre l'immersivité et la dissociation du monde réel, l'expérience de prototypage de services et l'efficacité. Cela a été fait par l'analyse statistique des données de l'expérience, comme nous avons analysé ces liens de dépendance. L'analyse statistique n'a été faite que sur les formulaires de SP avec plus de 100 participants, ce qui signifie qu'une autre analyse a été faite spécialement pour MRSP. L'objectif était de mener toutes les expériences sur les formulaires SP en même temps, mais en raison du retard dans le processus d'acquisition des appareils Hololens, cela n'a pas été possible. Les résultats de l'expérience ont été instructifs, notamment en montrant que les hypothèses étaient validées et les questions de recherche résolues, mais nous avons estimé qu'un point de vue industriel sur l'expérience et les résultats de la recherche serait bénéfique. Les résultats de l'expérience ont ensuite été présentés et discutés dans un environnement de service industriel afin d'évaluer le degré d'acceptation et d'adoption d'une organisation de service industriel. Les ateliers et les discussions des groupes de discussion ont été fructueux, car le prototypage de services et les technologies immersives ont été bien acceptés et le sentiment des parties prenantes était positif. L'acceptation de l'organisation a également été ressentie, puisque la société a engagé deux nouveaux employés pour s'occuper des prototypes de services et des technologies immersives dans le cadre des ateliers de prototypage de services qui ont eu lieu au cours des deux dernières années.

L'expérience a été réalisée dans un cadre universitaire, où la reproduction pourrait être difficile car la diversité des participants des trois campus est aléatoire et hétérogène, de sorte que si l'expérience était menée avec un groupe homogène, d'autres résultats pourraient être obtenus. La validation statistique du modèle a été faite avec plus de 100 participants, ce qui était suffisant ; cependant, le fait d'avoir plus de participants aurait été plus significatif. Néanmoins, comme la durée de la session d'expérimentation était d'environ 1 heure, il aurait fallu plus de 1000 heures, ce qui aurait été difficile à réaliser en seulement 3 ans. Une expérience de référence a été menée en Allemagne avec 30 étudiants volontaires afin d'établir un point de référence pour la mesure de l'observation, car il était beaucoup trop difficile d'attirer de vrais professionnels. L'expérience de base a révélé pourquoi il est important d'utiliser un psychologue scolaire, mais comme tous les participants étaient des étudiants, leur expérience et leurs niveaux de connaissances sont limités, ce qui pourrait se refléter dans leurs performances et leurs réactions. En ce qui concerne le taux d'occupation, il était de 70% d'étudiants et 30% de professionnels. Cela peut également être considéré comme une limitation, mais comme mentionné avant l'expérience est sur une base volontaire, et le nombre de professionnels participant était relativement élevé considérant qu'ils ont dû passer une heure sur l'expérience. Quant à la tranche d'âge des participants, la plupart des participants sont alors plus jeunes, en fait seulement 34% des participants avaient plus de vingt-cinq ans, ce qui peut être considéré comme une limitation car les plus jeunes participants peuvent être plus affinés numériquement que les plus âgés, mais comme il s'agit d'un cadre universitaire, les volontaires étaient surtout des étudiants et de jeunes collègues qui étaient intéressés par l'expérimentation de nouvelles technologies et de nouveaux processus.

L'expérience aurait dû commencer avec les deux CSP et les trois ISP, mais en raison de circonstances imprévues, l'appareil de MR n'était pas disponible en même temps que les autres appareils. L'expérience a donc été menée avec les 103 participants avec seulement PSP, MSP, VRSP et ARSP. Comme l'expérience d'extension MRSP n'a été menée qu'avec 30 participants, cela pourrait signifier que si nous testons avec plus de 100 participants, nous pourrions obtenir un résultat différent. L'expérience aurait pu être menée individuellement, ce qui signifie que les expériences auraient été divisées en 6 expériences distinctes, une pour chaque formulaire PSP, et ensuite chacune des expériences aurait nécessité environ 20 minutes chacune, mais nous aurions dû expérimenter avec 100 participants chacun. Cela signifie qu'il aurait fallu faire l'expérience 600 fois, ce qui aurait pris plusieurs années, car nous aurions dû attirer chaque année environ 100 à 150 participants parmi les étudiants des instituts. Les participants à l'expérience MRSP n'étaient également que des étudiants, ce qui limite l'aspect de différence de connaissances si nous avons des différences de performances dues à la connaissance, à l'expérience ou au savoir-faire. Le problème de la MRSP est qu'elle nécessite un appareil de RM, dans ce cas un Hololens, qui est coûteux, car une telle AR serait la solution la plus abordable pour les cas qui seront utilisés par un plus grand nombre d'utilisateurs, car elle pourrait être utilisée sur leur appareil mobile de travail ou même personnel. L'expérience aurait pu être plus solide si elle avait été étendue aux prototypes de services de simulation et aux prototypes de services verbaux, afin de comparer pleinement les CSP et les FAI, et de pouvoir comparer les trois FAI avec trois CSP. Le problème est que cela aurait fait de l'expérience environ deux heures, ce qui aurait été impossible d'en obtenir 100 en un an, car j'ai à peine pu obtenir 100 participants en plus d'un an dans trois campus universitaires, et alors que la durée de l'expérience n'était que d'une heure. Les données étaient riches, mais l'étude a nécessité une période plus longue pour étudier toutes les formes de SP et tous les aspects des impacts des technologies immersives dans plusieurs études de cas.

Les résultats de l'expérience de SP ont été présentés lors d'un atelier industriel, car il n'était pas possible de demander aux employés de mener l'expérience à bien par eux-mêmes, car cela aurait pris plus de temps et aurait coûté cher à l'entreprise. Il a été décidé de ne leur présenter le processus et les résultats de l'expérience que pour avoir une discussion ouverte. En tant qu'observateur et chercheur menant une étude, nous sommes conscients d'une certaine subjectivité, mais nous essayons d'être impartiaux afin que d'autres chercheurs puissent avoir une autre subjectivité et obtenir d'autres résultats. Le principal obstacle à la mise en œuvre de la MRSP à grande échelle est le coût du dispositif, puisque le dispositif MR Hololens coûte entre 3500 et 5000 € selon la version pour laquelle il est acheté. L'utilisation de la MR comporte également d'autres coûts, car il faut compter environ 100 € par mois pour les abonnements aux logiciels et les coûts de développement de la programmation. Il existe plusieurs autres appareils sur le marché, mais ils sont encore en phase de développement et la plupart des organisations souhaitent avoir un partenariat avec une entreprise bien établie, notamment dans ce domaine.

La fiabilité de la recherche signifie si cette recherche peut être transférable à d'autres contextes de services, et si d'autres chercheurs peuvent faire la même étude et aboutir à des résultats similaires (Trochim, 2006). La recherche a été construite avec l'idée de transférer les résultats vers des filières de recherche similaires de prototypage de services. Le modèle et l'instrument de recherche ont été créés pour étudier l'impact des technologies immersives sur différentes formes de prototypes de services. Il s'agit également de comparer les performances des fournisseurs de services Internet et des fournisseurs de services de communication, tout en évaluant l'expérience des utilisateurs et leur acceptation de l'utilisation des technologies immersives dans le prototypage de services. Il existe quatre principales menaces à la fiabilité (Murphy et Davidshofer 1988), à savoir (a) les caractéristiques générales des participants, (b) les caractéristiques spécifiques des participants, (c) les aspects de la situation d'expérimentation et (d) les facteurs de chance. En prenant en considération les erreurs des participants, nous avons conçu l'expérience pour qu'elle soit menée sur différentes séquences de manière à ce que chaque forme de SP soit utilisée dans un cycle avec les autres formes, chacune d'entre elles étant la forme de SP de départ afin d'éliminer tout biais des participants en commençant par la même forme de SP à chaque fois. L'expérience a également été menée à différents moments de la journée, afin d'éliminer toute déviation due à la conduite de l'expérience à un moment spécifique de la journée, où les participants pourraient ne pas être encore frais au début de la journée ou trop fatigués à la fin de la journée. L'expérience a également été menée dans trois campus universitaires différents, deux en France et un en Allemagne, car les participants ont des sexes, des professions, des âges et des parcours différents. Le biais des participants est pris en compte car les évaluations des participants peuvent être trop positives ou trop négatives en raison de l'observation du processus d'évaluation par le chercheur, mais dans cette étude, les participants ont pu donner leur avis sur l'application Jaxber, car ils ont également donné leur évaluation et leur avis sur l'application sur la tablette mobile dans une pièce séparée en tant qu'observateur afin d'éliminer l'effet de biais.

En raison de la proportion d'étudiants et de professionnels dans l'expérience, ce qui pourrait être considéré comme un niveau de biais de connaissance. Le niveau de biais d'expérience est presque éliminé car la plupart de ces participants ne connaissaient pas l'observateur et ne disposaient d'aucune information sur la recherche avant le début de l'expérience. L'erreur du chercheur est basée sur le montage de l'expérience et la qualité des interprétations du chercheur, où le plus grand nombre d'erreurs dans la conception de la recherche pourrait se produire. L'expérience a été conçue pour être menée dans différentes séquences, afin d'éliminer tout biais des participants, et a également été menée sur une période de plus d'un an afin d'éviter toute erreur de la part du chercheur, qui aurait été trop fatigué ou pas assez concentré pendant l'observation de la recherche. Le biais de recherche est basé sur les réponses et les interprétations humaines et, comme nous faisons tous des erreurs, il est difficile d'éliminer toutes les erreurs humaines de la recherche, car les erreurs de mesure agissent comme des variables aléatoires sur un grand nombre d'individus (Murphy et Davidshofer 1988). Les résultats de la recherche ont été à la fois mesurés en fonction des évaluations des participants et de la mesure de l'efficacité, et évalués en fonction des commentaires que les participants ont laissés dans chacune de ces évaluations ; ce qui conduit à interpréter tous les résultats ensemble pour créer une image complète des résultats de la recherche. La collecte des données expérimentales a été effectuée à l'aide d'une application, ce qui a permis de combiner plus facilement les aspects subjectifs et objectifs de la recherche, puisque le chercheur doit évaluer les résultats de manière subjective mais neutre pour expliquer pourquoi ces résultats sont fiables et pourraient être transférés dans d'autres volets de recherche. La recherche a été soigneusement conçue pour éliminer les quatre menaces à la fiabilité mentionnées ci-dessus, comme expliqué précédemment, car ces quatre erreurs ne se sont pas produites dans cette étude.

La fiabilité de l'instrument concerne son utilisation dans d'autres contextes ou recherches. L'instrument de recherche est basé sur un instrument de recherche réel utilisé auparavant dans d'autres expériences (Pallot et al., 2017 ; Dupont et al., 2017 ; Krawczyk et al., 2017 ; Topolewski et al. 2019), car il a été démontré que le modèle et l'instrument sont utilisés dans des technologies immersives et des recherches sur l'expérience utilisateur similaires. L'expérience a été menée sur trois campus différents, et en quatre cycles différents sur une période d'un an. L'instrument de recherche a été utilisé pour évaluer les cinq différentes formes de SP dans l'expérience, car il a montré une performance et un classement cohérents dans toutes les formes, et a également montré un retour positif des participants, ce qui montre la fiabilité de l'instrument en forme parallèle. On parle de cohérence interne lorsque des propriétés mesurant les mêmes constructions présentent les mêmes tendances, ce qui ressort de l'analyse statistique et des évaluations de l'instrument par les participants (Cortina, 1993). Si une expérience fiable peut fournir des informations utiles et valables sur l'application, une expérience qui n'est pas fiable ne peut cependant pas être valable (Murphy et Davidshofer, 1988).

La validité conceptuelle de la recherche, c'est lorsque nous clarifions si la recherche mesure ce qu'elle prétend mesurer (Brown, 1996 ; Polit et Beck, 2008), ce qui permet de discuter de la validité conceptuelle, interne, externe et pragmatique de cette étude. Nous avons choisi ce type de recherche car aucune autre enquête similaire comparant plusieurs prototypes de services immersifs et conventionnels n'a été trouvée. Comme le sujet de recherche est nouveau, nous avons décidé d'utiliser une approche de méthodes mixtes afin d'avoir non seulement les résultats des évaluations quantitatives mais aussi les explications qualitatives de ces résultats, et l'interprétation sur les résultats globaux. La stratégie de recherche consistait à créer un cadre, un modèle et un instrument, et à viser à valider les hypothèses par la conduite d'une expérience comparative. L'expérience a été créée pour inclure l'expérience d'immersion, l'expérience de l'utilisateur, l'expérience de prototypage de services et l'intention de l'utilisateur d'adopter, où la triangulation des évaluations des participants, du retour d'information et des résultats des performances conduisent toutes aux mêmes conclusions. L'expérience a été menée dans un cadre académique ; elle est donc valable dans le même contexte académique ; elle peut également être valable dans le contexte de l'apprentissage industriel ou de la formation car les participants auront la même attitude envers l'apprentissage que dans un cadre académique. Je voulais étudier l'impact des technologies immersives sur le prototypage de services, car personne d'autre ne le faisait en tant qu'investigation. Nous avons donc décidé d'étudier en utilisant des méthodes mixtes, car cela nous permettrait de connaître l'impact en termes de performance, d'expérience et d'acceptation, ainsi que la raison qui sous-tend cette démarche. Validité interne du modèle, analyse statistique, quels sont les liens occasionnels entre les variables (Liebert et Neale, 1973), ce qui est considéré comme la relation entre les constructions dépendantes (IX, RWD, SPE, SPX, ItA) et indépendantes (PX, EX, CX). L'hypothèse selon laquelle il existe une relation entre ces constructions est basée sur le fait qu'elle a été utilisée dans d'autres études similaires, et sur le travail d'un des directeurs de thèse. En raison de l'absence d'indicateurs réfléchis ou d'un élément global, nous n'avons pas effectué d'"analyse de redondance", mais nous avons comparé les charges et les charges croisées. Nous nous attendions à ce que les charges soient plus importantes que les charges croisées, car nous nous attendons à ce que les éléments se chargent plus fortement sur leur construction respective que sur toute autre construction, de sorte que la convergence des éléments est suffisante.

Cette expérience a été menée en utilisant un échantillon de la population universitaire, de sorte qu'une réplication dans un environnement universitaire pourrait probablement obtenir les mêmes résultats, mais comme pour une réplication industrielle 1:1, la fidélité et la résolution du prototype pourraient avoir des limites, ce qui pourrait offrir une facilité d'utilisation limitée pour les professionnels. Les résultats de l'expérience peuvent être généralisés dans les milieux universitaires et, dans le cas d'une utilisation industrielle, uniquement dans un cadre d'orientation pédagogique et d'apprentissage. Les participants à l'expérience étaient tous des volontaires, il n'y avait donc pas de critères de sélection car un groupe aléatoire de participants volontaires a participé à l'expérience, ce que montrent les résultats démographiques des participants. La taille de l'échantillon des 103 participants à l'expérience SP (n=103) était représentative, car l'expérience a été menée dans trois endroits différents, avec trois groupes cibles différents, des ingénieurs, des technologues et des étudiants en informatique et même certains professionnels de ces domaines ont également participé à l'expérience. Le Conseil national de la recherche indique qu'un modèle ne peut être validé que par rapport à un domaine d'application donné, un modèle valable pour une application pouvant être invalidé pour d'autres applications (Conseil national de la recherche, 2012). Par conséquent, les résultats de l'étude sont valables pour le prototypage de maintenance et pour les services industriels basés sur l'apprentissage, les résultats peuvent être valables pour d'autres applications mais ils n'ont pas été validés ni testés. La principale question de recherche est d'étudier les impacts de l'utilisation des technologies immersives dans le prototypage de services, ce qui divise l'étude pour mesurer les impacts de l'immersivité sur la dissociation du monde réel, l'expérience du prototypage de services et l'efficacité. Nos hypothèses étaient que plus le degré d'immersivité est élevé, plus la dissociation par rapport au monde réel, le SPX et l'efficacité sont élevés. Les résultats des résultats quantitatifs et qualitatifs montrent que le SPX est positivement influencé par le IX, et que le IX influence également l'efficacité, l'acceptation et la dissociation du monde réel de différentes manières, selon le degré d'immersion et d'interactivité. Cela permet également de vérifier l'instrument de recherche qui permet d'évaluer les aspects d'expérience, d'efficacité et de dissociation du monde réel pendant les expériences. L'instrument peut être réutilisé dans l'expérience où d'autres formes de SP sont comparées les unes aux autres.

Les résultats de l'étude sont solides, car ils montrent non seulement les impacts en termes de performances, mais aussi l'expérience des utilisateurs et les aspects liés à l'acceptation. Les technologies immersives ont eu un impact positif sur le prototypage des services, en améliorant l'efficacité, en améliorant l'expérience et en obtenant un meilleur taux d'acceptation par les utilisateurs. Le MRSP a été le plus efficace et le plus performant, et aussi le plus élevé en termes d'expérience de l'utilisateur et de taux d'acceptation, mais les autres formes de SP ont également eu leurs avantages et leurs inconvénients. L'efficacité du MSP était étonnamment élevée, et même le PSP, car les participants étaient les plus négatifs et leurs réactions et sentiments étaient également négatifs, mais ils ont réussi à accomplir la tâche avec moins d'erreurs que les autres formulaires, à l'exception du MRSP. Les plus jeunes participants étaient vraiment ennuyés par le fait qu'ils devaient lire une seule feuille de papier ou qu'ils devaient regarder deux vidéos d'une durée combinée de trois minutes, ce qui montre que plus le participant était jeune, plus sa capacité d'attention était réduite. Certains des participants plus âgés étaient plus ennuyés par les technologies immersives en raison de leur cyber-maladie, ou parce qu'ils estimaient que c'était "exagéré" ou "inutile", mais la majorité avait un sentiment positif et pour la plupart d'entre eux c'était la première fois qu'ils essayaient une technologie immersive. Certaines des différences de performances et de notations entre les sexes et les professions ne peuvent pas être expliquées par une simple analyse des données, une étude plus large est nécessaire pour étudier ces différences en profondeur.

L'attitude des participants à l'expérience a également été une indication sur le succès de chacune des formes de PS. Les participants ont eu un comportement plus heureux en utilisant le SP que lorsqu'ils utilisaient le CSP. Les participants utilisant la MRSP étaient les plus heureux (83%), suivis par la VRSP (63%) et ensuite par l'ARSP (40%). Cela indique que les participants sont plus heureux lorsqu'ils utilisent et appliquent n'importe quel formulaire ISP, et qu'ils préféreraient l'utiliser plutôt que la CSP s'ils ont le choix. Le pourcentage de participants frustrés utilisant la PSP (4 %) était étonnamment plus faible que celui de la MSP (6 %) et même de l'ARSP (4 %) et de la MR SP (7 %). Cela pourrait indiquer que la PSP a besoin de moins de temps pour s'adapter car le papier est une méthode d'apprentissage établie, et lorsque les nouvelles technologies sont utilisées, certains pourraient se sentir mal à l'aise en les utilisant. Les participants qui utilisent la RVS ont été les moins frustrés (3%), ce qui pourrait être dû au fait que l'environnement de VR est très amusant et donne une grande expérience. Certains participants ont également été confrontés à un certain malaise cybernétique lors de l'utilisation de la VR et de la RM, ce qui pourrait également expliquer le pourcentage de pourcentage de frustration. Les participants utilisant la VR étaient également frustrés par le fait qu'ils devaient ajuster l'appareil mobile de VR pour pouvoir voire les étapes nécessaires et certains n'avaient pas la formation appropriée pour utiliser la VR.

Notre analyse statistique confirme l'effet de l'immersion sur la RWD et la SPX, mais l'effet de l'immersion sur la SPX est considérablement plus fort que l'effet sur la RWD, et les directions des relations pour tous les concepts, qui sont les signes des coefficients, sont positives comme prévu. L'analyse statistique a également montré que la RWD est affectée par des facteurs différents de l'immersivité car elle n'explique que certaines parties de la RWD, et l'analyse des données a également montré que l'effet de l'immersivité sur la SPE est confirmé. Les notes globales de l'enquête sur l'expérience sont constituées des notes de construction de chacun des formulaires de la SP utilisés pour l'ensemble des 103 participants à l'expérience. Le chemin le plus significatif est celui de la SPE à la SPX à l'ItA, ce qui explique également que l'efficacité du prototype est directement liée à l’expérience et également liée à l'intention d'accepter et d'adopter un prototype.

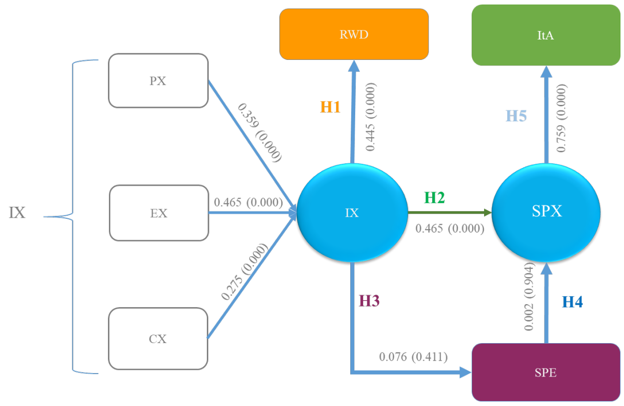

Fig.14 Prototypage de services Constructions et modèles

La première hypothèse propose que plus le degré d'immersivité est élevé, plus la dissociation du monde réel est importante. Il a été démontré que l'impact du IX sur la RWD est positif et significatif, ce qui soutient l'hypothèse de recherche H1. Cette hypothèse est confirmée par le fait que les acteurs seront plus immergés, alors que leur sens du temps, leur environnement et les facteurs externes diminueront avec l'augmentation de l'immersivité. La deuxième hypothèse propose que plus le degré d'immersion est élevé, meilleure est l'expérience du prototype de service. Les hypothèses de recherche sur les prédécesseurs et leur importance, selon lesquelles IX est le prédécesseur de SPX, sont confirmées puisque dans le modèle valide, cette voie est significative. Cela signifie que les parties prenantes disposeront d'un SPX plus satisfaisant qui augmentera les chances de les convaincre de l'adopter, ou de le réutiliser, et même de le recommander à d'autres. La troisième hypothèse propose que plus le degré d'immersivité est élevé, plus le processus de prototypage de services est efficace. Il convient d'ajouter que IX a un impact plutôt faible sur la RWD depuis le coefficient de détermination, mais qu'il affecte néanmoins positivement la SPE avec un coefficient de détermination élevé qui soutient cette hypothèse. Cela indique que le SPE aura un impact positif sur l'efficacité du prototype. La quatrième hypothèse qui propose que plus l'efficacité du processus de prototypage du service est élevée, meilleure est l’expérience du prototype du service. Compte tenu des hypothèses de recherche sur les prédécesseurs et leur importance, les SPE sont les prédécesseurs des SPX sont soutenus puisque dans le modèle valide, cette voie est significative. Cela signifie que le participant appréciera davantage le processus de prototypage de services s'il réussit mieux à accomplir la tâche sans aide ni erreur et dans la durée la plus courte possible. La cinquième hypothèse qui propose que plus l'expérience du prototype de service est bonne, plus le degré d'acceptation et d'adoption par les parties prenantes est élevé. IX a également un effet positif sur la SPE, ici avec un coefficient de détermination élevé, ce qui soutient cette hypothèse de recherche. Cela montre que comme le SPX a un impact positif sur la conviction des parties prenantes d'adopter, de vouloir réutiliser, et sur le degré de recommandations aux autres.

Les participants semblent avoir évalué le concept d'immersion MRSP, VRSP et ARSP, qui consiste en une immersion perceptive, émotionnelle et cognitive, avec la note la plus élevée par rapport à toutes les autres formes de PS, ce qui confirme notre hypothèse selon laquelle il existe des prototypes de services immersifs offrant une expérience perceptive, émotionnelle et cognitive plus élevée que les expériences conventionnelles. Plus l'immersivité est élevée, plus la dissociation du monde réel est importante, comme dans le cas des VRSP, ce qui confirme notre première hypothèse selon laquelle plus le IX est élevé, plus le RWD est élevé. La deuxième hypothèse était que plus l'immersion est élevée, plus l'expérience de prototypage de services est élevée, ce qui est confirmé dans les cas de MRSP, VRSP et ARSP, car ils ont des indices IX et SPX plus élevés que les PSP et MSP. La troisième hypothèse concernait l'expérience de prototypage de services, où nous avons supposé que plus l'immersion était grande, plus l'efficacité était élevée. Cela a pu être confirmé car le SPX de la MRSP avait la note d'expérience la plus élevée, suivie par la VRSP. Cela montre que le MR a offert la plus grande expérience aux participants, qui a également le taux d'immersion le plus élevé. La quatrième hypothèse est que plus l'efficacité du prototype de service est élevée, plus l'expérience du prototype de service est satisfaisante, ce qui pourrait être confirmé également dans le cas de la MRSP, puisque ses cotes SPE et SPX sont les plus élevées.

