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Bringing the User Experience to early product design: from idea generation to idea evaluation

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T H È S E

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BRINGING THE USER EXPERIENCE TO EARLY PRODUCT DESIGN: FROM IDEA GENERATION TO IDEA EVALUATION

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ACRONYMS

UX = User Experience

KE = Kansei Engineering

KES = Kansei Engineering System

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INTRODUCTION

OBJECTIVES

This thesis is part of the field design research. It addresses the emerging topic of User Experience (UX). While User Experience with final products is an already widely treated issue for marketing and ergonomics, this thesis asks how User Experience can be anticipated during early product design. Designers, engineers and marketers, as part of product conception teams, appear in this thesis but the focus lies on