Les participants de chaque lieu se sont comportés différemment selon les différentes formes de PS, cela pourrait être dû au fait que chaque lieu d'expérimentation était situé sur le campus d'une université ou d'un institut académique, où les participants volontaires sont issus de milieux différents mais de formations similaires. C'était inattendu, mais comme il a été constaté que le campus qui se concentre davantage sur les technologies immersives a évalué les technologies d'une manière plus critique et a donné un retour d'information étendu, mais beaucoup d'entre eux étaient plus intéressés par la technologie que par l'application ou dans ce cas par l'idée de prototypage elle-même. Alors que les autres campus qui se concentrent davantage sur l'ingénierie, les technologies de l'information et les solutions industrielles ont donné des notes et des commentaires qui varient entre positifs et peu négatifs. Les quelques participants qui étaient ouvertement négatifs tout en étant pessimistes sur la technologie et le processus ; et les autres qui étaient positifs sur la technologie et le processus et comprenaient l'avantage du prototypage et de l'application des technologies immersives et avaient même quelques idées constructives d'extensions ou de nouvelles façons d'explorer. Cela s'est également reflété dans les résultats, puisque les participants des campus les plus techniques ont obtenu de meilleurs résultats en termes d'efficacité et d'efficience, tout en attribuant à la CSP une note plus élevée qu'au campus basé sur la technologie immersive. Ces métamorphoses du parcours éducatif et de l'expérience dans l'expérience étaient attendues, mais pas autant que ce qui a été remarqué dans la comparaison entre les performances des campus et les résultats de l'évaluation. Cela montre que l'expérience et le parcours peuvent être un facteur non seulement dans l'utilisation des technologies immersives, mais aussi dans son degré d'adoption.

Tab. 20 Avantages et inconvénients de la SP immersive

Avantages	**désavantages**
Efficacité (durée d'exécution des tâches plus rapide de la part de l'ISP)	Cyber-maladie (surtout lors de l'utilisation de DMH VR et moins lors de l'utilisation de MR Hololens)
Efficacité (moins d'erreurs et de demandes d'explications dans les PSI)	Coûts plus élevés (coûts du HMD, coûts d'Hololens, coûts des logiciels)
Expérience électronique plus satisfaisante (note SPX plus élevée chez les FAI)	Processus initial d'adaptation et d'apprentissage (les débutants peuvent trouver difficile d'utiliser la VR et la AR sans formation)
Acceptation et adoption plus élevées (les notes moyennes de l'ItA des fournisseurs de services Internet sont beaucoup plus élevées que celles des fournisseurs de services de communication)	Le rapport avantages-coûts doit avoir un sens pour les cadres supérieurs (Discussion du groupe de discussion industriel)
Processus de formation et d'apprentissage sans risque (Commentaires et réactions de l'expérience SP)	
Facilite la compréhension (Commentaires de l'expérience SP)	
Une meilleure façon de collaborer, d'explorer et d'évaluer les idées de services (discussion en groupe industriel)	

La structure des impacts XR s'inspire des travaux de Medlej et al. Sur les avantages des prototypes (2017). L'adaptation initiale aux technologies XR pourrait être difficile au début, car elle nécessite une sorte d'introduction à la technologie et un effort pour apprendre comment développer, mettre en œuvre, appliquer et même utiliser. Le rapport coût-bénéfice pourrait être un problème en raison des coûts plus élevés, car il y a des coûts initiaux, de dispositifs, de technologie et de formation associés à la XR. Cependant, tous les contacts personnels avec les entreprises industrielles ont permis de constater que ces dernières reconnaissent les avantages de l'utilisation de la XR dans leurs processus, en particulier dans le secteur des services. La tendance à choisir et à utiliser les rayons XR dans la représentation et l'expérience du service a également été observée.

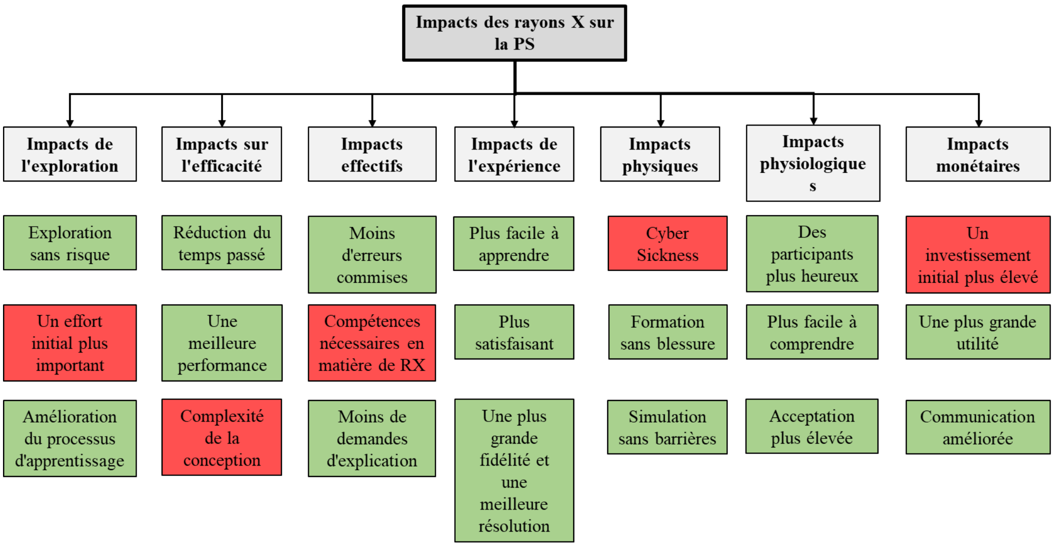

Fig. 15 Les impacts de la XR sur les SP

Les avantages potentiels de l'utilisation des rayons XR dans le prototypage de services dans un contexte industriel peuvent être résumés comme suit : (1) améliorer l'exploration des idées de service avec les parties prenantes, (2) améliorer la capacité à évaluer les idées de service grâce à une expérience améliorée, (3) étendre les moyens de communication entre les parties prenantes pour améliorer la visibilité et la compréhension, (4) formation sans risque pour les parties prenantes internes au service avant même que le service n'existe réellement, (5) utiliser le service pour améliorer le processus d'apprentissage et augmenter l'absorption des connaissances, et (6) créer une meilleure façon de collaborer à l'exploration, l'évaluation et la communication de nouvelles idées de service. Il y avait également plusieurs inconvénients : (1) un effort initial plus important pour créer le domaine de la XR, la simulation ou l'animation, (2) l'utilisation de la XR augmente également la complexité de la conception, ce qui peut rendre le processus de développement du service plus long, (3) des connaissances et des compétences en XR sont nécessaires pour développer et utiliser des prototypes de service XR, (4) le cyberespace peut toucher peu d'utilisateurs lors de l'utilisation d'un dispositif XR, et (5) l'investissement initial dans les dispositifs, le matériel et les logiciels peut être élevé par rapport aux méthodes conventionnelles. Ces recherches peuvent servir de guide pour de futures applications industrielles, pour la sélection de formes de SP en fonction des différents attributs.

Cette étude et ses résultats pourraient être comparés à d'autres études de PS, ainsi qu'à des études d'assemblage immersif. Les études SP ont couvert de multiples facettes du prototypage de services. (1) explorer les définitions du prototypage de services (Blomkvist et Holmlid, 2010), (2) améliorer les processus de service (Oh et al., 2013 ; Fukuhara et al., 2014), (3) tester les systèmes produits-services (Exner et al., 2014), (4) l'utiliser dans une simulation de VR (Kwon et al, 2015), (5) expérimentation d'un guide d'assemblage de la AR (Bode, 2019), (6) test des processus de service (Peng et al., 2017), (7) évaluation des prototypes de service en utilisant des procédures pas à pas (Arvola et al., 2012 ; Boletsis et al., 2017), (8) influence du changement transformationnel (Kuure et al., 2014 ; Boletsis, 2018), et (9) utilisation du prototypage de service pour une application mobile de AR (Satti et al., 2019). Les études trouvées dans la littérature varient entre les études quantitatives et les études qualitatives, alors que la plupart des études trouvées sont qualitatives. Les études de prototypage de services immersifs dans lesquelles les auteurs comparent différentes formes de prototypage ont également été trouvées récemment (Satti et al., 2019 ; Bode, 2019), mais aucune étude comparant 5 formes différentes de SP entre elles n'a été trouvée. De même, aucune étude n'a été trouvée utilisant des méthodes mixtes pour vérifier leurs résultats, et expliquer leurs résultats quantitatifs, ou pour valider leurs résultats qualitatifs. La majorité des autres résultats de recherche suggèrent que les systèmes de guidage basés sur la AR sont excellents et seraient acceptés par les nouveaux utilisateurs dans l'industrie, ce qui confirme également notre connaissance de l'acceptation par l'industrie telle que vue dans l'interview du groupe de discussion ou l'acceptation par les professionnels dans l'expérience. Hoover et ses collaborateurs (2020) ont comparé le temps de réalisation, le nombre d'erreurs et le score du guide d'assemblage Hololens MR avec les instructions AR de bureau, de tablette et de tablette, où l'utilisation du MR a permis un gain de temps de 16% par rapport à l'AR de tablette, et a également eu un taux d'erreur plus faible. Ces résultats semblent également confirmer nos résultats, mais le gain de temps réalisé par la MRSP par rapport à l'ARSP n'était que de 3 %. Wang et ses collègues (2020) ont examiné l'impact des instructions d'assemblage de l'AR, et ils ont constaté que les instructions de l'AR ont une forte stimulation visuelle qui se traduit par une plus longue durée d'attention liée à la tâche, et augmente l'efficacité et la qualité de l'information.

Cette étude diffère des autres études car elle utilise à la fois les méthodes de recherche qualitatives et quantitatives, comme toutes les autres études similaires qui utilisent des méthodes qualitatives ou quantitatives. Les résultats quantitatifs de l'expérience sont statistiquement valables car elle a été menée avec plus de 100 participants, en comparaison avec les cas d'utilisation quantitative trouvés dans la littérature qui ont eu beaucoup moins de participants. Cette étude a été la première à comparer cinq formes différentes de prototypes de services, ainsi qu'une expérience de référence pour comparer non seulement les performances en termes d'efficacité et d'efficience, mais aussi le facteur d'immersion, l'expérience de l'utilisateur et l'acceptation de l'utilisateur. L'étude a également une application industrielle et sera utilisée comme guide pour de futures expérimentations industrielles. Nous avons eu plusieurs discussions avec des chercheurs universitaires qui s'intéressaient à nos recherches, et nous avons également eu plusieurs ateliers et discussions industriels, qui reflétaient l'intérêt industriel pour le prototypage de services. Nous avons également été invités à publier plusieurs chapitres dans des ouvrages universitaires axés sur les services, et nous avons publié un nouvel ouvrage sur le prototypage de services multidimensionnels. Nous avons également publié plusieurs articles de conférence et de revue, qui ont eu un succès relatif en raison du nombre de lectures et de citations. Nous pensons que la recherche sur les aspects et l'application du prototypage de services est encore en phase de croissance.

Nous avons identifié plusieurs domaines de recherche de prototypage de services qui sont pertinents pour notre recherche. Ces domaines pourraient être décrits par cinq domaines de prototypage de services, (1) optimisation des processus, (2) amélioration de la conception, (3) méthodologie, (4) formation, et (5) comparaisons. Ces domaines de recherche SP susmentionnés sont présentés dans l'onglet. (5.8) ci-dessus avec les publications les plus pertinentes dans chacun des domaines. Cette étude vient compléter la littérature car elle est la seule à avoir utilisé une approche de recherche à la fois quantitative et qualitative des méthodes de mixage, et à utiliser une expérience comparative avec plus de 100 participants pour valider le modèle proposé. Les résultats se confirment avec la littérature trouvée, car toutes les études qualitatives et quantitatives sont arrivées à des conclusions et des résultats similaires. L'étude a également été la première à comparer cinq formes différentes de SP en ce qui concerne les performances, l'expérience, l'intention d'accepter et d'adopter, et l'attitude des utilisateurs. L'étude a également ajouté à l'ensemble des connaissances de nouvelles définitions (voir le tableau 2.15 pour les définitions complètes).

L'étude caractérise également les prototypes de services sous deux formes : Prototypes de services conventionnels (CSP), Prototypes de services immersifs (ISP). Les résultats de l'étude indiquent que les formes de SP ont un impact sur les attributs, les objectifs et les activités des PS, ce qui peut être constaté dans les effets sur les attributs suivants. (1) En ce qui concerne l'attribut de fidélité, les CSP ont tendance à avoir un niveau de fidélité faible à moyen, tandis que les ISP ont un niveau de fidélité élevé à très élevé. Cela indique que le FAI pourrait fournir un niveau de détail et de fonctionnalité plus élevé pour le service intégré dans le prototype. (2) En ce qui concerne la résolution, les CSP ont tendance à avoir un niveau de résolution faible à moyen, tandis que les ISP ont tendance à avoir un niveau de résolution élevé à très élevé. Cela indique que les FAI offriront un degré de ressemblance plus élevé entre le prototype et la conception finale du service. (3) En ce qui concerne l'effort, le niveau d'effort des CSP est généralement faible à moyen, tandis que celui des ISP est élevé à très élevé. Cela montre que les ISP utilisent plus de ressources organisationnelles pour achever, explorer et mettre en œuvre le prototype que les CSP. (4) En ce qui concerne l'interactivité, les fournisseurs de services de communications électroniques ont tendance à avoir un niveau d'interactivité faible à moyen, tandis que les fournisseurs de services Internet ont un niveau d'interactivité élevé à très élevé. Cela indique que les ISP ont un degré plus élevé d'interaction avec le prototype, plus libre et plus fluide pour l'utilisateur. (5) En ce qui concerne l'attribut UX, le CSP a tendance à avoir un niveau d'UX faible à moyen, tandis que le ISP a un niveau d'UX élevé à très élevé : cela indique que le ISP offre une expérience perceptuelle, émotionnelle et cognitive plus élevée que le CSP, et a également un niveau de réponse plus élevé à l'utilisation prévue d'un prototype.

Les participants de l'atelier industriel et du groupe de discussion étaient également intéressés par l'apprentissage du prototypage de services et de ses applications dans leurs projets correspondants. Les questions posées portaient sur la manière d'utiliser le prototypage de services pour développer des prototypes de services, introduire de nouveaux services sur de nouveaux marchés et appliquer le prototypage de services à des concepts de formation. Ils souhaitaient également obtenir davantage de conseils sur l'application et l'utilisation des technologies immersives dans leur projet de service, en particulier sur les preuves et les raisons de leur utilisation. Une autre grande partie de leurs questions portait sur les coûts, qu'il s'agisse des coûts initiaux du matériel, des logiciels et de la formation. Les participants ont également indiqué que le degré d'adoption des technologies de prototypage de services et des technologies immersives était plus élevé après l'atelier industriel et la discussion en groupe. Les commentaires des participants (voir tableau 4.37) ont également permis de mieux comprendre l'intérêt des organisations industrielles et leur degré d'acceptation du prototypage de services et des technologies immersives. Comme il y a des effets différents pour chacune des formes de SP, il existe une forme qui convient le mieux à chaque objectif et activité de service, mais aussi en fonction des exigences, des besoins et des attributs de chaque organisation. L'étude a mis en lumière les effets du rayonnement X sur l'application industrielle du prototypage de services, notamment de : (1) les impacts de l'exploration (exploration sans risque, processus d'apprentissage amélioré, meilleure collaboration), (2) les impacts de l'efficacité (durées plus rapides, utilité plus élevée, meilleure performance), (3) les impacts de l'efficacité (moins d'erreurs, moins de demandes d'explication), (4) les impacts de l'expérience (meilleur apprentissage, plus satisfaisant, meilleure acceptation), (4) les impacts physiques (cyber-maladie, formation sans blessure), (5) les impacts physiologiques (participants plus heureux, plus faciles à comprendre), et (6) les impacts monétaires (coût d'investissement plus élevé, utilité plus élevée sur le long terme, coûts de formation).

Les impacts sur les pratiques de travail pourraient être résumés en (1) l'utilisation du prototypage de service soutient le processus de développement du service et les résultats de l'étude ajoutent aux connaissances pour la sélection et l'utilisation des formes de prototypes de service, (2) il est important de savoir quand mettre en œuvre quelle forme de prototype de service car les processus de prototypage de service immersif peuvent nécessiter plus de ressources organisationnelles mais ils produisent également une meilleure représentation du futur service, (3) selon le but organisationnel et l'objectif, différentes formes de prototypes de services doivent être mises en œuvre en ce qui concerne la fidélité, la résolution et l'effort nécessaires, (4) l'exploration des idées de services avec les parties prenantes est essentielle dans le processus de développement des services, et en utilisant les ISP, les parties prenantes peuvent avoir une meilleure expérience, (5) la SP soutient l'exploration, l'évaluation et la communication des idées de services ; par l'utilisation du processus de prototypage de service au lieu de simplement en apprendre sur lui dans les processus traditionnels de conception de service, (6) la communication des concepts de service aux parties prenantes internes peut être grandement améliorée par l'utilisation du prototypage de service car ils peuvent être intégrés dans la formation au service avant même que le service n'existe, et (7) les résultats ont montré que l'utilisation du ISP dans le processus d'assemblage, que ce soit dans la formation avant l'orientation de l'assemblage ou l'apprentissage par la pratique sur le terrain, est bénéfique.

L'objectif de cette étude a été atteint en évaluant l'impact des technologies immersives, plus particulièrement les technologies XR (VR, AR et MR) sur la SP. Les objectifs de recherche ont été abordés ainsi que les questions de recherche. La revue de la littérature a révélé le manque d'études empiriques sur la SP et aussi sur la comparaison de la SP et de la SP ainsi que du modèle. En ce qui concerne les conclusions, les résultats de l'enquête UX révèlent, sans surprise, que les participants préfèrent les formes d'ISP plutôt que les formes de CSP, ce qui confirme notre attente. En outre, les résultats confirment également que l'utilisation de technologies immersives telles que la cybersanté ne peut pas être ignorée et négligée. Les résultats révèlent également que la solution la plus appropriée pourrait consister à combiner deux, ou éventuellement plusieurs, formes de SP en fonction de la complexité et de la stratégie du service, étant donné que les ISP et les CSP offrent des avantages différents tout en apportant certains inconvénients inévitables et des coûts et résultats différents. Néanmoins, il semble qu'en raison des coûts d'investissement, les formes de CSP pourraient être plus appropriées pour le stade précoce de la co-création de services lors de la description d'une nouvelle idée de service. Cependant, si l'investissement initial est déjà budgété pour un autre service et que les appareils à rayons XR sont là, alors la co-création par l'utilisation d'un fournisseur de services Internet pourrait susciter des idées plus nombreuses et meilleures et un retour d'information de la part des parties prenantes du service. Dans l'idéal, les formes de ISP pourraient être considérées comme plus appropriées pour les étapes ultérieures de services moins complexes ou au début pour les services plus complexes qui nécessitent un prototypage multidimensionnel.

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Au-delà des résultats, on pourrait conclure que la meilleure approche pourrait être une combinaison des deux formes de CSP et de ISP pour le processus de prototypage et de développement de services car elle ajoute de nombreux éléments bénéfiques, comme une meilleure expérience, une meilleure compréhension et un plus haut degré d'acceptation, au processus. D'une part, les CSP pourraient être plus appropriés pour des scénarios de services non complexes ou de courte durée afin d'économiser du temps et de l'argent dans le processus de prototypage. D'autre part, il est certain que les FSI nécessitent un investissement financier important pour l'achat de l'équipement immersif nécessaire et un effort personnel pour la mise en œuvre des solutions de prototypage immersif alors qu'elles sont plus appropriées pour les processus de service multidimensionnels. D'autres études récentes démontrent également l'intérêt de l'industrie des services, les ISP commençant à être utilisés dans plusieurs organisations industrielles et manufacturières, car ils apportent de nombreux avantages aux parties prenantes des services : (1) anticiper le degré de satisfaction des utilisateurs du service alors que celui-ci n'existe pas encore ; (2) évaluer les performances du service ; (3) identifier les inconvénients potentiels du service ; (4) obtenir davantage de retours d'information de la part des parties prenantes au service et contribuer par des idées d'amélioration. De toute évidence, il est probable que les CSP seront utilisés dès le début pour présenter grossièrement un nouveau service, en combinaison avec les ISP utilisés pour expérimenter l'ensemble du scénario du service avant même qu'il n'existe, optimiser le processus du service et évaluer les interactions avec les utilisateurs. En bref, la capacité à prévoir les besoins, l'expérience et les résultats d'un nouveau scénario de service avant qu'il ne soit créé ou mis en œuvre est essentielle pour créer la meilleure expérience de service possible. L'aspect le plus important dans la sélection de la forme de SP la plus appropriée à la tâche est qu'elle doit être adaptée à l'objectif et à l'activité fixés par les parties prenantes du service et aux niveaux de fidélité, de résolution et d'effort appropriés.

Cette thèse pourrait servir de guide pour aider les chercheurs et les concepteurs de services à choisir la forme de prototypage des services pour leurs processus de communication de services. Ce travail pourrait être considéré comme une étude exploratoire, car il s'agit de la première étude à comparer plusieurs prototypes conventionnels et immersifs tout en utilisant une approche mixte de méthodes de recherche qualitatives et quantitatives. Cette étude représente également l'état de l'art dans la recherche sur les prototypes de services conventionnels et immersifs. L'étape suivante consiste à poursuivre la recherche sur les applications industrielles du prototypage de services et à continuer à explorer de nouvelles applications industrielles. Notre objectif futur est d'introduire et de familiariser le prototypage de services à un large éventail d'organisations industrielles, où il sera appliqué dans la création de services réels tandis qu'il pourrait être étudié pour un développement ultérieur. Le travail sur le prototypage de services se poursuit également dans le cadre de mon rôle actuel au sein du centre de compétence en matière de services de l'université de Furtwangen, puisque le projet est financé par le ministère de la recherche et de l'éducation de Bade Württemberg. La recherche consiste à interagir avec les PME industrielles de la région pour les aider à innover dans leurs offres de services et leur faire découvrir les avantages du prototypage de services, en particulier ceux qui sont immersifs. Ce travail se poursuit également dans le sens d'applications industrielles, car l'accent sera davantage mis sur la mise en œuvre et moins sur la théorie. La recherche sur l'application du prototypage de services pour le développement de services industriels montre de plus en plus l'intérêt et l'acceptation de l'industrie. Le prototypage de services est un processus nouveau qui a pour but de créer une expérience d'un service avant qu'il n'existe, ce qui ouvre de nombreuses possibilités pour le développement de services. Le processus de Co-création du prototypage de services permet aux concepteurs de services, aux opérateurs de services et aux clients de se réunir et de travailler ensemble pour trouver la méthode la plus appropriée pour fournir le service.

Appendix 2: PhD Related Publications

Publication	Authors	Conference
Innovation by Service Prototyping	Abdul Rahman Abdel Razek, Christian van Husen, Marc Pallot, Simon Richir	ICE IEEE 2017 Madeira, Portugal
Introduction to a Service Prototyping Tool Box	Abdul Rahman Abdel Razek, Christian van Husen, Saed Imran	ICServ 2017 Vienna, Austria
A Comparative Study on Conventional versus Immersive Service Prototyping (VR, AR, MR)	Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir	VRIC 2018 Laval, France
A Proposed Research Model for Service Prototyping	Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir	ICE IEEE 2018 Stuttgart, Germany
Comparing Conventional versus Immersive Service Prototypes An Empirical Study	Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir	Laval Virtual 2019, Laval France
Comparing Different Performance Factors of Conventional VS Immersive Service Prototypes	Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir	ICE IEEE 2019, Sophia Antipolis, France
Extension on Comparing Conventional versus Immersive Service Prototypes An Empirical Study	Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir	IJVR Journal 2019 (2) Special Issue - Best Papers of Virtual Reality International Conference (VRIC'19)

Appendix 3: Secondary Publications

Publication	Authors	Conference / Publisher
Innovation in Prototyping for Technical Product- Service Systems	Miriam Sämann, Abdul Rahman Abdel Razek, Saed Imran, Christian van Husen and Carsten Droll	ICE IEEE 2016 Trondheim, Norway
A Coherent Set of Customer Experience Factors for the Developers of Industrial Product Services	Carsten Droll, Saed Imran, Miriam Sämann, Christian van Husen, Dieter Haeberle, Abdul Rahman Abdel Razek	Reser 2016, Naples, Italy
An Approach for Enhancing the Value of Industrial Service Prototyping	Saed Imran, Martin Raban, Christian van Husen, Abdul Rahman Abdel Razek	Reser 2018, Gothenburg, Sweden
Service Prototyping: Design Dimensions	Abdul Rahman Abdel Razek, Martin Raban, Christian van Husen	Digivation 2018 Aachen, Germany
The development of Co-Creative Services by Service Prototyping	Christian van Husen, Abdul Rahman Abdel Razek, Martin Raban, Saed Imran	*Cooperative services - areas of tension between service cooperation and cooperation* Book Chapter 4, Springer Gabler 2019
Service Prototyping: Design Dimensions	Abdul Rahman Abdel Razek, Martin Raban, Christian van Husen	*Digital service innovation - develop smart services in an agile and customer-oriented manner* Book, Chapter 5, Springer Gabler 2019
Multidimensionales Service Prototyping - dimenSion	Alexander Hengels, Christian van Husen, Abdul Rahman Abdel Razek	ERP Management 1/2019, ISSN 1860-6725
From the process model to the digitally tangible prototype pay-per-use concept for a packaging system	Christian van Husen, Abdul Rahman Abdel Razek	In Automatisierung und Personalisierung von Dienstleistungen (pp. 389-412). Springer Gabler, Wiesbaden 2020.
Evaluating User eXperience as a Means to Reveal the Potential Adoption of Innovative Ideas	Marc Pallot, Kulwant Pawar, Piotr Krawczk, Marcin Topolewski, Adrien Lecossier, Abdul Rahman Abdel Razek	ICE IEEE Conference 2020, Cardiff, Wales (Online)

Appendix 4: Publications Abstracts

"Innovation in Prototyping for Technical Product- Service Systems" – ICE IEEE 2016 Trondheim, Norway

Authors – Miriam Sämann, Abdul Rahman Abdel Razek, Saed Imran, Christian van Husen and Carsten Droll

Keywords – Service Prototyping; Service Innovation; Virtual Reality; Augmented Reality

Abstract – In this paper we investigate whether Virtual Reality (VR) and Augmented Reality (AR) technologies offer potential to serve as an innovative approach for industrial service prototyping. We present three fundamental sets of service prototyping requirements: monetary; non-monetary; and industrial requirements, after conducting series of interviews and surveys. The identified service prototyping requirements are further classified into two prime categories, presenting information on the demands for service prototyping and the hurdles faced by the industry when developing new services. This study then advocates the novel use of VR and AR technologies in service prototyping and ascertain that these technologies satisfies most of the industrial prototyping demands and to greater extent can overcome the hurdles efficiently. We discuss the relative advantages and limitations of using VR and AR technologies in service prototyping

"A Coherent Set of Customer Experience Factors for the Developers of Industrial Product Services" – RESER 2016 Naples, Italy

Authors – Carsten Droll, Saed Imran, Miriam Sämann, Christian van Husen, Dieter Haeberle, Abdul Rahman Abdel Razek

Keywords – Customer Experience, Product Service System

Abstract – It is widely regarded and accepted among the developers of industrial product services that offering a compelling product service environment, which provides value for their customers in the form of experiences, has far-reaching positive consequences on long term profitability and competitiveness. The customer experience factors play an increasingly significant role in determining the success of a company's offering. Yet, little is explored concerning the factors that can distinguish this compelling service experience for service development. Consequently, our aim in this paper is to show how to possibly distinguish coherent customer experience factors in service design by selecting a set of established service dimensions. This procedure can serve to determine qualified service dimensions through an empirical study that tends to comply with the expectations of customer-specific industry services.

“Innovation by Service Prototyping” IEEE/ICE 2017 Madeira, Portugal

Authors – Abdul Rahman Abdel Razek, Christian van Husen, Marc Pallot, Simon Richir

Keywords – Service Prototyping; Service Design; Service Innovation; Service Development; Service Operations; User eXperience

Abstract – Service prototyping is a novel innovative discipline that intents to improve service creation and enhance service delivery. This study aims to leverage the innovation level of service prototyping while leading to an enhanced experience of services in the design and development stages. Service prototyping requires innovative use of current prototyping techniques, procedures, methods and tools impacting the success rate of services. We seek to provide a hands-on wide-ranging model of innovative service prototyping toolbox that incorporates seven toolsets. It is intended to improve decision-making and expand alternatives to ensure the successful accomplishment of the service with an ideal value proposition (cost-benefit-ratio). This service prototyping development toolbox is expected to positively impact the service creation process and service concept development. These toolsets were developed in correlation with a service prototyping development matrix and key development aspects. By using the targeted service prototyping concepts and accompanying technologies, toolsets are expected to accelerate the prototyping process, improve the service completion rate and finally, ensure the success of the service.

“Introduction to a Service Prototyping Tool Box” ICServ 2017, Vienna, Austria

Authors – Abdul Rahman Abdel Razek, Christian van Husen, Saed Imran

Keywords – Service Prototyping, Service Innovation, Service Design, Service Digitalization & Visualizations

Abstract – Service prototyping is a relatively new discipline that requires s innovative ways for using current technologies, tools and approaches to offer rapid, accurate and cost-effective service prototyping solutions. These solutions should bear the capability to mitigate the risks connected with unforeseen problematic issues based on the service design specification, or aspects of it delivery. Thus, offering cost saving and effective service prototyping solutions with improved quality. One of key challenge in this quest relates to the selection of tools and established techniques that can provide fast iteration development process to service prototyping by enabling the integration of user comments and suggestions. For this reason, an innovative toolbox approach is taken for services prototyping where set of appropriate tools depending on the nature of service can be picked at different phases of service prototyping lifecycle. The paper presents the investigation conducted under the scientific project dimenSion, where initially service prototyping development matrix is created to support service provider to design and experience offered services as realistic as possible, thereby, laying the foundation to establish toolbox solution for service prototyping.

"An Approach for Enhancing the Value of Industrial Service Prototyping" ReSer 2018, Gothenburg, Sweden

Authors – Saed Imran, Martin Raban, Christian van Husen, Abdul Rahman Abdel Razek

Keywords – Service Prototyping, Industrial Services

Abstract – In this advance era of high technology, the service prototyping is not novel to the industrial manufacturers, where the aim is to provide enhancement and effectiveness in their service rendering. Therefore, strengthening the quality of the service prototyping is of high importance and a challenging consideration particularly in different areas of industrial service creation. Consequently, the aim of this investigation is to distinguish possible relevant features that may have accounted for overall performance of the process of industrial service prototyping. Thereby, set a path to establish relevant influential factors that may support high degree of value for service prototyping process.

"Service Prototyping: Design Dimensions" Digivation 2018, Aachen, Germany

Authors – Abdul Rahman Abdel Razek, Martin Raban, Christian van Husen

Keywords – Service Prototyping, Service Innovation, Co-creation

Abstract – Currently, the world is almost saturated with products and material objects. Organizations are looking for new streams for profit. Services and product-service-systems are the future of revenue rivulets. For organizations to fully leverage services to increase their revenue, they must first comprehend how to describe and develop a service. Service Prototyping is an innovative discipline that offers a co-creative service development process to ensure the success of planned future services. This paper intent to explain and define the service prototyping design dimensions, which is the first step in designing, describing, and experiencing a service. There are four design dimensions: actors, processes, artefacts, and environment. A service prototype can contain one design dimension, a combination of design dimensions or all of them at once. The design dimensions enable service stakeholders to fully control the pivotal dimension for the service prototyping process. The service prototyping design dimensions allow a holistic service experience even before the service exists. We will also discuss our service prototyping conceptual framework, validation of the framework will be discussed in future work. Our aim is to enrich the knowledge on service prototyping, offer service stakeholders a better service prototyping experience and provide a standard definition to the service prototyping design dimensions.

“A Comparative Study on Conventional versus Immersive Service Prototyping” VRIC 2018, Laval, France

Authors – Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir

Keywords – Service Innovation, Service Engineering, Service Prototyping, Immersive Service Prototyping, Immersive Applications, Virtual Reality, Augmented Reality, Mixed Reality, eXtended Reality

Abstract – Product prototyping, through the use of immersive technologies, has demonstrated its huge potential enabling co-creation, exploration of different usage scenarios and evaluation of the User eXperience. It is already an extremely relevant and valuable activity in many industries and revealed as an essential element of eXperience Design. Service prototyping is a new prominent progressive process used within service innovation intended to improve the service eXperience and quality while accelerating the service development process. Different types of service prototypes can be used to encompass all the different service elements throughout the service design and engineering processes. This paper presents a comparative study between the conventional and immersive service prototyping This comparison encompasses application, advantages and disadvantages of these different service prototyping. Several use cases of immersive service prototyping, either based on Virtual, Augmented or Mixed Reality technologies, are presented. This study aims to improve the body of knowledge on the use of immersive service prototyping. This is intended to help service designer understand what can be done with immersive service prototyping, and increase awareness on service prototyping. The main objective is to provide a guidance to service designers for selecting the most appropriate immersive service prototyping techniques per each case specificity.

“A Proposed Research Model for Service Prototyping” – ICE IEEE 2018 Conference, Stuttgart Germany

Authors – Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir

Keywords – Service Innovation; Service Prototyping; Service Experience; User eXperience, Customer Experience, Immersive Service Prototyping

Abstract – Companies around the world are willing to improve their new service development process through the use of service prototyping. We report in this paper about the first part of our research study on service prototyping that led to design a specific framework, model and instrument to be evaluated during several experiments. Service prototyping offers an early service experience enabling stakeholders to explore a new service idea, communicate a new service concept, and evaluate a new service design, even before the service exists. This paper presents the outcome of the literature review and the resulting

designed research framework, model and instrument. The main goal is to increase and clarify the knowledge on service prototyping and to introduce the service prototyping framework and model for further validation and exploration through a series of experiments.

"Comparing Conventional versus Immersive Service Prototypes: An Empirical Study" Laval Virtual 2019 VRIC, Laval, France

Authors – Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir

Keywords – Service Innovation, Service Prototyping, Virtual Reality, Augmented Reality, Mixed Reality, Immersive Service Prototyping, Immersive Applications

Abstract – For years, Immersive Technologies and 3D printing, demonstrated their capacity to quickly build product prototypes in order to reach a common understanding among all stakeholders, especially potential users. Service prototyping is a novel agile process intended to accelerate the service development, while improving the overall anticipated service experience. The use of Immersive Technologies in service prototyping is intended to enable a co-creative and explorative service experience, even before the service really exists. Service prototyping transforms intangible processes into a real experience. Immersive Technologies are already deployed in several industrial applications ranging from product design to product and service exploration. They are also used for conducting training even before the product or service exists. The main concern remains in the fact that there is a lack of study for comparing and selecting the most appropriate form of Service Prototypes (SP) to explore a new service. This paper presents our empirical study comparing different SP forms and the results of two experiment sessions that were conducted at ENSAM Laval and Angers campuses. These results reveal that participants preferred immersive forms rather than conventional forms. However, it also unveils some difficulties in properly handling Immersive Technologies.

"Comparing Different Performance Factors of Conventional VS Immersive Service Prototypes" ICE IEEE 2019, Sophia Antipolis, France

Authors – Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir

Keywords – Service Innovation; Service Prototyping; Service Experience; User eXperience, Virtual Reality, Augmented Reality, Mixed Reality

Abstract – Service prototyping is an innovative iterative process envisioned to enhance the service development process while refining the anticipated service experience. Immersive technologies, such as: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), in service prototyping have the potential to enhancing the co-creation of service ideas. It is intended to transform intangible

service aspects into an experience, even before the service exists. However, there is a lack of research studies comparing different forms of service prototype. Such studies would help to find out the most appropriate Service Prototype (SP) form for exploring, communicating and evaluating new service ideas. Several SP experiment sessions were conducted in France and Germany within an academic context in 2018 to compare different performance factors of conventional Service Prototypes (CSP) versus Immersive Service Prototypes (ISP). The participants have to disassemble and then reassemble a simple three-part mechanical element with the aid of four different SP forms. This paper presents the results of the experiment sessions, involving 38 participants, conducted at Furtwangen University campus in Germany. These results reveal that participants preferred ISP forms rather than CSP forms. However, it also confirms that there are still some difficulties in applying and using VR or AR devices.

"Comparing Conventional versus Immersive Service Prototypes: Extension on an Empirical Study" International Journal of Virtual Reality 2019 (2)

Authors – Abdul Rahman Abdel Razek, Marc Pallot, Christian van Husen, Simon Richir

Keywords – Service Innovation – Service Prototyping – Virtual Reality – Augmented Reality – Mixed Reality – Immersive Service Prototyping – Immersive Applications

Abstract – For years, Immersive Technologies and 3D printing, demonstrated their capacity to quickly build product prototypes in order to reach a common understanding among all stakeholders, especially potential users. Service prototyping is a novel agile process intended to accelerate the service development, while improving the overall anticipated service experience. The use of Immersive Technologies in service prototyping is intended to enable a co-creative and explorative service prototype, even before the service really exists, transforming an intangible process into a service experience. Immersive Technologies are already deployed in several industrial applications ranging from product design to product and service exploration. They are also used for conducting training even before the product or service exists. The main concern remains in the fact that there is a lack of study for comparing and selecting the most appropriate form of Service Prototype (SP) to explore a new service. This paper presents our empirical study comparing different SP forms and the results of two experiment sessions that were conducted at ENSAM Laval and Angers campuses. These results reveal that participants preferred immersive forms rather than conventional forms. However, it also unveils some difficulties in properly handling Immersive Technologies.

Evaluating User eXperience as a Means to Reveal the Potential Adoption of Innovative Ideas

Authors: Marc Pallot, Kulwant Pawar, Piotr Krawczk, Marcin Topolewski, Adrien Lecossier, Abdul Rahman Abdel Razek

Keywords – user experience, formative measurement model, mixed-methods, quantitative & qualitative methods, research, design, reliability, validity, goodness of fit.

This paper presents an empirical study dedicated to the evaluation of user experience (UX) and its causality on adoption. This empirical study was conducted in the context of an Innovation Management track in Fall 2019 where student teams had to co-create innovative mobile app ideas. The applied UX-based adoption model, which has confirmed its reliability, validity, and goodness of fit, was initiated through a first tentative model created in 2016. For each mobile app idea, a bipolar survey allowed us to collect both quantitative and qualitative data in order to evaluate the degree of UX satisfaction and its causal effect on adoption. This new study validates the UX multidimensional aspect in demonstrating that several UX facets, belonging to different dimensions, directly influence the anticipated UX and intention to adopt. It also reveals that this approach could be used to sift innovative ideas during the Fuzzy Front End stage in predicting their potential success on the market. Finally, it also confirms the hypothesis that the higher the degree of UX satisfaction, the deeper the intention to adopt.

Appendix 5: PhD Seminars and Workshops

Seminar, Workshop	Credit	Location	Date
Scientific English – English for Research Publications	8 UE	HFU Academy, Furtwangen	28.10.2016
NITIM Graduate Summer School 2016	162 UE	Trondheim, Norway	15-17.06.2016
DETHIS PhD Research Workshop		Jacobs University Bremen, Germany	31.01.2017
Inter- and Transdisciplinary Research Introduction	8 UE	HFU Academy, Furtwangen University	27.01.2017
Project Management Advanced Seminar for Professional Project Execution	16 UE	HFU Academy, Furtwangen University	06-07.03.2017
Microsoft Hololens – Mixed Reality Meets Universities		Microsoft Headquarters, Munich, Germany	15.05.2017
Effective Visual Communication of Science Seminar	16 UE	HFU Academy, Furtwangen University	29-30.05.2017
Promotions Map: Career Opportunity Promotion Seminar	2 UE	HFU Academy, Furtwangen University	13.06.2017
NITIM Graduate Summer School 2017	162 UE	Madeira, Portugal	24-26.06.2017
Copyright and Higher Education Seminar	8 UE	HFU Academy, Furtwangen University	25.09.2017
Planning, Implementation and Statistical Evaluation of Standardized Surveys Seminar	8 UE	HFU Academy, Furtwangen	06.10.2017
Digivation PhD Graduate Seminar 2017		Passau University	11.10.2017
Liebherr Service Prototyping Workshops		Liebherr Headquarters, Germany	02.011.2017 06.07.2018
Building Ideas in Teaching and University Context Seminar		WING HFU, Furtwangen University	07-09.02.2018
Time and Self-Management: Work and Life in Balance Seminar	16 UE	HFU Academy, Furtwangen	23-24.04.2018
NITIM Doctoral Summer School 2018	162 UE	Konstanz, Germany	20-23.06.2018
Service Prototyping dimenSion Industrial Workshop		VDC, St Georgen, Germany	15.11.2018
Time and self-management simply well organized	16 UE	HFU Academy, Furtwangen	02-03.07.2018
Project Management Basic Seminar – Basics for Successful Projects	16 UE	HFU Academy, Furtwangen	05.-06.11.2018
NITIM Doctoral Summer School 2019	162 UE	Nice, France	15-17.06.2019
Design Thinking: User-Friendly Solutions in Teamwork	24 UE	HFU Academy, Furtwangen	23-24.07.2019
Remote Smart Services Congress (Speaker)		Hotel Palace, Berlin	01-02.10.2019
Industrial Workshop and Focus Group Discussion		Liebherr, Germany	07-08.10.2019

Appendix 6: Research Instrument (Survey)

Demographic Survey

Q ID	Questions	Rating scope	
		Rating	*Selected Option*
0	Please enter your subject ID and your experiment cycle	1	Cycle 1
		2	Cycle 2
		3	Cycle 3
		4	Cycle 4
1	Gender	1	Male
		2	Female
		3	Unspecified
2	Age Slice	1	17-25
		2	26-35
		3	36-45
		4	46-65
		5	66-75
3	Occupation	5	Professor
		4	Doctorant
		3	Academic Employee
		2	Student
		1	Other
4	Service Development Knowledge	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
5	Immersive Technologies Knowledge (VR, AR, MR)	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
6	Service Prototyping Knowledge	1	No Knowledge
		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
7	Service Prototyping Experience	1	None
		2	Conventional Service Prototyping
		3	Immersive Service Prototyping
		4	Both
8	Immersive Service Prototyping Knowledge	1	No Knowledge

		2	Beginner
		3	Practitioner
		4	Specialist
		5	Expert
9	Location	1	Furtwangen
		2	Laval
		3	Angers

Demographic Survey (French)

ID Q	Des questions	Portée d'évaluation	
		No.	***Option sélectionnée***
0	Veuillez entrer votre identifiant de sujet et votre cycle de test	1	Cycle 1
		2	Cycle 2
		3	Cycle 3
		4	Cycle 4
1	le genre	1	Mâle
		2	Femelle
		3	Non spécifié
2	Tranche d'âge	1	17-25
		2	26-35
		3	36-45
		4	46-65
		5	66-75
3	profession	5	Professeur
		4	Docteur
		3	Employé académique
		2	Étudiant
		1	Autre
4	Connaissances en développement de services	1	Pas de connaissances
		2	Débutant
		3	Praticien
		4	Spécialiste
		5	Expert
5	Connaissance des technologies immersives (VR, AR, MR)	1	Pas de connaissances
		2	Débutant
		3	Praticien
		4	Spécialiste
		5	Expert
6	Connaissance du service prototypage	1	Pas de connaissances
		2	Débutant
		3	Praticien

		4	Spécialiste
		5	Expert
7	Expérience de prototypage de service	1	Non
		2	Service de prototypage conventionnel
		3	Prototypage de service immersif
		4	Tous les deux
8	Connaissance du prototypage de service immersif	1	Pas de connaissances
		2	Débutant
		3	Praticien
		4	Spécialiste
		5	Expert
9	Emplacement	1	Furtwangen
		2	Laval
		3	Angers

Demographic Survey (German)

Q ID	**Fragen**	**Bewertungsumfang**	
		Antwort	***Ausgewählte Optionen***
0	Bitte geben Sie Ihre Betreff-ID und Ihren Versuchszyklus ein	1	Cycle 1
		2	Cycle 2
		3	Cycle 3
		4	Cycle 4
1	Geschlecht	1	Männlich
		2	Weiblich
		3	Keine Angabe
2	Alter Gruppe	1	17-25
		2	26-35
		3	36-45
		4	46-65
		5	66-75
3	Tätigkeit	5	Professor
		4	Doktorand
		3	Akademischer Mitarbeiter
		2	Student
		1	Sonstiges
4	Service Entwicklung Kenntnisse	1	Keine Kenntnisse
		2	Anfänger
		3	Praktizierender
		4	Spezialist
		5	Experte
5	Immersive Technologies Kenntnisse (VR, AR, MR)	1	Keine Kenntnisse

		2	Anfänger
		3	Praktizierender
		4	Spezialist
		5	Experte
6	Service Prototyping Kenntnisse	1	Keine Kenntnisse
		2	Anfänger
		3	Praktizierender
		4	Spezialist
		5	Experte
7	Service Prototyping Experience	1	Keine
		2	Conventional Service Prototyping
		3	Immersive Service Prototyping
		4	Beide
8	Immersive Service Prototyping Erfahrung	1	Keine Kenntnisse
		2	Anfänger
		3	Praktizierender
		4	Spezialist
		5	Experte
9	Ort	1	Furtwangen
		2	Laval
		3	Angers

Bipolar Experiment Survey (English)

Questions	**Rating scope**	
	(-2 to +2)	***Selected Option***
Please put your ID number	-	-
Which Prototype did you use?	-	Paper Service Prototype
	-	Mock-up Service Prototype
	-	Virtual Reality Service Prototype
	-	Augmented Reality Service Prototype
How intuitive is the prototype?	-2	Unintuitive
	-1	Mostly Unintuitive
	0	Almost Intuitive
	1	Mostly Intuitive
	2	Intuitive
How interactive is the prototype?	-2	Passive
	-1	Mostly Passive
	0	Almost Interactive
	1	Mostly Interactive
	2	Interactive
How friendly is the prototype?	-2	Unfriendly

	-1	Mostly Unfriendly
	0	Almost Friendly
	1	Mostly Friendly
	2	Friendly
How attractive is the prototype?	-2	Unattractive
	-1	Mostly Unattractive
	0	Almost Attractive
	1	Mostly Attractive
	2	Attractive
How pleasant is the prototype?	-2	Unpleasant
	-1	Mostly Unpleasant
	0	Almost Pleasant
	1	Mostly Pleasant
	2	Pleasant
How emotionally engaging were you with the prototype?	-2	Uncommitted
	-1	Mostly Uncommitted
	0	Almost Committed
	1	Mostly Committed
	2	Committed
How interesting is the prototype?	-2	Unexciting
	-1	Mostly Unexciting
	0	Almost Exciting
	1	Mostly Exciting
	2	Exciting
How cognitively engaging was the prototype?	-2	Unthinking
	-1	Mostly Unthinking
	0	Almost Thinking
	1	Mostly Thinking
	2	Thinking
How Useful is the prototype?	-2	Useless
	-1	Mostly Useless
	0	Almost Useful
	1	Mostly Useful
	2	Useful
Please rate the feeling of time while using the prototype	-2	Timely
	-1	Mostly Timely
	0	Almost Timeless
	1	Mostly Timeless
	2	Timeless
How attentive were you of your surroundings?	-2	Attentive
	-1	Mostly Attentive
	0	Almost Inattentive
	1	Mostly Inattentive

	2	Inattentive
How responsive were you to external factors, during the prototype use?	-2	Responsive
	-1	Mostly Responsive
	0	Almost Unresponsive
	1	Mostly Unresponsive
	2	Unresponsive
Please rate the degree of convincingness to adopt	-2	Unconvinced
	-1	Mostly Unconvinced
	0	Almost Convinced
	1	Mostly Convinced
	2	Convinced
How willing are you to re-use this prototype?	-2	Unwilling
	-1	Mostly Unwilling
	0	Almost Willing
	1	Mostly Willing
	2	Willing
Please rate the level of recommendation of the prototype	-2	Dissuade
	-1	Mostly Dissuade
	0	Almost Recommend
	1	Mostly Recommend
	2	Recommend

Bipolar Experiment Survey (French)

ID	Des questions	Portée d'évaluation	
		No.	***Option sélectionnée***
0.0	S'il vous plaît mettre votre numéro d'identification	-	-
0	Quel prototype avez-vous utilisé?	-	Prototype de service papier
		-	Prototype de service de maquette
		-	Prototype de service de réalité virtuelle
		-	Prototype de service de réalité augmentée
1	A quel point le prototype est-il intuitif?	-2	Non intuitif
		-1	Principalement non intuitif
		0	Presque intuitif
		1	Surtout intuitif
		2	Intuitif
2	A quel point le prototype est-il interactif?	-2	Passif
		-1	Principalement passive

		0	Presque interactif
		1	Principalement interactif
		2	Interactif
3	Le prototype est-il convivial?	-2	Hostile
		-1	Généralement inamical
		0	Presque amical
		1	Surtout amical
		2	Amical
4	Quel est l'attrait du prototype?	-2	Peu attrayant
		-1	Surtout peu attrayant
		0	Presque attrayant
		1	Surtout attrayant
		2	Attrayant
5	A quel point le prototype est-il agréable?	-2	Désagréable
		-1	Surtout désagréable
		0	Presque agréable
		1	Plutôt agréable
		2	Agréable
6	Dans quelle mesure étiez-vous émotionnellement avec le prototype?	-2	Non engagé
		-1	Généralement non engagé
		0	Presque engagé
		1	Principalement commis
		2	Engagé
7	Quel est l'intérêt du prototype?	-2	Peu passionnant
		-1	Surtout peu passionnant
		0	Presque excitant
		1	Surtout passionnant
		2	Passionnant
8	À quel point le prototype était-il stimulant sur le plan cognitif?	-2	Irréfléchi
		-1	Surtout ne pas penser
		0	Presque penser
		1	Pensant surtout
		2	En pensant

9	Quelle est l'utilité du prototype?	-2	Inutile
		-1	Surtout inutile
		0	Presque utile
		1	Surtout utile
		2	Utile
10	S'il vous plaît noter le sentiment de temps tout en utilisant le prototype	-2	Opportun
		-1	Surtout opportun
		0	Presque intemporel
		1	Principalement intemporel
		2	Intemporel
11	A quel point étiez-vous attentif à votre environnement?	-2	Attentif
		-1	Surtout attentif
		0	Presque inattentif
		1	Principalement inattentif
		2	Inattentif
12	Dans quelle mesure avez-vous été sensible aux facteurs externes lors de l'utilisation du prototype?	-2	Sensible
		-1	Surtout réactif
		0	Presque insensible
		1	Surtout insensible
		2	Ne répond pas
13	Veuillez évaluer le degré de persuasion à adopter	-2	Non convaincu
		-1	Surtout pas convaincu
		0	Presque convaincu
		1	Surtout convaincu
		2	Convaincu
14	Dans quelle mesure êtes-vous disposé à réutiliser ce prototype?	-2	Ne veut pas
		-1	Surtout pas disposé
		0	Presque disposé
		1	Surtout disposé
		2	Prêt
15	Veuillez évaluer le niveau de recommandation du prototype	-2	Dissuader

		-1	Surtout dissuader
		0	Presque recommander
		1	Surtout recommander
		2	Recommander

Bipolar Experiment Survey (German)

Fragen	**Bewertungsumfang**	
	(-2 to +2)	***Ausgewählte Optionen***
Bitte geben Sie Ihre ID-Nummer ein	-	-
Welchen Prototyp haben Sie verwendet?	-	Paper Service Prototype
	-	Mock-up Service Prototype
	-	Virtual Reality Service Prototype
	-	Augmented Reality Service Prototype
Wie intuitiv ist der Prototyp?	-2	nicht intuitiv
	-1	überwiegend nicht intuitiv
	0	annähernd intuitiv
	1	überwiegend intuitiv
	2	intuitiv
Wie interaktiv ist der Prototyp?	-2	passiv
	-1	überwiegend passiv
	0	annähernd interaktiv
	1	überwiegend interaktiv
	2	interaktiv
Wie benutzerfreundlich ist der Prototyp?	-2	unfreundlich
	-1	überwiegend unfreundlich
	0	annähernd freundlich
	1	überwiegend freundlich
	2	freundlich
Wie attraktiv ist der Prototyp gestaltet?	-2	unattraktiv
	-1	überwiegend unattraktiv
	0	annähernd attraktiv
	1	überwiegend attraktiv
	2	attraktiv
Wie wirkt der Prototyp auf Sie?	-2	nicht ansprechend
	-1	überwiegend nicht ansprechend
	0	annähernd ansprechend
	1	überwiegend ansprechend
	2	ansprechend
Wie stark berührt der Prototyp Ihre Emotionen?	-2	sehr gering
	-1	überwiegend gering

	0	annähernd stark
	1	überwiegend stark
	2	stark
Wie interessant ist der Prototyp?	-2	uninteressant
	-1	überwiegend uninteressant
	0	annähernd interessant
	1	überwiegend interessant
	2	interessant
Wie verständlich fanden Sie den Prototyp?	-2	unverständlich
	-1	überwiegend unverständlich
	0	annähernd verständlich
	1	überwiegend verständlich
	2	verständlich
Wie nützlich fanden Sie den Prototyp?	-2	unnützlich
	-1	überwiegend unnützlich
	0	annähernd nützlich
	1	überwiegend nützlich
	2	nützlich
Wie bewerten Sie Ihr Zeitempfinden während der Nutzung?	-2	real
	-1	überwiegend real
	0	annhähernd zeitlos (verzerrt)
	1	überwiegend zeitlos (verzerrt)
	2	zeitlos (verzerrt)
Wie bewusst waren Sie sich Ihrer Realen Umgebung?	-2	bewusst
	-1	überwiegend bewusst
	0	annähernd unbewusst
	1	überwiegend unbewusst
	2	unbewusst
Wie stark reagierten Sie auf externe Faktoren Ihrer Umgebung während des Prototypeinsatzes?	-2	Reaktion
	-1	überwiegend starke Reaktion
	0	annähernd Reaktion
	1	überwiegend schwach Reaktion
	2	keine Reaktion
Wie überzeugt sind Sie von der Anwendung des Prototyps?	-2	nicht überzeugend
	-1	überwiegend nicht überzeugend
	0	annähernd überzeugend
	1	überwiegend überzeugend
	2	überzeugend
Wie groß ist Ihre Bereitschaft, diesen Prototyp wiederzuverwenden?	-2	nicht bereit
	-1	überwiegend nicht bereit
	0	annähernd bereit
	1	überwiegend bereit

	2	bereit
Wie empfehlenswert finden Sie den Prototyp?	-2	nicht empfehlenswert
	-1	überwiegend nicht empfehlenswert
	0	annähernd empfehlenswert
	1	überwiegend empfehlenswert
	2	empfehlenswert

Appendix 7: Further Analysis

Baseline Experiment Extended Results:

Table 1 Total Durations, Errors, and Explanation Requests

Participant	Total Task Duration (seconds)	Total Errors (Number)	Total Explanation Requests (Number)
P1	365	2	1
P2	404	2	3
P3	946	6	7
P4	1120	5	7
P5	883	10	6
P6	744	7	4
P7	606	8	4
P8	1071	11	9
P9	420	1	2
P10	654	1	2
P11	597	3	6
P12	381	3	2
P13	592	6	2
P14	625	2	3
P15	373	0	0
P16	384	4	4
P17	532	4	3
P18	623	5	6
P19	917	6	7
P20	881	1	9
P21	747	2	9
P22	284	0	0
P23	326	3	1
P24	431	3	2
P25	666	4	8
P26	304	0	3
P27	1001	8	6
P28	1104	6	5
P29	1177	8	4
P30	921	8	5
Average	**669**	**4.30**	**4.33**

The participants' task completion duration, along with the number of errors committed and explanation requested are shown in Tab. (1) above.

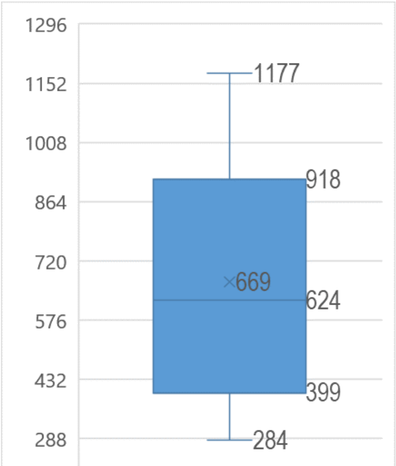

Fig. 1 Baseline Experiment Total Duration Ranges (seconds)

The task completion duration was clocked in minutes and seconds, and then is displayed in seconds in the boxplot as shown in the Fig. (1) above.

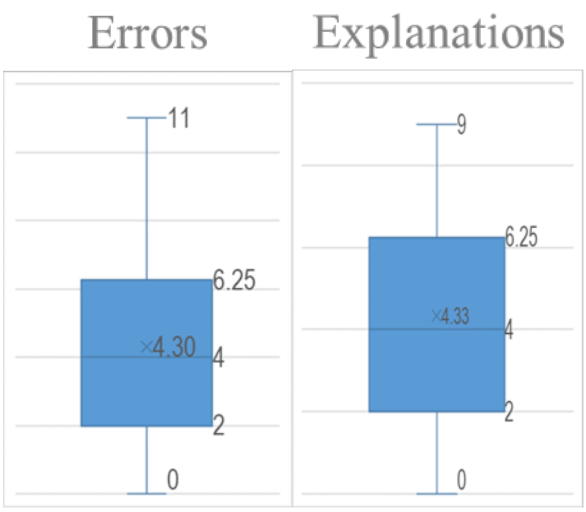

Fig. 2 Baseline Experiment Total Errors and Explanation Requests Ranges

The total amount of errors committed while completing the task and explanation requests made during completing the task are shown in Fig. (2) above.

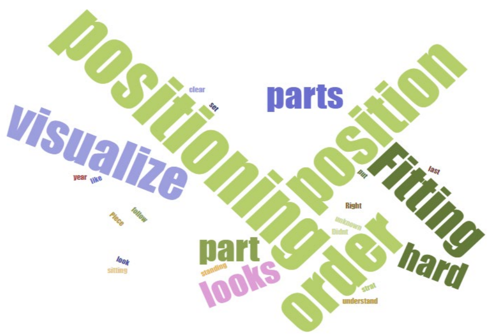

Fig. 3 The "challenges" question feedback in a Word cloud

The Word cloud in Fig. (3) above confirms what was also mentioned in the comments table in the main text in Chapter 4, where the most prevalent words in the feedback were positioning, visualize, fitting and order. We can also see the words hard, parts and looks, which might suggest that the participants also faced challenges in putting the parts, which was hard to see how it looks afterwards.

Fig. 4 The "recommendation" question Feedback in a Word cloud

In Fig. (4) we can also see the most used words in the participant's feedback, where (1) video, (2) step, (3) VR, (4) AR and (5) combination were the most mentioned comments, which confirms also the table above. These comment show that participants found a step by step instructional guide or training simulation or a combination as useful and helpful for completing the task.

Fig. 5 The "other" question feedback in a Word cloud

The participants' other comments are summarized and displayed in a Word cloud in Fig. (5). As shown from the figure above that most of the comments revolve on the same things as before, as such we extracted the most relevant comments and feedback from the participants are as follow: (1) "3D pictures, videos, or animation would have been better than nothing", (2) "Any support or training would have been helpful", (3) "Step by step guide is somehow necessary", (4) "MR for Hands-free working", (5) "Not so easy to visualize without any support", and (6) "I had wrong visualization before finishing".

SP Experiment Extended Results:

The total number of participants to partake in the SP Experiment (PSP; MSP, VRSP, ARSP) was 103 volunteer, more than 80% of them are male, while less than 20% are female, where more than 70% of the volunteers were students, while the rest 30% where professionals.

PSP (Paper Based) Extended Results

Observations Results

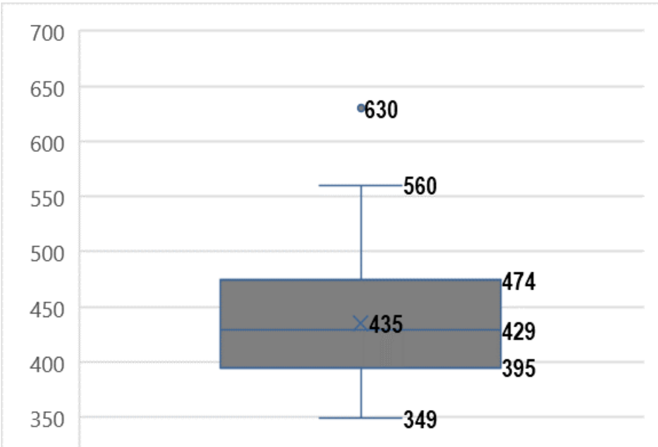

Fig. 6 PSP Task Completion Durations Range

The range of the participants' task completion durations while completing the task by using PSP are shown in Fig. (6) above.

Table 2 PSP Min – Max Observation Values

PSP	**Average**
Task Completion Duration (TCD) [min:sec]	**07:15**
Usage Error Average Per Participant (EA)	**0.08**
Error Opportunity Rate (EOR)	**0.39%**
Error Frequency Rate (EFR)	**5.83%**
Error Intensity (EI)	**2**

Usage Explanation Requests Average (XA)	**0.11**
Explanation Requests Opportunity Rate (XOR)	**0.53%**
Explanation Requests Frequency Rate (XFR)	**9.90%**
Explanation Requests Intensity (XI)	**2**

The summary of the observed performance of the participants while using PSP is shown in Tab. (2) above.

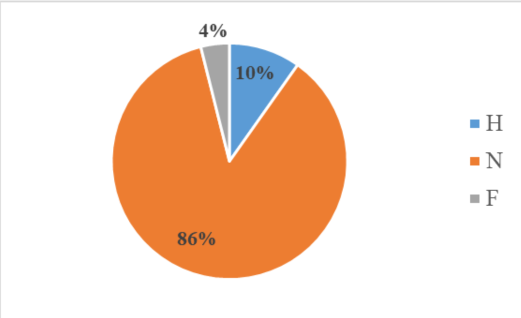

Fig. 7 Participants Attitude While using PSP

The participants' attitude, shown in Fig. (7), was observed from their facial expressions and overall demeanour, and was categorized into three ratings, Happy (H), Neutral (N), and Frustrated (F).

Survey Ratings

Table 3 PSP Survey Ratings Overview

High Construct	**Middle Construct**	**Lower Construct**	**Survey**	**Properties**	**Rating (-2→2)**
SPX	**IX**	**PX**	**Q1**	*Intuitiveness*	-0.04
			Q2	*Interactivity*	-1.34
		EX	**Q4**	*Attractiveness*	-0.93
			Q6	*Emotionally Engagement*	-1.2
		CX	**Q7**	*Interestingness*	-0.9
			Q8	*Cognitive Engagement*	-0.09
	RWD		**Q10**	*Timelessness*	-1
			Q11	*Attentiveness*	-0.81
			Q12	*Responsiveness*	0.03
	SPE		**Q3**	*Friendliness*	-0.49
			Q5	*Pleasantness*	-0.63

		Q9	*Usefulness*	0.47
ItA		**Q13**	*Convincingness to adopt*	-0.12
		Q14	*Willingness to re-use*	0
		Q15	*Readiness to recommend*	-0.18
PSP SPX				**-0.48**

The average ratings of the participants in each of the UX ratings is showed in the Tab. (3) above.

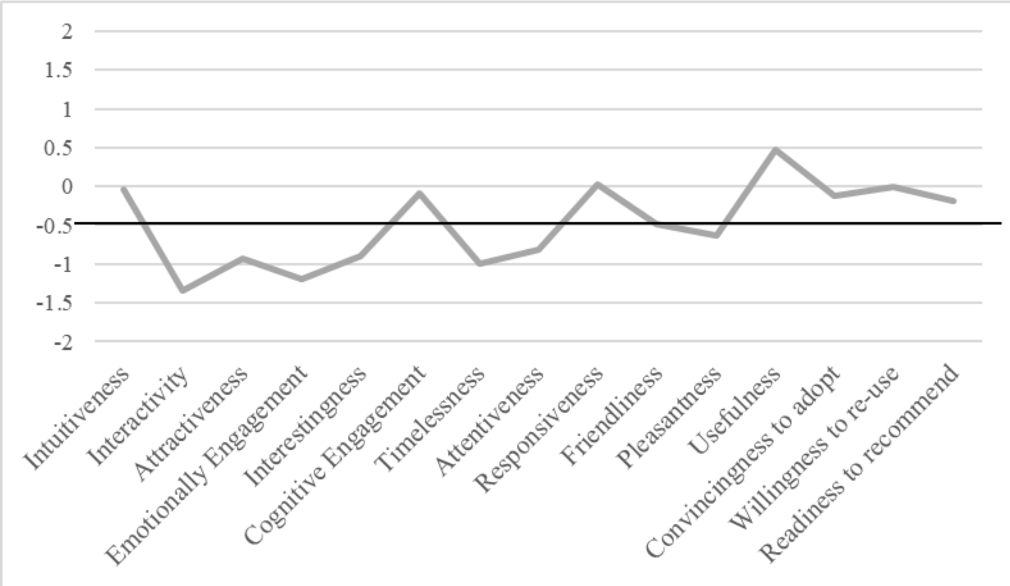

Fig. 8 PSP Survey Quantitative Results Curve

A graph of the PSP average ratings for each of the properties is shown in Fig. (8) above, where the PSP average is overlaid with a horizontal line at the -0.48. Almost all the properties were negatively rated except the usefulness property, which could be due to the fact that paper is useful as its shelf life is almost infinite if stored properly and almost everyone used some kind of paper leaflet in some point of their life. The intuitiveness, usefulness adoption degree, willingness to re-use, and recommendation degree all were rated above the average PSP rating but still all negatively rated. To be able to understand more about each lower and higher constructs ratings, a graphical analysis of the rating was made to elaborate on the PSP properties. The highest rated property of PSP was the usefulness, which might be due to the fact that paper is useful material that we all know how to utilize in various things. The neutral rating for the responsiveness property might be due to the fact that almost all of the participants have used a paper instructional leaflet before. The participants also rated the properties of the acceptance construct all above of the average survey rating, which could be a sign that some of the participants accept PSP as an appropriate method for completing this task.

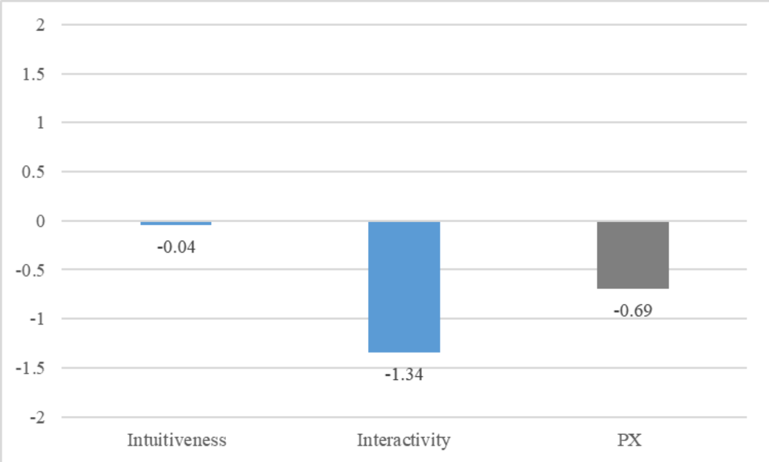

Fig. 9 PSP Perceptual Immersion Average Rating

The participants rated the perceptual immersion (PX) negatively, which is understandable as paper doesn't offer any interaction which is reflected in the rating of interactivity property. The PX rating is the average of intuitiveness, and interactivity as shown in Fig. (9) above, where the participants gave it an average of -0.69 which has relatively lower than the SPX rating.

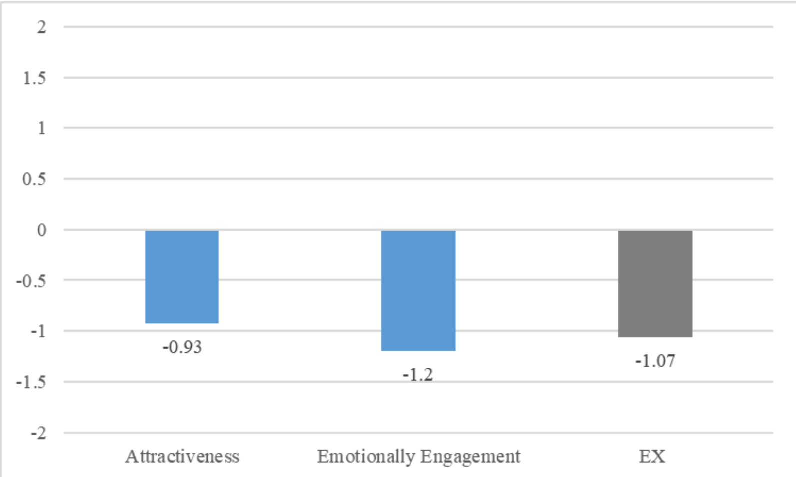

Fig. 10 PSP Emotional Immersion Average Rating

The emotional immersion (EX) construct, which consists of attractiveness, and emotional engagement, was also negatively rated by the participants as shown in Fig. (10). This could be due to the fact that it is hard to have an emotional engagement with a paper without some kind of storytelling elements. The participants rated the EX with an average of -1,07 which is considerably lower than the SPX, and even rated lower than PX. This shows that the paper was not attractive to most of the participant, and they even found it unpleasant and not emotionally engaging.

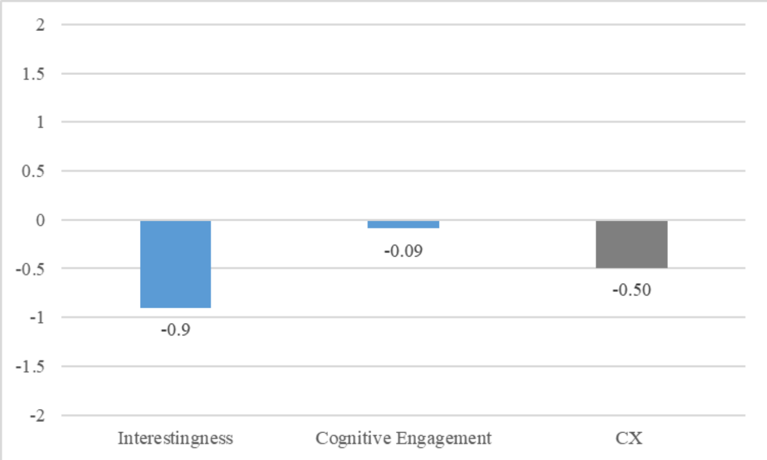

Fig. 11 PSP Cognitive Immersion Average Rating

The Cognitive immersion (CX) of a paper depends on the ratings of the two properties, interestingness, and cognitive engagement as shown in Fig. (11). The degree of interestingness was rated negatively, and the cognitive engagement was rated negatively as well however with an insignificant value which almost is a neutral rating. The participants then rated the CX with -0.50 which is rated almost as high as the SPX average, however it was rated considerably higher than PX, and EX. This might be due to the fact that some participants found the paper form cognitively engaging as they had to visualize and think about the steps.

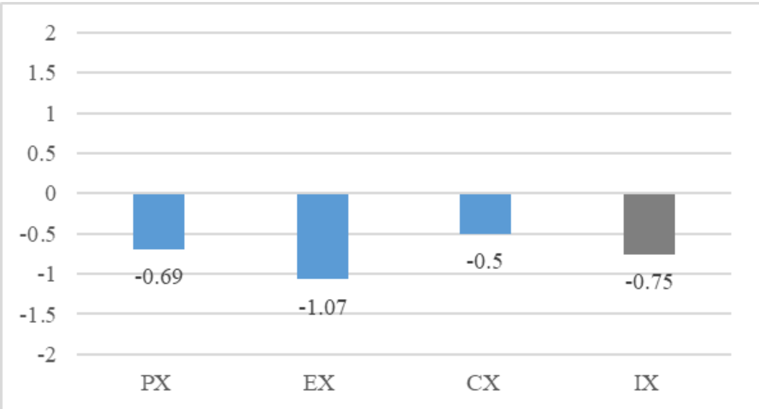

Fig. 12 PSP Immersion Construct Rating

The immersion (IX) higher construct is the average of the three immersion lower constructs PX, EX, and CX as shown in Fig. (12) above. IX rating is -0.75 which is 50% lower than average; this was expected as paper lacks perceptual and emotional Immersiveness as it is mono-dimensional. PSP offered only the instructions needed to complete the task while there was no story around it and no storyboard to add to the immersive engagement of the participants. Some participants found the paper form cognitively engaging as such the CX rating is higher than the EX and PX ratings.

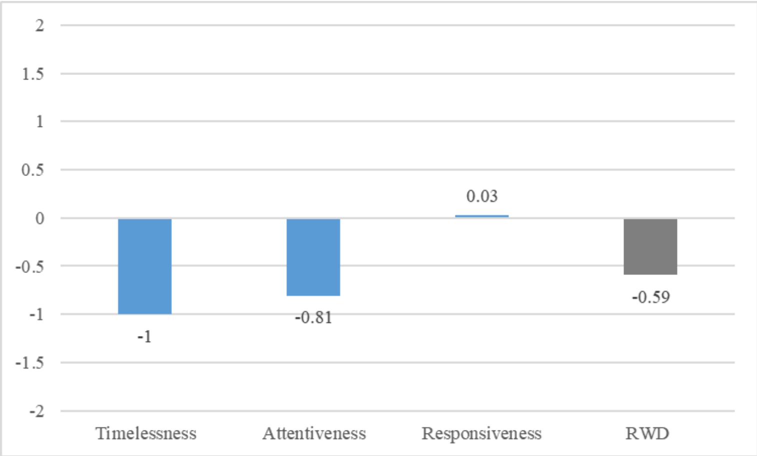

Fig. 13 PSP Real World Dissociation Average Rating

The real world dissociation construct (RWD) is comprised of the participant sense of time, sense of attention, and responsiveness as shown in Fig. (13) above. The participants rated RWD relatively negative, as the sense of time and sense of attention were negatively rated as the participants felt that they were “bored” and not feeling attentive to the task. The participants rated the responsiveness with a slight positive rating, although insignificant but could be considered as a neutral rating. RWD was rated not much lower than the SPX rating, and has a higher rating than IX.

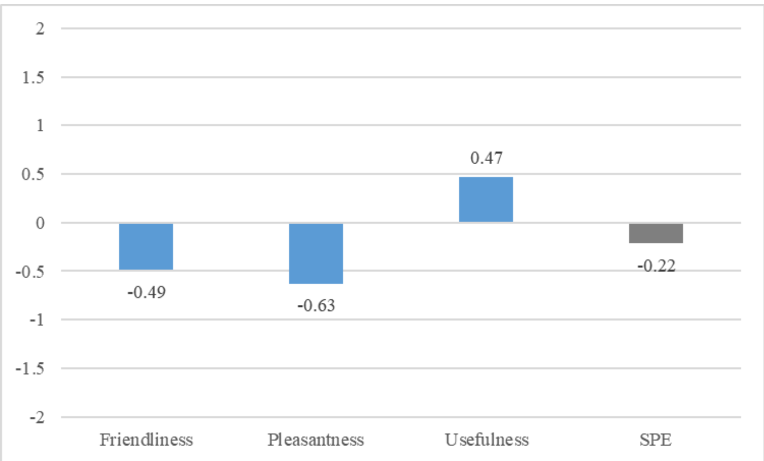

Fig. 14 PSP Service Prototype Effectiveness Rating

The intention to accept and adopt is based on the three ratings of friendliness, pleasantness, and usefulness as shown in Fig. (14) above. The SPE rating of -0.22 is much higher than the SPX, which could be attributed to the usefulness rating, as most of the participants rated PSP positively in the case of the usefulness of paper as it as widely used in many application, from getting a new device or even putting together an IKEA furniture.

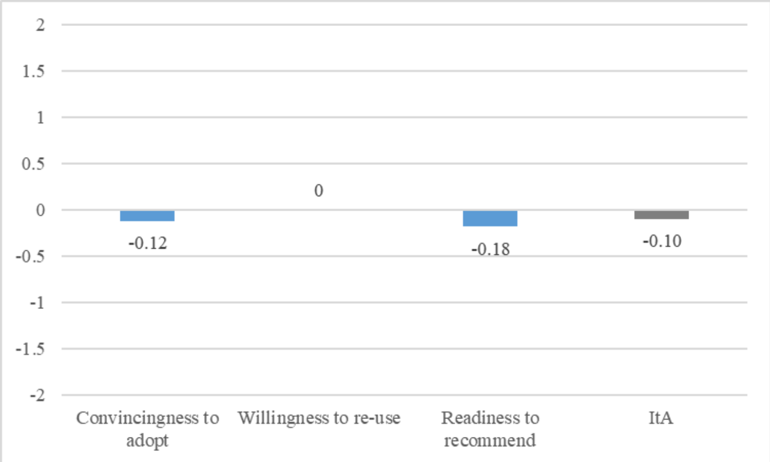

Fig. 15 PSP Intention to Accept and Adopt Average Rating

The intention to accept and adopt (ItA) of the participants can be gauged by averaging the three questions asking about the adoption degree, willingness to re-use, and the tendency to recommend as displayed graphically in Fig. (15) above. The participants rated their degree for adoption with an insignificant negative rating, which shows that the participants were almost neutral on the adopting PSP. The participants rated the willingness to re-use with a 0 rating, which is a neutral sign showing that the participant were divided on whether or not to re-use paper or that they all felt that they felt impartial about reusing PSP. ItA was much higher rated than the SPX rating, which shows that the form had a neutral acceptance from the participant, where they felt disinterest or impartially towards paper.

Survey Justification

Table 4 PSP Survey Rating Justifications

Survey	**Average (-1 → +1)**
Intuitiveness	-0.1
Interactivity	-0.79
Friendliness	-0.6
Attractiveness	-0.65
Pleasantness	-0.49
Emotionally Engagement	-0.64
Interestingness	-0.6
Cognitive Engagement	-0.17
Usefulness	0.31
Timelessness	-0.6
Attentiveness	-0.34
Responsiveness	-0.06
Adoption degree	-0.23
Willingness	-0.13

Recommendation degree	-0.27
PSP Sentiment	**-0.36**

The sentiment of the answers of the participants, as shown in Tab. (4), were rated according to the justification made by the participants, where a positive comment equates (+1), neutral comment equates (0) and a negative comment (-1).

Fig. 16 PSP Sentiment Word cloud

The participants' comments on the ratings were clustered in a cloud of words were the most mentioned words were "*clear*", "*boring*", "*read*", "*instructions*", "*normal*", and "*pictures*" as seen in the Fig. (16) above. This shows that participants vocabulary used in PSP rating justifications had a negative sentiment, as they used words like boring, normal or simple. The participants found that reading is tiring and redundant, and some called it clear, and some in cases they didn't find the information easily as they had to read the whole instructions. The participants also pointed out that the drawings of the parts were not helpful, but as a prototype the leaflet contained all the necessary instructions to complete the task as many of the participants suggested.

MSP (Video Based) Extended Results

Observations Results

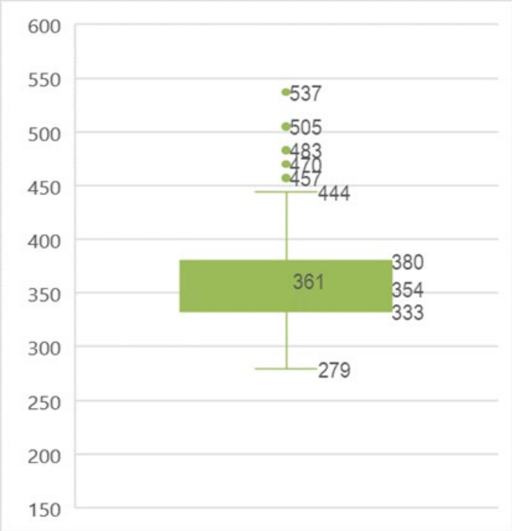

Fig. 17 MSP Task Completion Durations Range

The duration range graph can illuminate on the consistency of an SP form, as it shows how consistent was the performance of the participants in relation to each. The participants' duration to complete the task is shown in Fig. (17) above.

Table 5 MSP Observed Performance Summary

Observations	Average
Task Completion Duration (TCD) [min:sec]	**06:01**
Usage Error Average Per Participant (EA)	**0.14**
Error Opportunity Rate (EOR)	**0.68%**
Error Frequency Rate (EFR)	**10.68%**
Error Intensity (EI)	**2**
Usage Explanation Requests Average (XA)	**0.14**
Explanation Requests Opportunity Rate (XOR)	**0.68%**
Explanation Requests Frequency Rate (XFR)	**11.65%**
Explanation Requests Intensity (XI)	**3**

The summary of the observed performance of the participants while completing the task by using MSP is shown in Tab. (5).

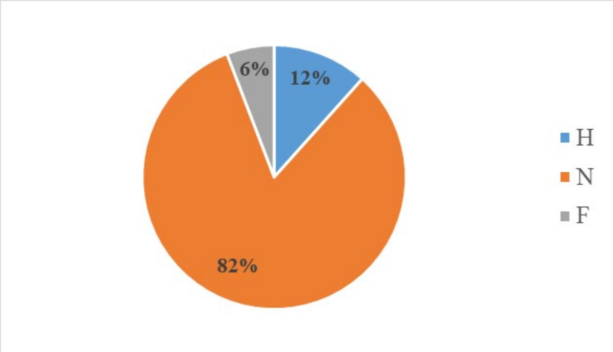

Fig. 18 Participants' attitude while completing the task with MSP

The attitude of the participants while using MSP is shown in Fig. (18), where H is for Happy, N for Neutral, and F is Frustrated.

Survey Ratings

Table 6 MSP Survey Rating Overview

High Construct	Middle Construct	Lower Construct	Survey	Properties	Rating
SPX	IX	PX	Q1	*Intuitiveness*	1.17
			Q2	*Interactivity*	-0.62
		EX	Q4	*Attractiveness*	0.32
			Q6	*Emotionally Engagement*	-0.86
		CX	Q7	*Interestingness*	0.37
			Q8	*Cognitive Engagement*	0.62
	RWD		Q10	*Timelessness*	-0.81
			Q11	*Attentiveness*	-0.69
			Q12	*Responsiveness*	0.2
	SPE		Q3	*Friendliness*	0.55
			Q5	*Pleasantness*	0.42
			Q9	*Usefulness*	1.05
ItA			Q13	*Convincingness to adopt*	0.72
			Q14	*Willingness to re-use*	0.83
			Q15	*Readiness to recommend*	0.81
MSP Average					**0.27**

The average ratings of the participant for each of the UX properties are displayed in Tab. (6) above.

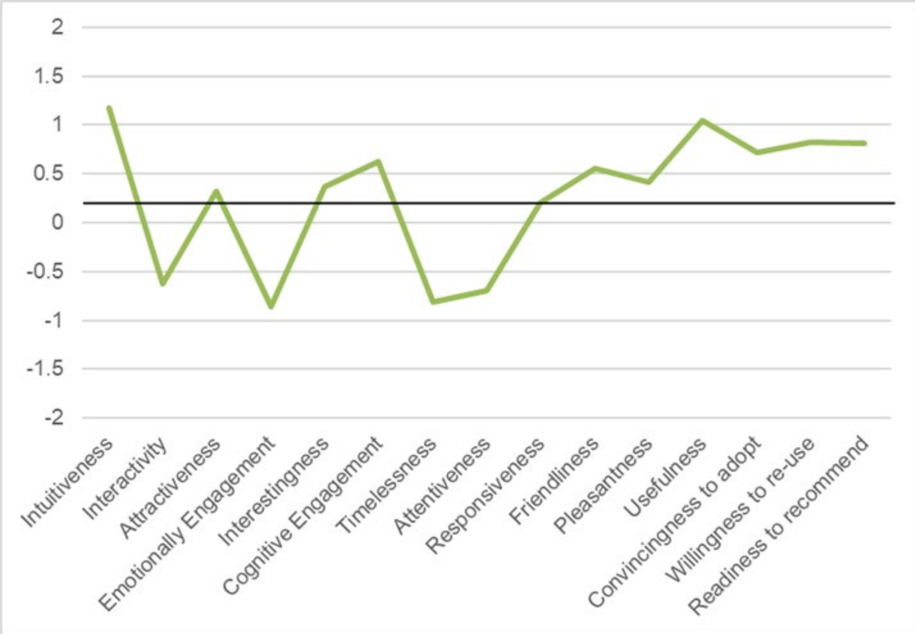

Fig. 19 MSP Survey Rating Curve

The MSP average survey rating is displayed on Fig. (19) above with a straight line representing the 0.27 average rating level. The curve shown in the figure shows that the participants rated MSP positively in several constructs, but also negatively in some other properties as well. To have a better understanding about these ratings a deeper dive in each of the five constructs that are divided upon the fifteen properties, a graphical representation of each of these constructs and their relationship to each other is discussed below.

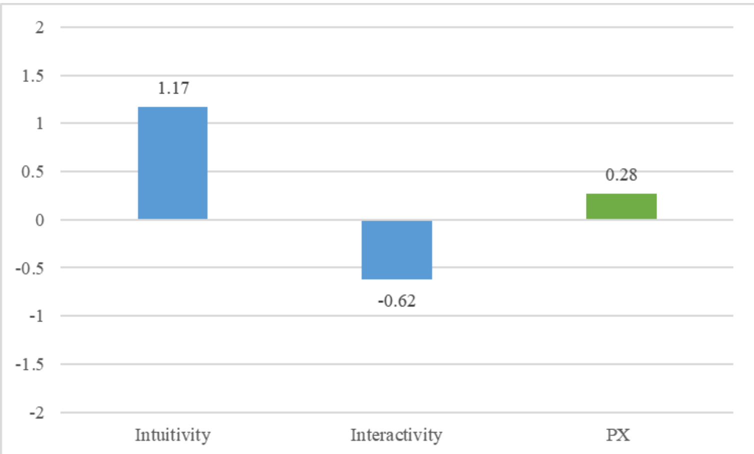

Fig. 20 Perceptual Immersion Average Ratings

The participants rated the Perceptual Immersion (PX) of MSP as shown from Fig. (20) above. The rating is constructed from the intuitiveness, and interactivity. The intuitiveness positive rating might be due to the fact that the videos replicate the task step by step without any audio aid or instructions, to simulate a learning by seeing and then by doing experiences. The interactivity of MSP was negatively rated, which could be expected as the only interaction with a video would be with the stop or start buttons. The PX average is 0.28 which a bit higher than the SPX rating, which shows the video offers a relatively high perceptual experience for some participants.

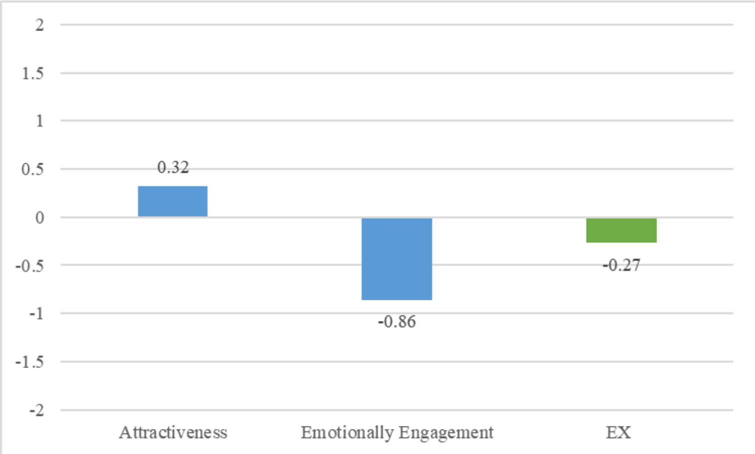

Fig. 21 Emotional Immersion Average Ratings

The emotional immersion (EX) construct is comprised of attractiveness, and emotional engagement as shown in Fig. (21) above. The video used in MSP was not emotionally engaging to the participants, as they negatively rated the property, that might be due to the silent non-verbal nature of the videos, as they were made to be as neutral as possible as such some participants might have felt distant and displeased with the MSP as a result of that neutrality. The EX average rating is -0.27, which is a negative rating but as the value is insignificant it could be considered as neutral. EX was rated considerably lower than SPX and PX ratings, which might show that participants connected perceptually with MSP however not emotionally.

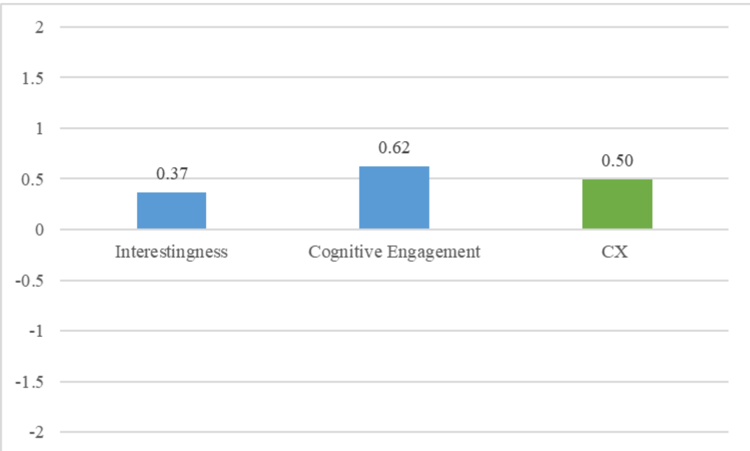

Fig. 22 Cognitive Immersion Average Ratings

The cognitive immersion (CX) construct, which is the collective of the interestingness, and cognitive engagement properties as shown in Fig. (22) above. CX average is 0.50, which is much higher than the

SPX rating. CX double the rating of PX and considerably higher than EX; this shows that the participants were cognitively engaged with the video, and were relatively interested in it as well. The video then offers a higher cognitive experience when it comes to using it for communication, even without verbal instructions the participants found it useful and engaging as well.

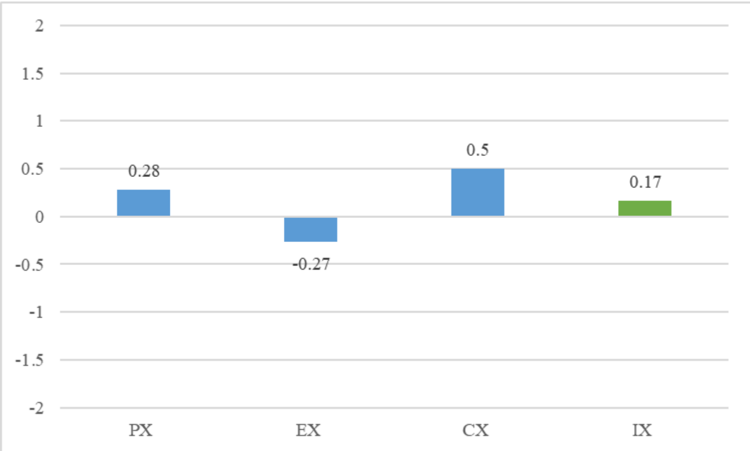

Fig. 23 Immersion Construct Ratings

The immersion (IX) construct rating is 0.17 this is comprised of averaging the PX, EX, and CX ratings as shown in Fig. (23). IX was rated lower than the SPX, meaning that even for a video without any verbal communication some participants were positively immersed in it. This was not surprising to see as the CX rating was the highest amongst the IX ratings, as the video cognitively engaged the participants through showing them the steps of the disassembling and assembling tasks as to be able to replicate them.

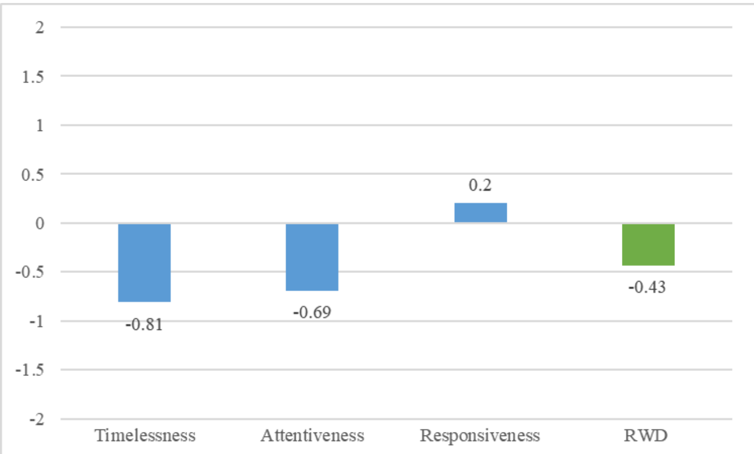

Fig. 24 Real World Dissociation Construct Ratings

The real world dissociation (RWD) construct shows if the participants have any distortion in the sense of time, sense of their surrounding and the ability to respond to any outside factors as represented in Fig.

(24) above. The participants rated the sense of time highly negative as they might have felt that video either went too fast, or too slow. The participants also rated the attentiveness property negatively as they felt that they couldn't be attentive to their surroundings while watching the video, which is logical as each video is only one minute and thirty seconds so they have to focus so they could extract the necessary information to complete the task. RWD was rated much lower than the average, this shows that the participants felt some distortion to their sense of time, attention or awareness.

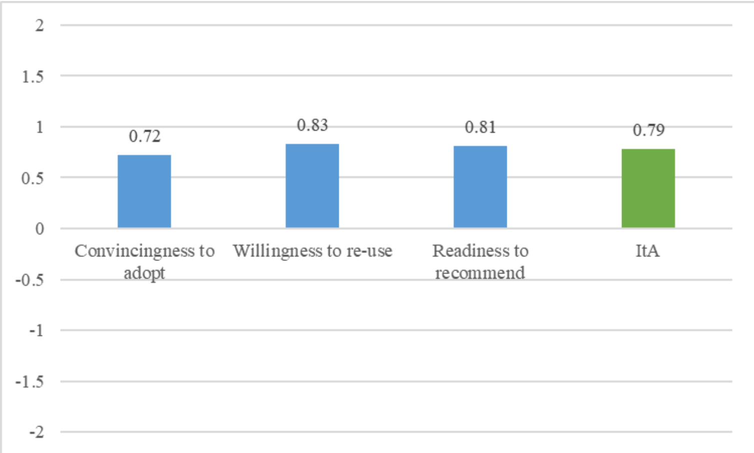

Fig. 25 Intention to Accept and Adopt Construct Ratings

The intention to accept and adopt (ItA) is based on whether the participants were pleased to adopt it, willing to re-use and even recommend it to others, as shown in Fig. (25) above. ItA was rated 0.79 which is the highest amongst all the MSP constructs, showing that the participants accept video as a good communication tool. ItA is considerably higher than the SPX, this reflects that most of the participants are convinced that MSP or video could be used for similar tasks, even they are even willing to adopt, use, and recommend it to others. The participants highly accepted MSP as an appropriate SP for such assembly task.

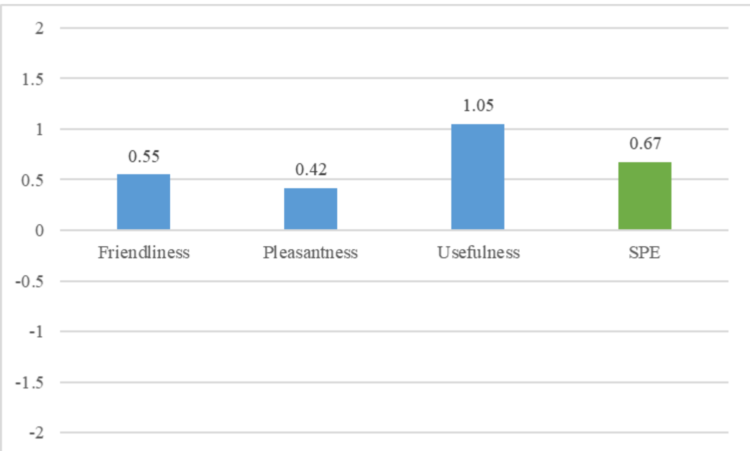

Fig. 26 Service Prototype Effectiveness Construct Ratings

The intention to accept and adopt is based on the three ratings of friendliness, pleasantness, and usefulness as shown in Fig. (26) above. The SPE rating of 0.67 is more than double that of the SPX, which might be an indicator that the participants found the MSP effective in delivering the information. The usefulness property was rated quite positively, which shows that the participants found the video as a useful prototyping form.

Ratings Justifications

Table 7 MSP Survey Ratings Justification Sentiment Analysis

Survey	**Average (-1 → +1)**
Intuitiveness	0.75
Interactivity	-0.35
Friendliness	0.25
Attractiveness	0.21
Pleasantness	0.25
Emotionally Engagement	-0.52
Interestingness	0.14
Cognitive Engagement	0.17
Usefulness	0.61
Timelessness	-0.43
Attentiveness	-0.28
Responsiveness	0.06
Adoption degree	0.49
Willingness	0.53
Recommendation degree	0.53
MSP Sentiment	**0.16**

The sentiment of the participants' justification, as shown in Tab. (7) above, was gauged by categorizing their justifications into three categories, positive (+1), neutral (0), and Negative (-1).

Fig. 27 MSP Survey Sentiment Word cloud

As seen in Fig. (27) above, there are several words that stands out, as “understand”, “*easy*”, “*instructions*”, “*long*”,” *video*”, “*watch*”, and “*clear*”. The participants used positive words to justify their ratings, as the felt that MSP offers an understandable step by step instructional guide to complete the task. The also felt that it is easy to understand, but many felt that it was too long, or that the video format requires them to watch and then perform which could be inefficient. The participants also felt divided in regard to the distraction and awareness to surroundings as some felt distracted and some felt normal and aware.

VRSP (Virtual Reality Based) Extended Results

Observations Results

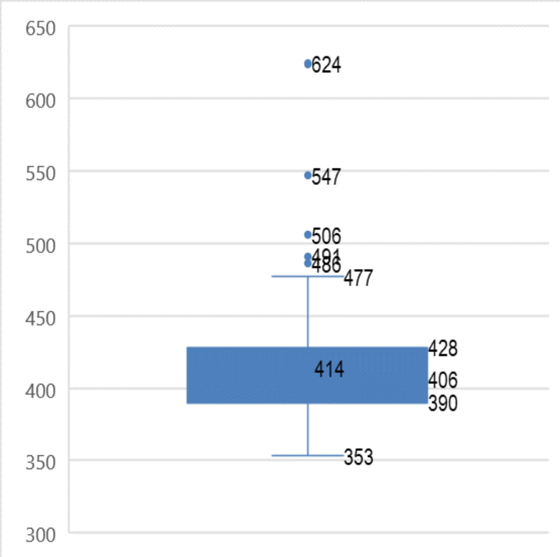

Fig. 28 VRSP Task Completion Durations Range (seconds)

The range of the participants' task completion durations while completing the task by using VRSP are shown in Fig. (28) above.

Table 8 VRSP Observations Summary

VRSP Observations	**Average**
Task Completion Duration (TCD) [min:sec]	*06:55*
Usage Error Average Per Participant (EA)	*0.14*
Error Opportunity Rate (EOR)	*0.69%*
Error Frequency Rate (EFR)	*7.77%*
Error Intensity (EI)	*3*
Usage Explanation Requests Average (XA)	*0.12*
Explanation Requests Opportunity Rate (XOR)	*0.58%*
Explanation Requests Frequency Rate (XFR)	*8.65%*
Explanation Requests Intensity (XI)	*3*

The summary of the observed performance of the participants while using VRSP is shown in Tab. (8) above.

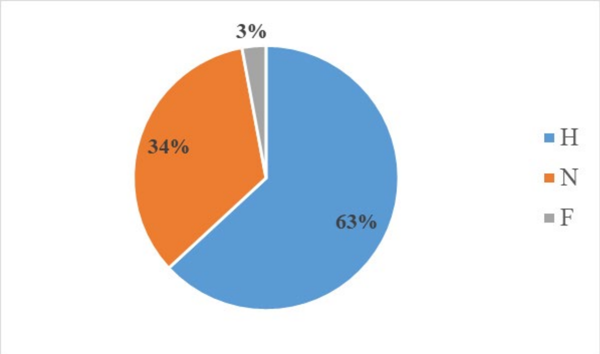

Fig. 29 The attitude of participants while completing the task

The participants' attitude, as shown in Fig. (29), was observed from their facial expressions and overall demeanour, and was categorized into three ratings, Happy (H), Neutral (N), and Frustrated (F).

Survey Ratings

Table 9 VRSP Survey Rating Overview

High Construct	Middle Construct	Lower Construct	Survey	Properties	Rating
SPX	IX	PX	**Q1**	*Intuitiveness*	0.9
			Q2	*Interactivity*	0.86
		EX	**Q4**	*Attractiveness*	1.06
			Q6	*Emotionally Engagement*	0.17
		CX	**Q7**	*Interestingness*	1.22
			Q8	*Cognitive Engagement*	1.02
	RWD		**Q10**	*Timelessness*	0.55
			Q11	*Attentiveness*	0.78
			Q12	*Responsiveness*	1.25
	SPE		**Q3**	*Friendliness*	0.72
			Q5	*Pleasantness*	0.93
			Q9	*Usefulness*	0.9
ItA			**Q13**	*Convincingness to adopt*	0.81
			Q14	*Willingness to re-use*	1.07
			Q15	*Readiness to recommend*	1.0
VRSP Average					**0.88**

The average ratings of the participant for each of the UX properties are displayed in Tab. (9) above.

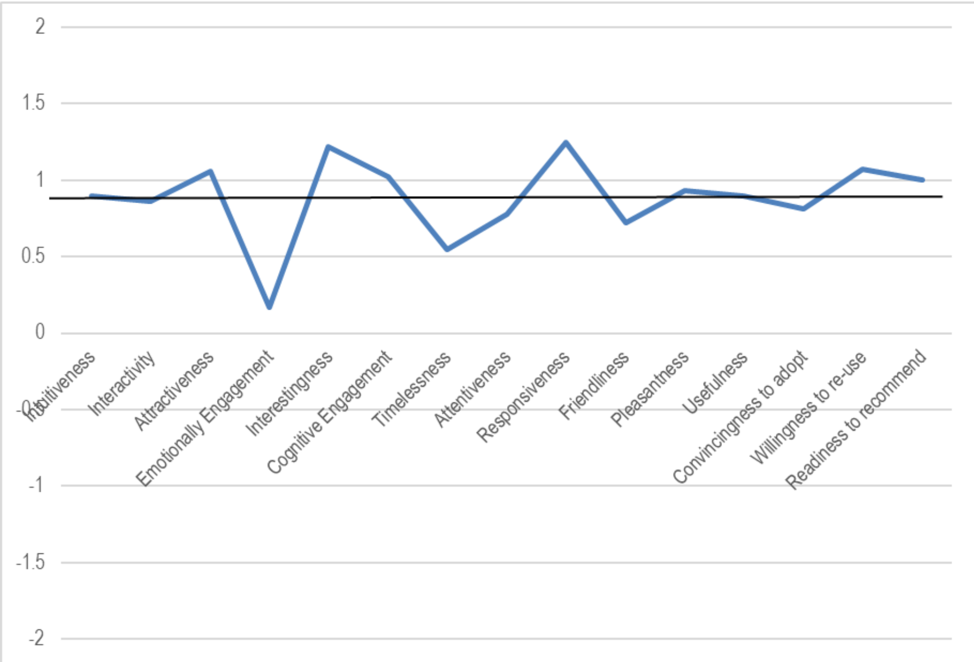

Fig. 30 VRSP Survey Quantitative Results Curve

A graphical representation of the VRSP ratings is displayed in Fig. (30) above. This seems to indicate that the VR simulation attracted and interested the participant, and especially the ones with no previous VR experience or biases of the technology. Cognitive engagement is a strong suite of VR, as the immersion can overpower the brain and imply to the user that they are in a different environment than they really are. The average rating of the emotional engagement property was lower than the survey average. This might be contributed to the fact that the simulated VR environment was giving a sterile feel to some participants as it was done from first person prospective and there were no avatars or characters used. Only simple virtual markers and a virtual replication of the metal construction for user illustration, where only the steps of the disassembly and reassembly metal construction are shown. The properties that was rated above the VRSP average ratings were the (a) attractiveness, (b) interestingness, (c) cognitive engagement, (d) responsiveness interactivity, (e) usefulness and (f) willingness to adopt properties. The VRSP ratings show that most of the properties where rated above the average rating but the (i) user friendliness, (ii) emotional engagement, (iii) attentiveness, and (iv) adoption degree properties were rated below the survey average rating.

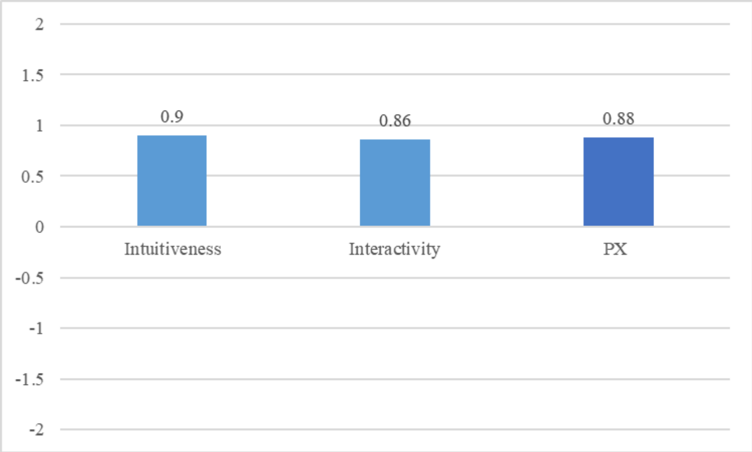

Fig. 31 VRSP Perceptual Immersion Rating

In Fig. (31) the Perceptual Immersion (PX) construct is presented with its two properties, intuitiveness, and interactivity. The PX average rating is equal the VRSP SPX rating, as such PX rating could be considered as average. This rating could be interpreted as that the participants did enjoy the intuitiveness and interactivity of the VR, but some might have felt discomfort or felt that it is not as friendly as they excepted.

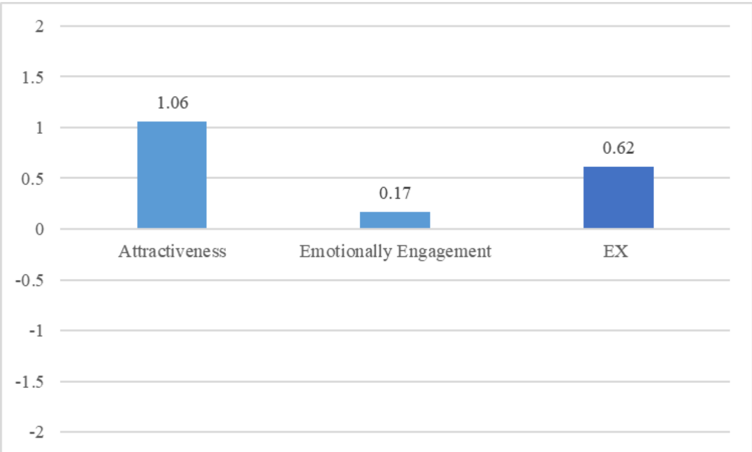

Fig. 32 VRSP Emotional Immersion Rating

In Fig. (32) the Emotional Immersion (EX) average rating is displayed, it is represented by averaging the attractiveness, and emotional engagement properties. The EX rating of 0.62, which is rated lower than both the SPX and PX ratings. This low rating is due to the emotional engagement property, as the VR lacked an avatar and had only a room with a sky background with three mechanical parts and a screw driver as the guiding to for the training. In this assisted simulation training the participant could interact with a step by step instructional manual of the mechanical construction in a 3D VR environment. Notably the participants rated the attractiveness highly, which might indicate that most of the participants also enjoyed the graphics and visualization of the VR environment.

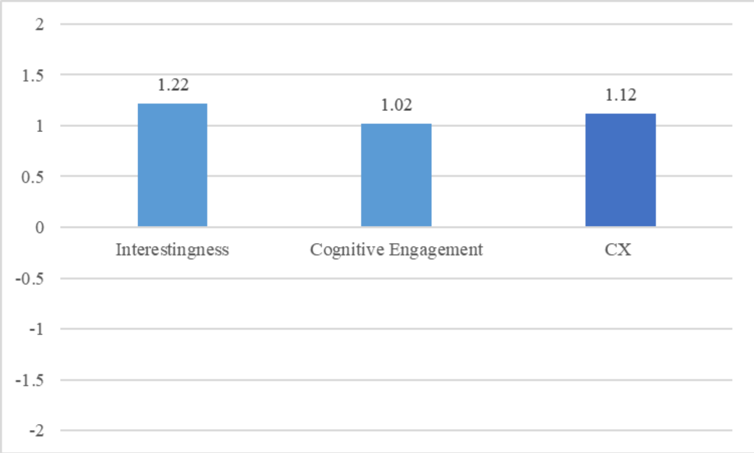

Fig. 33 VRSP Cognitive Immersion Rating

In Fig. (33) Cognitive Immersion (CX) construct is displayed, which is the construct based on the average of the interestingness, and cogitative engagement properties. The average rating of 1.12 is higher than the VRSP SPX rating, and also higher than the PX and EX ratings. The CX ratings might indicate that VR is interesting to the participants as well as cognitively engaging, which is to be expected as it totally immerses that participant in another environment, which seems to be working for most of the participants.

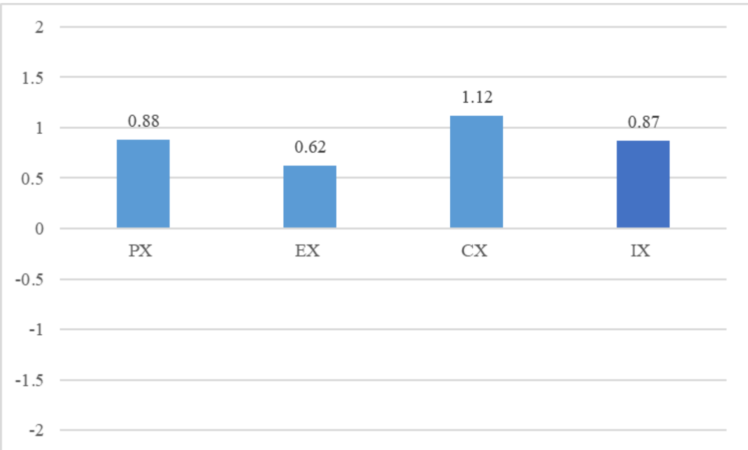

Fig. 34 VRSP Immersiveness Rating

Presented in Fig. (34), the Immersiveness (IX) construct is based on the average of the of (a) Perceptual, (b) Emotional, and (c) Cognitive eXperience ratings. The IX rating was expected to be the highest rating in regards to the VRSP form, as VR it offers the highest form of immersion. This could be attributed to the fact that participants were fully immersed in a VR environment to learn disassembling and reassembling the mechanical parts to be able to do it in the reality. A higher IX might improve the understanding or impact the learning curve as it learned through an experience, and the experience might improve significantly if the senses are immersed. The IX rating is 0.87 which is almost exactly the same as the VRSP SPX rating.

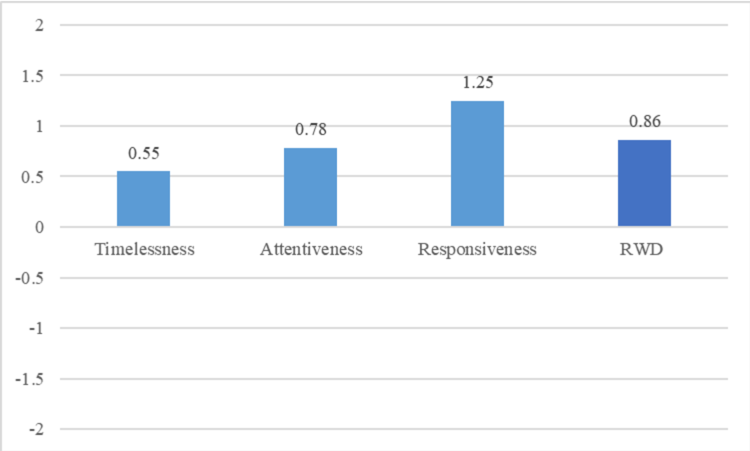

Fig. 35 VRSP Real World Dissociation Rating

In Fig. (35) Real World Dissociation (RWD) rating is graphically displayed, it is calculated by averaging the timelessness, attentiveness, and responsiveness properties together. The RWD is rated with 0.86, which is almost the same as the average survey rating, this shows that the participants might have had some kind of time and place distortion but they felt that the responsiveness of the prototype was positive. The RWD rating is also almost the same as the IX rating, which might suggest that the participant felt more immersed than disassociated, which might be a positive sign for usage.

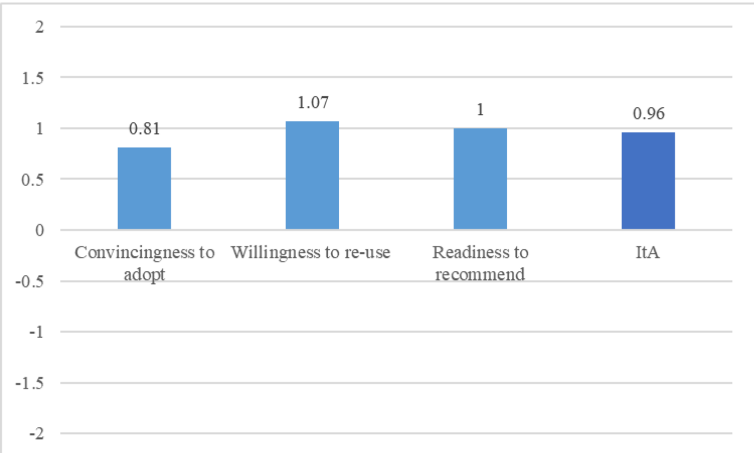

Fig. 36 VRSP Intention to Accept/Adopt Rating

Fig. (36) shows the participants' intention to accept and adopt (ItA) rating, which is composed of the convincingness to adoption, willingness to re-use, and readiness to recommend to others. The ItA rating of 0.96, which is only 10% higher than the average survey rating. This difference shows that the adoption is also above average and that more participants are willing to re-use in their own process and also willing to recommend for others. ItA rating is also higher than that of IX. The acceptance and adoption intention level is vital, as it is the most important aspect for future implementation, as even the best methods or tools might not be used due to low user acceptance.

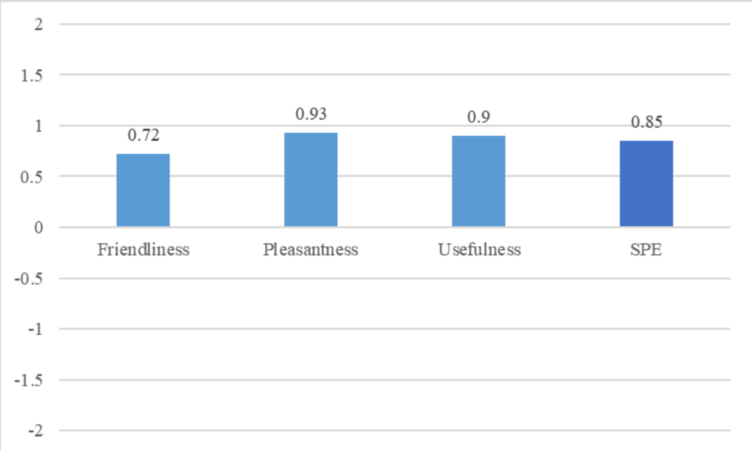

Fig. 37 VRSP Service Prototype Effectiveness Rating

As shown from Fig. (37) the VRSP SPE rating consists of the average of the friendliness, pleasantness, and usefulness ratings. The SPE rating is 0.85 which is also near to the SPX rating, which shows that most of the participants found VRSP effective and pleasant to use.

Survey Justification

Table 11 VRSP Sentiment Analysis

Survey Properties	Average (-1 → +1)
Intuitiveness	0.57
Interactivity	0.52
Friendliness	0.42
Attractiveness	0.62
Pleasantness	0.58
Emotionally Engagement	0.06
Interestingness	0.76
Cognitive Engagement	0.69
Usefulness	0.61
Timelessness	0.34
Attentiveness	0.53
Responsiveness	0.71
Adoption degree	0.48
Willingness	0.59
Recommendation degree	0.58
VRSP Sentiment	0.54

The sentiment of the participants' justification, as shown in Tab. (11) above, was gauged by categorizing their justifications into three categories, positive (+1), neutral (0), and Negative (-1).

Fig. 38 VRSP Sentiment Word cloud

As shown in Fig. (38), where all the rating justifications of VRSP are summed up in a graphic of a cloud of words. The most repeated word for the VRSP was understand, useful, interaction, easy, steps, time, good and immersed as well. This shows that VRSP according to the participant's comments, interactive, with isolated environment, where it is easy and simple to understand while also being user-friendly and immersive.

ARSP (Augmented Reality Based) Extended Results

Observations Results

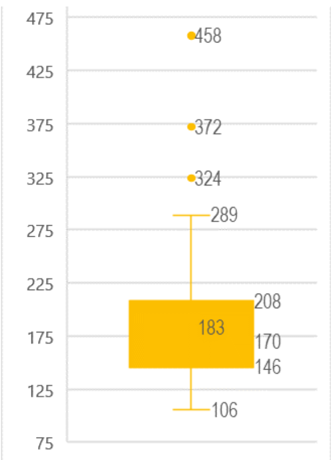

Fig. 39 ARSP Task Completion Durations Range

The range of the participants' task completion durations while completing the task by using ARSP are shown in Fig. (39) above.

Table 12 ARSP Observed Performance Values

Observations	Average
Task Completion Duration (TCD) [min:sec]	**03:03**
Usage Error Average Per Participant (EA)	**0.14**
Error Opportunity Rate (EOR)	**0.68%**
Error Frequency Rate (EFR)	**10.68%**
Error Intensity (EI)	**2**
Usage Explanation Requests Average (XA)	**0.31**
Explanation Requests Opportunity Rate (XOR)	**1.55%**
Explanation Requests Frequency Rate (XFR)	**18.45%**
Explanation Requests Intensity (XI)	**4**

The summary of the observed performance of the participants while using ARSP is shown in Tab. (12) above.

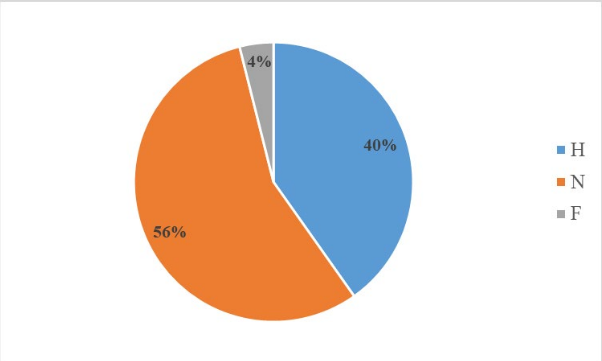

Fig. 40 The attitude of the participants' towards ARSP

The participants' attitude, as shown in Fig. (40), was observed from their facial expressions and overall demeanour, and was categorized into three ratings, Happy (H), Neutral (N), and Frustrated (F).

Survey Ratings

Table 13 ARSP Survey Properties Ratings

High Construct	Middle Construct	Lower Construct	Survey	Properties	Rating
SPX	**IX**	**PX**	**Q1**	*Intuitiveness*	1.34
			Q2	*Interactivity*	0.96

		EX	**Q4**	*Attractiveness*	1.12
			Q6	*Emotionally Engagement*	-0.18
		CX	**Q7**	*Interestingness*	1.19
			Q8	*Cognitive Engagement*	1.05
		RWD	**Q10**	*Timelessness*	-0.09
			Q11	*Attentiveness*	-0.75
			Q12	*Responsiveness*	0.34
	SPE		**Q3**	*Friendliness*	1.06
			Q5	*Pleasantness*	0.93
			Q9	*Usefulness*	1.2
ItA			**Q13**	*Convincingness to adopt*	1.09
			Q14	*Willingness to re-use*	1.18
			Q15	*Readiness to recommend*	1.25
ARSP Average					**0.78**

The average ratings of the participant for each of the UX properties are displayed in Tab. (13) above.

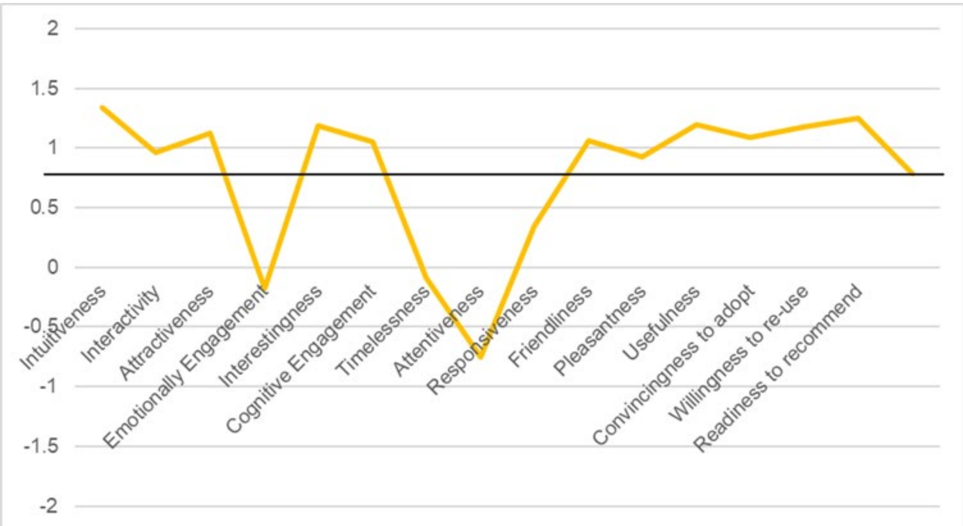

Fig. 41 ARSP Survey Quantitative Results Curve

The ratings curve and the average rating is shown in Fig. (41) above. ARSP was one of the highest rated SP forms with an average of 0.78 displayed with the black straight line cutting the curve above. Almost all of the properties were rated above the average, except the emotional engagement, timelessness, attentiveness, and responsiveness were all rated below the average. The intuitiveness interestingness, and willingness to re-use properties were rated exceptionally well. To be able to fully understand ARSP survey ratings, it is needed to do an analysis on its five constructs, the IX, RWD, SPE, ItA and SPX, which covers the whole survey quantitative results.

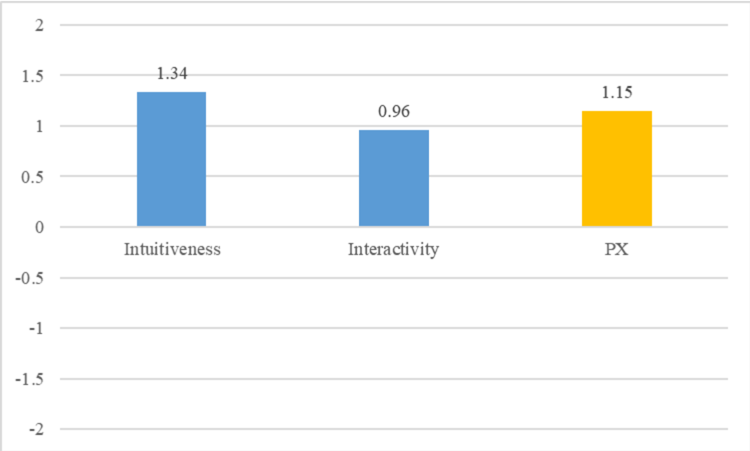

Fig. 42 ARSP Perceptual Immersion Survey Rating

The first construct to discuss is the perceptual immersion (PX) is shown in Fig. (42), where the PX is the average of the two properties intuitiveness, and interactivity. The PX average is 1.15 this is a high rating, considering the average rating of the 0.78, this shows that is PX is much higher than the average. This high rating might be due to the perceptual prowess of AR, which fascinates a lot of people as it a power visual tool.

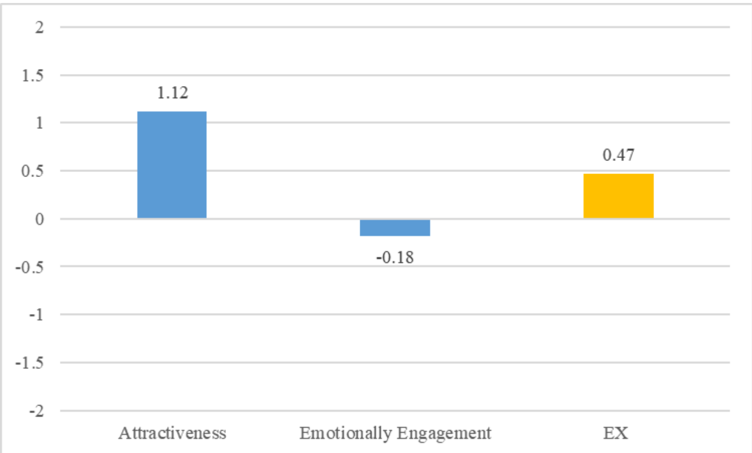

Fig. 43 ARSP Emotional Immersion Survey Rating

The second construct is the emotional immersion (EX), as shown in Fig. (43), which is composed of the collective ratings of the attractiveness and emotional engagement ratings. The participants rated the EX with 0.47 which is much lower than the SPX average rating. This might be attributed to the negative rating of the emotional engagement, as it is only an AR tablet App with an almost clinical instructional step by step guide, which might not engage the participants on their emotional aspects by using an avatar or some kind of personalization of a higher “sense of being”.

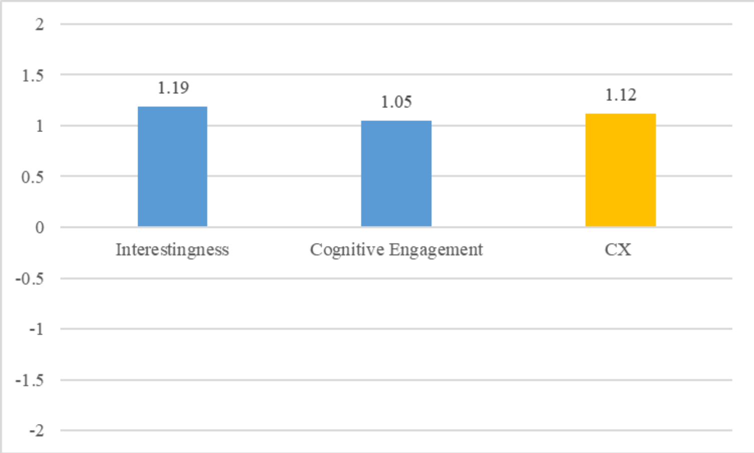

Fig. 44 ARSP Cognitive Immersion Survey Rating

The cognitive immersion (CX) rating consists of the average of the interestingness, and cognitive engagement as shown in Fig. (44). CX average is 1.12 which is higher than the other IX properties, and much higher than the survey average rating as well. The CX is much higher rated than the SPX average rating, which shows the AR visualization effect on the participants as they rated it highly in the interestingness and usefulness properties. AR was expected to excel in the cognitive immersion aspect, as it engages with the participants with overlaying the instructional information to aid them in completing the task.

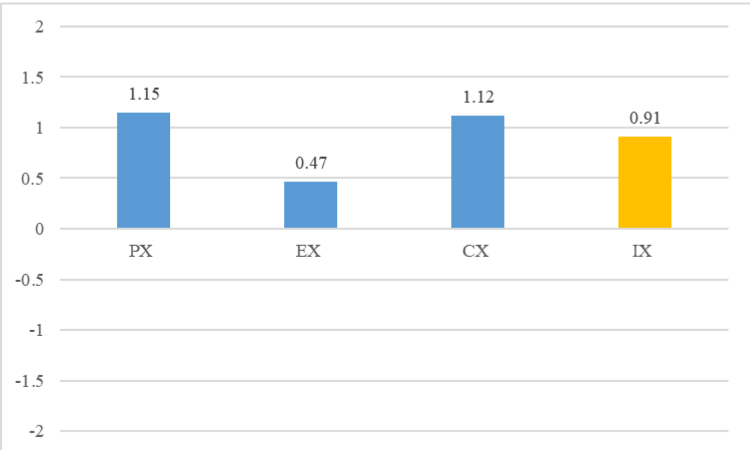

Fig. 45 ARSP Immersiveness Rating

The Immersiveness construct rating is composed of the average of the PX, EX, and CX ratings as shown in Fig. (45). IX rating is 0.91, which is relatively higher than the SPX rating. This might suggest that the participants felt a high immersion due to the AR visualizations, however it shows that the emotional experience of AR is lacking as it rated much lower than the perceptual and cognitive experiences. IX of ARSP is % lower than that of VRSP, which is also logical as VR offers a higher degree of immersion as such was expected that it would have a higher rating.

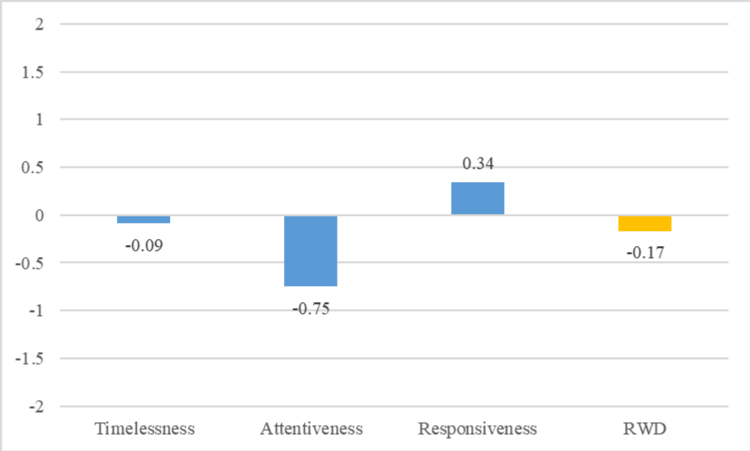

Fig. 46 ARSP Real World Dissociation Rating

The real world dissociation rating is the average of timelessness, attentiveness, and responsiveness ratings of the participants as displayed in Fig. (46) above. The RWD was negatively rated due to the negative rating of the attentiveness, as numerous participant's mentioned that they are "absolutely normal" or that they are highly attentive to their surroundings, and having a clear view of the surroundings. The RWD rating is -0.17 which is 120% lower rated than the SPX rating, which is considerably low but is understandable as the participant are not immersed at all, as such feeling as it is normal or real, so less dissociation compared to VRSP and MRSP.

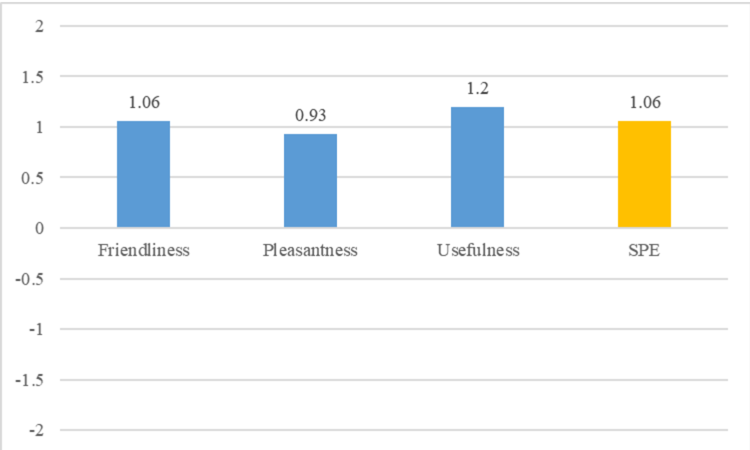

Fig. 47 ARSP Service Prototype Effectiveness Rating

The intention to accept and adopt is based on the three ratings of friendliness, pleasantness, and usefulness as shown in Fig. (47) above. The SPE rating is 1.06 which is relatively high compared to the SPX average rating. This rating might be an indicator that most of the participants accepted the ARSP and are willing to adopt it as a service prototyping form.

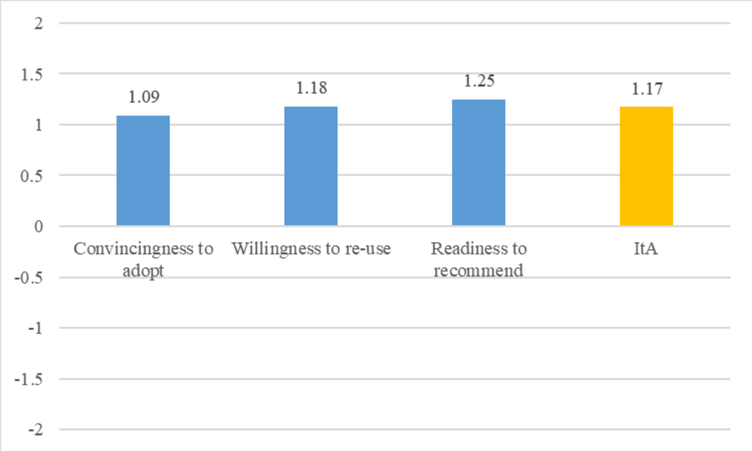

Fig. 48 ARSP Intention to Accept and Adopt Rating

The acceptance of any SP form is one of the most important aspects for the success of this SP form, the acceptance construct rating is based on the adoption degree, willingness to re-use, and recommendation degree ratings. The ItA rating was 1.17 as represented in Fig. (48), this shows that AR has a high acceptance rate as all the properties was rated higher than the SPX rating by more than 50%. This rating shows that the participants are willing to re-use AR in their own process, and even recommended to others, which shows that the AR technology is getting more recognition and can be adopted well with the mass in similar processes.

Justifications Ratings

Table 14 ARSP Survey Justification Sentiment

Survey	Average (-1 → +1)
Intuitiveness	0.79
Interactivity	0.54
Friendliness	0.7
Attractiveness	0.79
Pleasantness	0.62
Emotionally Engagement	-0.14
Interestingness	0.72
Cognitive Engagement	0.66
Usefulness	0.77
Timelessness	0.15
Attentiveness	-0.33
Responsiveness	0.08
Adoption degree	0.66

Willingness	0.72
Recommendation degree	0.7
ARSP Sentiment	**0.50**

The sentiment of the participants' justification, as shown in Tab. (14) above, was gauged by categorizing their justifications into three categories, positive (+1), neutral (0), and Negative (-1). The results are displayed in a table form and in form of Word cloud, where all the justification for one questions are combined in a cloud of words to show, to show which words were the most mentioned ones.

Fig. 49 ARSP Survey Sentiment Word cloud

The participants' feedback in form of the ratings justifications was overall positive, and this can be seen from the words they used to justify their ratings, as seen in Fig. (49) above. The most used words were "understand", "easy", "useful", "clear" and "focused", which all suggest that the participants referred to ARSP as a good communication tool that is easy and clear to use. The participants also felt focused on the task and had clear instructions on how to complete the task, without any further explanation.

MRSP (Mixed Reality Based) Extended Results

Observations Results

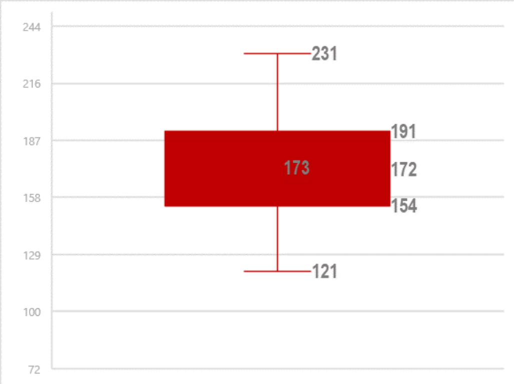

Fig. 50 MRSP Task Completion Duration Range (seconds)

The range of the participants' task completion durations while completing the task by using MRSP are shown in Fig. (50) above.

Tab. 15 MRSP Observations Summary

MRSP Observations	**Average**
Task Completion Duration (TCD) [min:sec]	02:53
Usage Error Average Per Participant (EA)	0
Error Opportunity Rate (EOR)	0%
Error Frequency Rate (EFR)	0%
Error Intensity (EI)	0
Usage Explanation Requests Average (XA)	0
Explanation Requests Opportunity Rate (XOR)	0%
Explanation Requests Frequency Rate (XFR)	0%
Explanation Requests Intensity (XI)	0

The summary of the observed performance of the participants while using PSP is shown in Tab. (15) above.

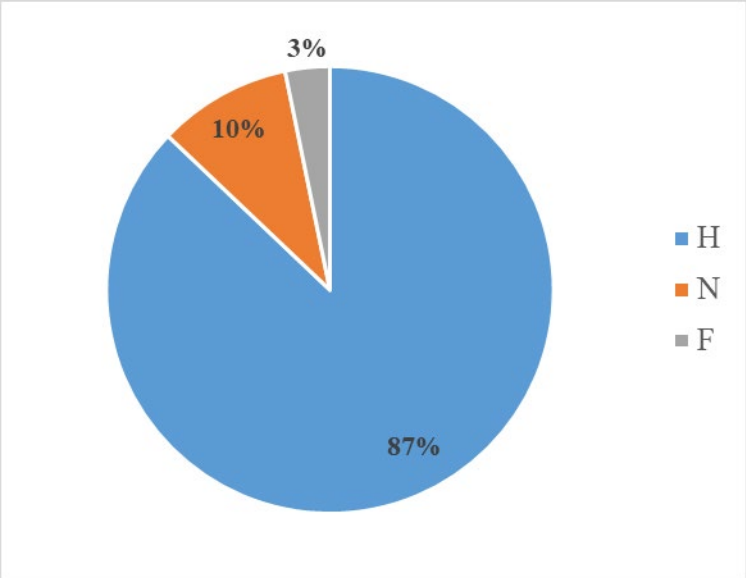

Fig. 51 The attitude of the participants using MRSP

The participants' attitude, as shown in Fig. (51), was observed from their facial expressions and overall demeanor, and was categorized into three ratings, Happy (H), Neutral (N), and Frustrated (F).

Survey Ratings

Table 16 MRSP Survey Ratings

High Construct	Middle Construct	Lower Construct	Survey	Properties	Rating
SPX	IX	PX	**Q1**	*Intuitiveness*	1.43
			Q2	*Interactivity*	1.17
		EX	**Q4**	*Attractiveness*	1.27
			Q6	*Emotionally Engagement*	-0.03
		CX	**Q7**	*Interestingness*	1.27
			Q8	*Cognitive Engagement*	1.60
	RWD		**Q10**	*Timelessness*	-0.23
			Q11	*Attentiveness*	-0.77
			Q12	*Responsiveness*	0.40
	SPE		**Q3**	*Friendliness*	1.4
			Q5	*Pleasantness*	1.27
			Q9	*Usefulness*	1.30
ItA			**Q13**	*Convincingness to adopt*	1.53
			Q14	*Willingness*	1.50
			Q15	*Readiness to recommend*	1.40

SPX	0.97

The average ratings of the participant for each of the UX properties are displayed in Tab. (16) above.

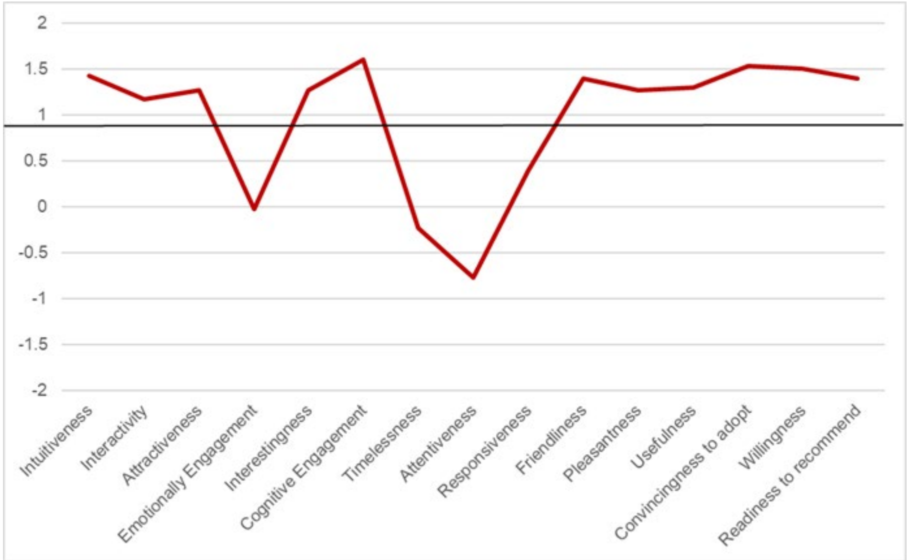

Fig. 52 MRSP Survey Quantitative Results Curve

As shown in Fig. (52) above, where the average rating curve is displayed for all the properties, is seems that most of the properties were rated higher than the average rating, and only the emotional engagement, sense of time, and sense of surroundings properties were rated negatively and also lower than the average. The negative rating in the sense of time and surroundings could be due the fact that the participants were wearing the Hololens and it give a distorted sense of time, and due to overlaid holograms could also distort the sense of environment awareness. To be able understand more the feedback of the participants a look on their ratings for the different lower and higher construct as an individual rating and in the collective as well.

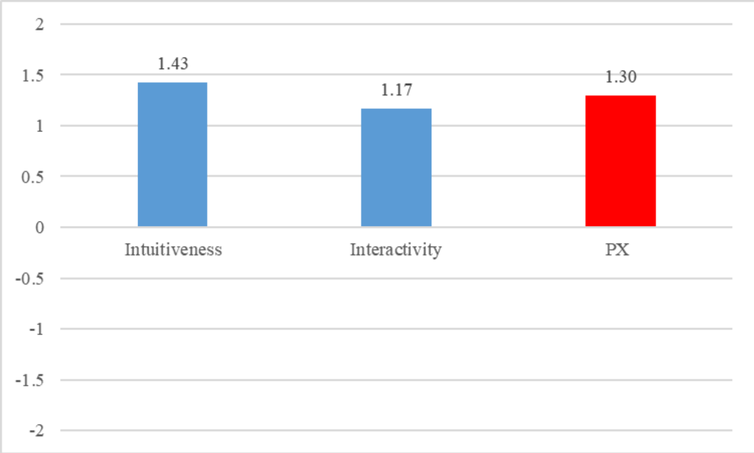

Fig. 53 MRSP Perceptual Immersion Rating

The perceptual immersion construct (PX) is comprised of the ratings of intuitiveness and interactivity, as shown in Fig. (53) above, where the participants rated the PX positively with a rating of 1.30. PX rating is more than 30% higher than the SPX rating, which suggests that the participants were highly fascinated with the intuitively of the prototype, and its user friendliness as well. The interactivity rating was lower than the other two properties of PX, but none the less it was positive, showing that most of the participants found MRSP interactive.

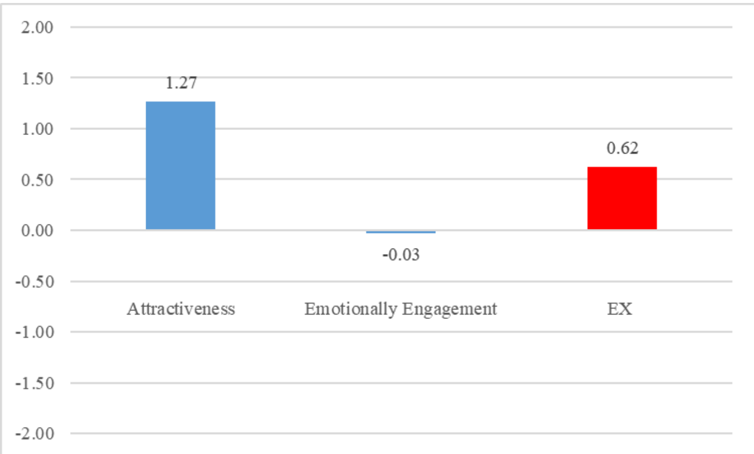

Fig. 54 MRSP Emotional Immersion Rating

The emotional immersion (EX) of MRSP was rated according to the attractiveness, and emotional engagement properties as shown in Fig. (54) above. EX was rated with 0.62, which was lower than the SPX average that could be due the almost neutral rating for the emotional engagement property. The participants found MRSP not emotionally engaging, which might be due to that there is no storytelling properties to the prototype, or as it lacks verbal interaction and also doesn't have any avatar or any personalization. Participants rated EX much lower than the PX, showing the difference of the emotional and perceptual engagement of MRSP.

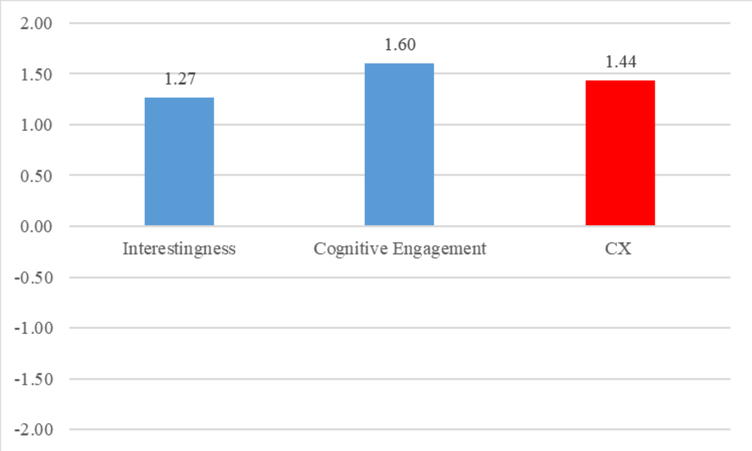

Fig. 55 MRSP Cognitive Immersion Rating

The cognitive immersion (CX) rating is shown in Fig. (55) above, where the participants rate their interest in the prototype, the prototype's, and ability to cognitively engage them. CX was rated 1.44, which is almost 50% higher than the SPX rating that shows that most of the participants were cognitively engaged with the prototype and they felt that is interesting and helpful in completing the task. CX was rated only a bit higher than PX, but much higher than EX, which might suggest that the participants felt that MRSP is more cognitively and perceptually than emotionally engaging. MRSP relies on the holograms and the immersion effects to enable the participants to extract the vital information for the assembly task.

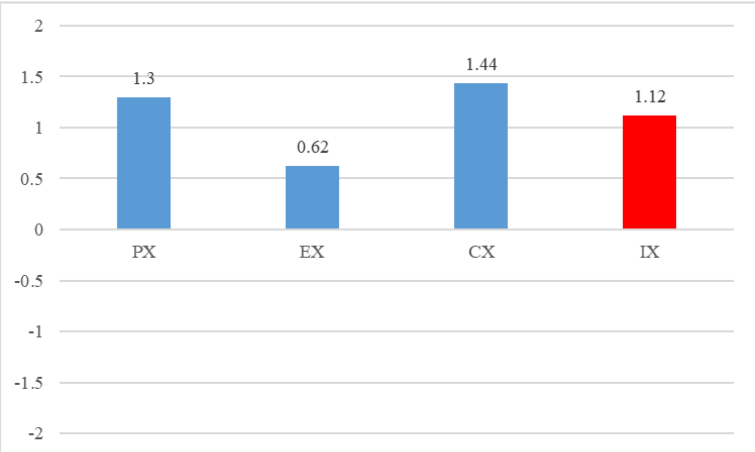

Fig. 56 MRSP Immersiveness Constructs

Immersiveness (IX) is constructed, as represented in Fig. (56) above, from averaging the PX, EX, and CX ratings. IX was rated 1.12 which is 23% higher than the average. This difference in ratings shows that the participants felt the immersiveness of the MR device and that was reflected in the highly positive rating. The ratings show that most of the participants were cognitively engaged with the prototype and they felt that is interesting and helpful in completing the task. CX was rated only a bit higher than PX, but much higher than EX, which might suggest that the participants felt that MRSP is more cognitively and perceptually than emotionally engaging. MRSP relies on the holograms and the immersion effects to enable the participants to extract the vital information for the assembly task.

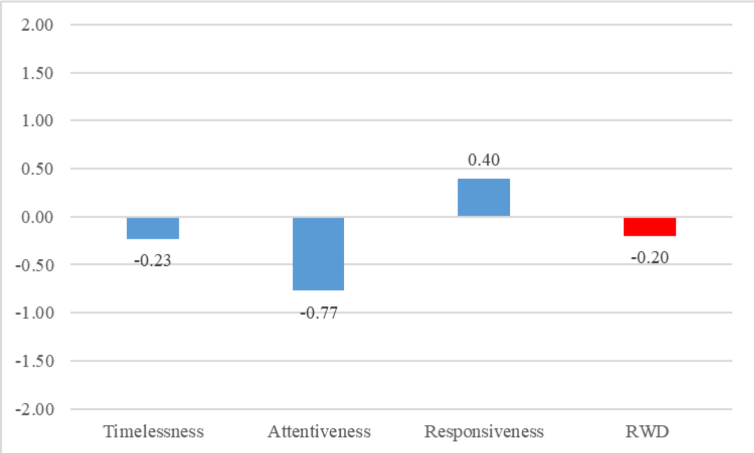

Fig. 57 Real World Dissociation Construct Rating

To describe the real world dissociation (RWD), the participants were asked to rate their sense of time, awareness of surroundings and the responsiveness to outside factors as seen in Fig. (57) above. RWD was rated with .020 by the participants, which could be attributed to the negative rating of the sense of awareness to surroundings. RWD is rated 166% lower than the average, this negative rating could be due to the fact that the participants had to wear the Hololens on their head and their vision or peripheral vision was partially impaired due to the device positioning or dimensions. The RWD rating of -0.2 is not significant negative rating per say as it near to the neutral rating, but nonetheless it shows there is a differences between the participants in the sense of time and awareness.

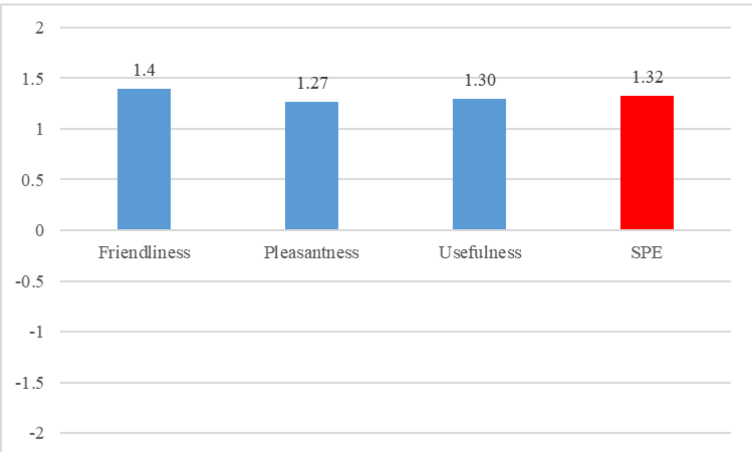

Fig. 58 SP Effectiveness Construct Rating

The intention to accept and adopt is based on the three ratings of friendliness, pleasantness, and usefulness as shown in Fig. (58) above. The participants rated the SPE with a 1.32, which is higher than the SPX rating. This high rating could be contributed to the fact that the participants felt that MRSP is friendly to use, and useful as well. This shows that the MRSP could be considered as the most effective SP form, as it has the highest SPE rating from all the SP forms in the experiment.

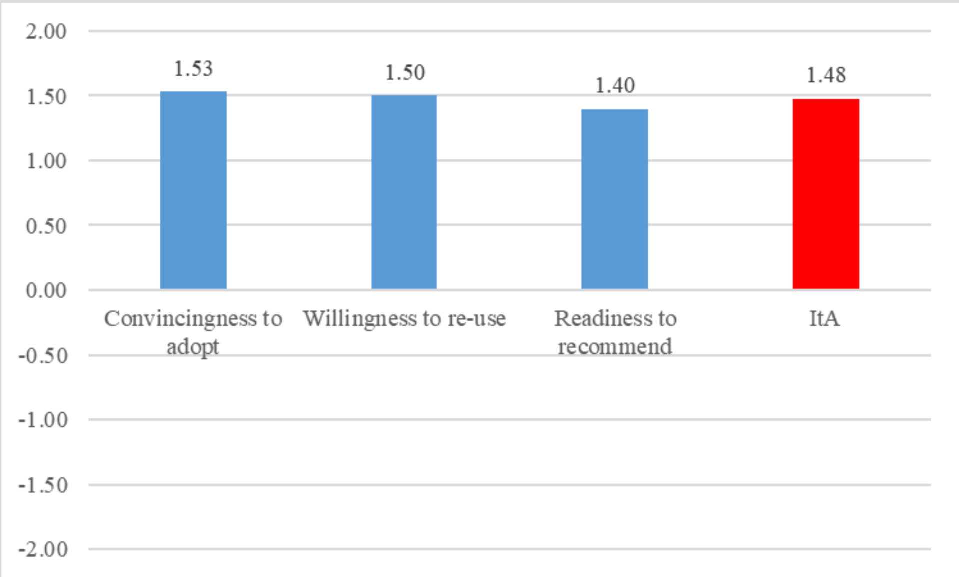

Fig. 59 Intention to Accept and Adopt Construct Rating

The participant's intention to accept and adopt (ItA) is described by the ratings of the degree of adoption, willingness to use, and the recommendation degree as seen in Fig. (59) above. ItA was rated with 1.48, which is 53% higher than the SPX that shows that most of the participants accepted MRSP as a tool for communicating, especially in a learning contexts. The ItA rating is an indication of how will this SP form perform in a real situation, as the participants' acceptance and willingness to reuse, and even recommend to other was high and apparent. The participant acceptance of any SP form is the first step of success for that form, and the participants did rate the ItA positively.

Rating Justifications

Table 17 MRSP Survey Rating Justifications Sentiment

Survey	**Sentiment Average (-1 → +1)**
Intuitiveness	*0.52*
Interactivity	*0.25*
Friendliness	*0.52*
Attractiveness	*0.59*
Pleasantness	*0.42*
Emotionally Engagement	*0.25*
Interestingness	*0.8*
Cognitive Engagement	*0.57*

Usefulness	*0.74*
Timelessness	*0.1*
Attentiveness	*0.15*
Responsiveness	*0.67*
Adoption degree	*0.75*
Willingness	*0.53*
Recommendation degree	*0.63*
MRSP Sentiment	**0.50**

The sentiment of the participants' justification, as shown in Tab. (16) above, was gauged by categorizing their justifications into three categories, positive (+1), neutral (0), and Negative (-1). To paint a complete picture on the MRSP sentiment, a Word cloud of the most mentioned words in the participant's comments was created.

Fig. 60 MRSP Sentiment Word cloud

The MRSP participants' sentiment was positive, which is also reflected in the words that the participants used in their comments in the justification section as shown in Fig. (60) above. The most mentioned words by the participants were "*time*", "*understand*", "*complex*", "*fun*", "*information*", "*useful*" and "*simple*". The participants verbally commented on the immersive capabilities of the MR device, and how the holograms distort the sense of time. The participants also were able to understand fully the instructions and they even recommended it for more complex processes, as it will provide the necessary information when needed. The participants' positive sentiment could be also seen as the participants mentioned word like fun and exciting, which shows that participants enjoyed using MRSP and that they felt that MRSP was simple, enjoyable and beneficial.

SP Sequence One Comparisons

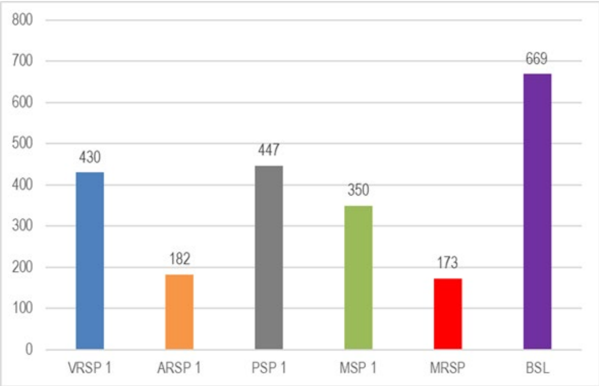

Fig. 61 SP Sequence One Task Completion Duration

The average duration of each SP form in comparison to each other and the duration of the benchmark from the baseline experiment, as shown in Fig. (61) above.

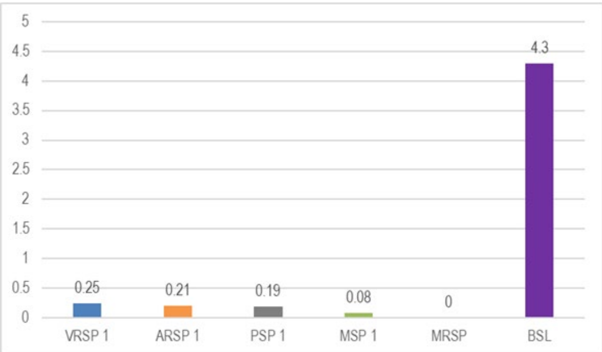

Fig. 62 SP Sequence One Errors Committed

The errors made while completing the task, whether with the use of a SP form in the first sequence and in the baseline experiment as well are shown in Fig. (62) above.

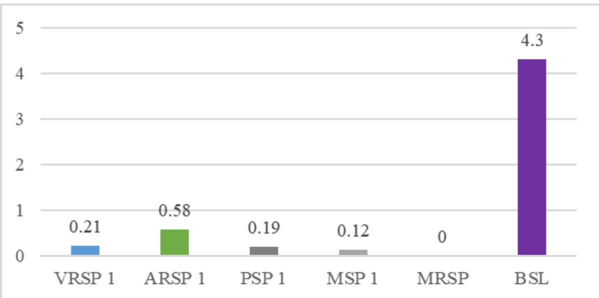

Fig. 63 SP Sequence One Explanation Requests

The explanations requested while using each of the SP forms in the first sequence against the baseline experiment in the first sequence are shown in Fig. (63).

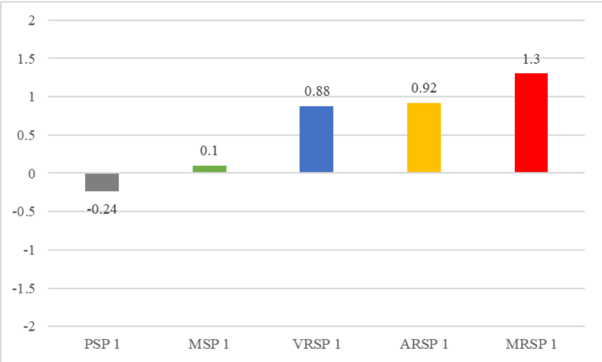

Fig. 64 Perceptual Immersion Ratings Sequence One

The PX construct ratings show that ARSP is the clear favorite after MRSP, as seen in Fig. (64) above. The rating of MRSP could be due to the fact that MR offers a high perceptual experience with overlaying information and visualization on top of the real world and offering interaction with natural hand gestures moves definitely added to the high rating. The participants were also pleased with ARSP as it offers a guided step by step instructions to complete the task with an element of immersion due to the AR markers projecting the next steps on the tablet screen.

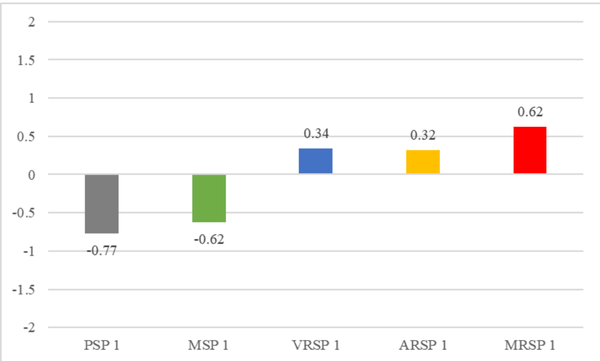

Fig. 65 Emotional Immersion Ratings Sequence One

The participants rated the EX construct highly in MRSP, but they rated VRSP and ARSP with similar rating as shown in Fig. (65) above. This shows that the participants were most emotionally engaged with the interaction of the MR holograms, but they were also positively motivated with the VRSP and ARSP. The opposite could be said for both PSP and MSP, as the participants rated EX in both SP forms negatively, as both offer limited or no interaction, and no storytelling elements or fascinating graphics.

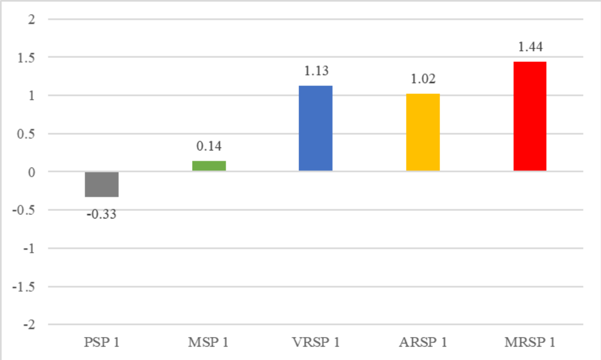

Fig. 66 Cognitive Immersion Ratings Sequence One

Immersive technologies excel in the cognitive immersion as shown from the participant's ratings in Fig. (66), MRSP was rated the highest, but ARSP and VRSP were both positively rated as well. This is capability of immersive technologies to trick the mind and body into thinking that we are someplace else or even trick our senses to think that these visualizations are real and out brain reacts positively to it. MSP was rated also positively as the participants felt that the video engaged them as well, this could be attributed to the fact that we are in the age of video, with platforms like YouTube and other streaming services, video content was never as easy to get to as now.

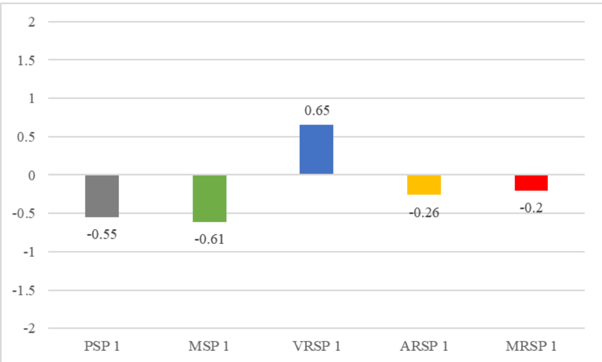

Fig. 67 Real World Dissociation Ratings Sequence One

The real world dissociation rating is based upon the sense of time, presence, and responsiveness, where +2 the highest rating meaning the highest dissociation, and -2 meaning the lowest dissociation, where 0 is the neutral, which is similar to the real world. The Fig. (67) above shows that MRSP and ARSP were both near to the neutral, which shows that the participants felt that they are in their normal condition. The participant's ratings of the VRSP RWD construct shows that they felt a distortion in their sense of time and presence where they felt the time passing faster and even some participants faced cyber-sickness as well. The participant's ratings of PSP and MSP RWD ratings demonstrate that they were feeling time was passing slower, some participants were bored and felt that it took too long.

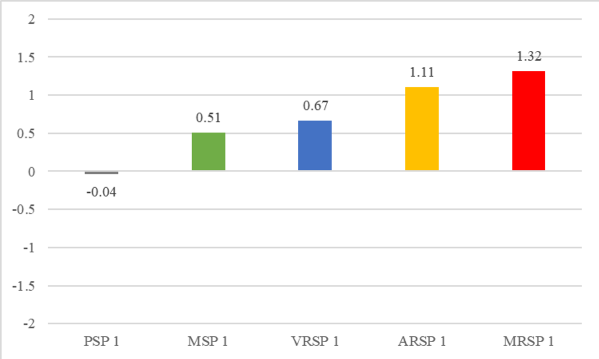

Fig. 68 Service Prototype Effectiveness Ratings Sequence One

The rating of the SPE as seen in Fig. (68), show that the participants rated the effectiveness of MRSP the highest, followed by ARSP. This represents a consensus that the participants found the AR and MR technologies to be the most effective in such assembly process, especially when it a guided instructional manual. The rating from VRSP came in third and MSP came near to the VRSP, which might indicate that the participants found both forms as effective but due to the fact that it is more like a training than a guided process, the ratings were much lower than MRSP and ARSP.

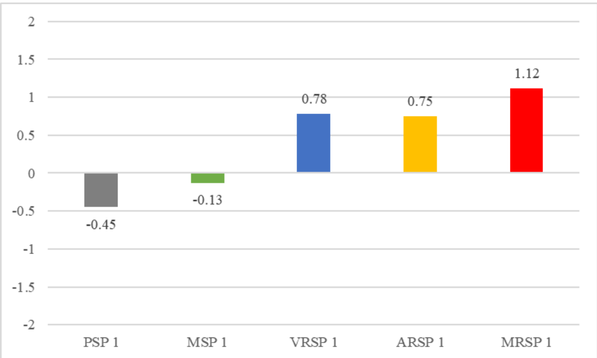

Fig. 69 Immersiveness Construct Ratings Sequence One

The immersion higher construct ratings are composed of the three lower constructs PX, EX and CX ratings, as such a comparison in their ratings is interesting to investigate. MRSP IX rating was the highest as shown in Fig. (69) above, as the participants were mostly impressed by the MR technology, and the realism of the holograms. The rating of ARSP and VRSP were also high but MRSP was rated higher than both, offering a more interactive hologram guide to the task that was not fully immersed seemed to be the most optimal solution for the participants. Surprisingly ARSP IX rating was higher than VRSP, which suggests that the participants found the AR guidance more immersive than the VR instruction simulation.

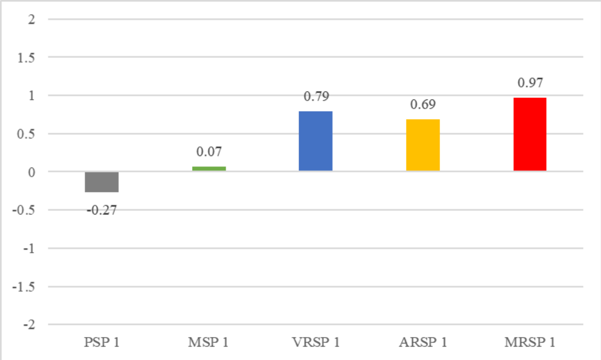

Fig. 70 Service Prototype Experience Ratings Sequence Position One

The SPX is based on the participant's average ratings combined, to gauge the experience of using the prototype, which is represented in Fig. (70) above. SPX displays an advantage for the MRSP on the VRSP, which shows that the participants enjoyed using VR much almost as much as they enjoyed MRSP, but their acceptance of it was much lower than MRSP. The participants gave PSP a negative SPX rating even in the first sequence, which shows that the dissatisfaction with the conventional service prototyping methods was not biased from a previous use of immersive SP as could be in the other sequences. This also shows that immersive technologies impacted the service prototyping experience as the ISPs were positive rated with a relatively good rating, while CSP were negatively rated. This shows that a higher immersion doesn't translate into a higher service prototyping experience, which invalidates the hypothesis about the SPX if adding MRSP to the comparison.

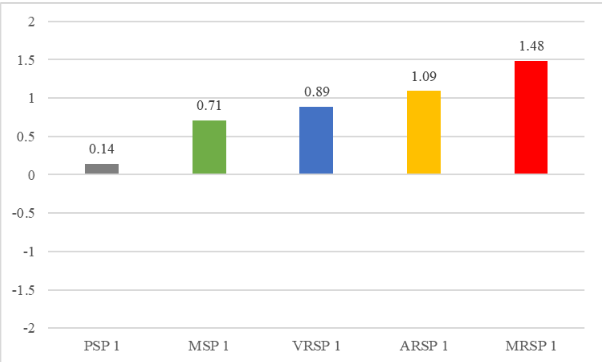

Fig. 71 Intention to Accept and Adopt Ratings Sequence One

The acceptance is a key factor in the success of any SP form, as such the acceptance degree of the participants was gauged by asking them if they would intend to accept and adopt the SP form, and the participants rating were positive in each of the SP forms as seen in Fig. (71) above. The MRSP has the highest intention for acceptance rating followed by ARSP, which shows that MR and AR technology have a high acceptance for prototyping purposes, especially for communicating and evaluating. The participants rating of MSP acceptance rating with a high as well, which came third after VRSP and higher than PSP, this shows that the participants acceptance for video as a communication tool is much higher than paper.

Résumé

De nos jours, le prototypage est largement utilisé dans l'industrie pour explorer des alternatives de conception en impliquant toutes les parties prenantes du projet. Cela est particulièrement vrai au stade antérieur du processus de conception lors des activités de Co-création et d'exploration. Cependant, les prototypes ont différentes formes, telles que : des formes physiques comme des maquettes, souvent basées sur l'impression 3D, ou des formes virtuelles basées sur des technologies immersives comme la réalité virtuelle (VR), la réalité augmentée (AR) ou même la réalité mixte (MR). Le principal avantage du prototypage a été synthétisé dans une phrase simple, exprimée par John Meada, un ancien professeur du MIT : « Si une image vaut mille mots, un prototype vaut mille réunions », cité par Banfield et al. (2017). Plus récemment, le secteur des services a également commencé à adopter le prototypage pour explorer des alternatives de conception de services (Blomkvist, 2014). Cela implique différents niveaux de complexité de service, tels que : conseil en ligne, configurateurs de machines et simulateurs pour la formation des opérateurs de machines ou plus simplement des conseils de montage et de démontage. Néanmoins, le corpus actuel de connaissances sur le prototypage de services manque de comparaison entre les formes de prototype de service (SP) - conventionnelles et immersives - qui aideraient les entreprises du secteur des services à sélectionner la forme de SP la plus appropriée. Dans ce contexte du secteur des services, notre enquête vise à apporter de nouvelles connaissances sur l'impact potentiel des technologies immersives sur la SP. Dans l'ensemble, cela aiderait les organisations de services à expérimenter une idée de service avant même que ce service existe réellement ou à prévoir la forme de SP la plus appropriée en fonction de leur contexte spécifique et du degré de complexité du service.

Une revue de la littérature a été réalisée afin d'identifier les facteurs d'impact objectifs et subjectifs potentiels. Notre modèle théorique d'adoption de SP créé permet de comparer différentes formes de prototypes de services en fonction de leurs performances respectives en termes d'achèvement, d'erreurs et de perception de l'utilisation. Ce modèle a été utilisé pour concevoir une expérience, qui implique des méthodes mixtes, permettant de collecter une quantité suffisante de données quantitatives pour exécuter une approche formative d'analyse statistique pour valider notre modèle d'adoption de SP. Tout d'abord, notre étude empirique a permis de valider notre modèle d'adoption de SP. Deuxièmement, il a dévoilé l'impact positif des technologies immersives sur le prototypage de services pour obtenir une expérience anticipée avant la mise en œuvre d'un service. Troisièmement, il a révélé les performances supérieures des formes AR et MR-SP par rapport aux formes VR et SP conventionnelles. Enfin, outre le fait évident que seules les formes AR et MR-SP permettent d'apprendre simultanément une opération de service, la forme VR-SP est celle qui présente le score d'immersion et d'adoption le plus élevé, notamment parce qu'elle permet d'explorer un service avant qu'il n'existe réellement.

Mots-clés : Conception de services, Prototypage de services, Technologies immersives, Réalité virtuelle, Réalité augmentée, Réalité mixte, Immersivité

Abstract

Nowadays, prototyping is widely used in the industry for exploring design alternatives by engaging all project stakeholders. This is especially true at the earlier stage of the design process during both co-creation and exploration activities. However, prototypes have different forms, such as: physical forms like mock-ups, often based on 3D-printing, or virtual forms based on immersive technologies like Virtual Reality (VR), Augmented Reality (AR) or even Mixed Reality (MR). The main advantage of prototyping has been synthesized in a simple sentence, expressed by John Meada, a former MIT professor: "If a picture is worth a thousand words, a prototype is worth a thousand meetings", cited by Banfield et al. (2017). More recently, the service sector has started to also adopt prototyping for exploring service design alternatives (Blomkvist, 2014). This involves different levels of service complexity, such as: online consultancy, machine configurators, and simulators for the training of machine operators or more simply assembly and disassembly guidance. Nevertheless, the current body of knowledge on Service Prototyping is lacking comparison among Service Prototype (SP) forms - conventional versus immersive - that would help businesses in the service sector to select the most appropriate SP form. In this context of the service sector, our investigation aims to bring new knowledge about the potential impact of immersive technologies on SP. Overall, it would help service organizations to experience a service idea even before this service really exists or to foresee which SP form is the most appropriate according to their specific context and degree of service complexity.

A literature review was carried out in order to identify potential objective and subjective impact factors. Our created theoretical SP adoption model allows comparing different forms of Service Prototypes according to their respective performance in terms of completion, errors, and usage perception. This model was used to design an experiment, which involves mixed methods, allowing collecting a sufficient amount of quantitative data for running a statistical analysis formative approach for validating our SP adoption model. First of all, our empirical study has allowed validating our SP adoption model. Secondly, it has unveiled the positive impact of immersive technologies on service prototyping for getting an anticipated experience before a service is implemented. Thirdly, it has revealed the higher performance of AR- and MR-SP forms compared to VR and conventional SP forms. Finally, besides the obvious fact that only AR- and MR-SP forms allow to simultaneously learn a service operation, the VR-SP form is the one exhibiting the highest immersiveness and adoption score, especially because it allows exploring a service before it really exists.

Keywords: Service Design, Service Prototyping, Immersive Technologies, Virtual Reality, Augmented Reality, Mixed Reality, Immersiveness

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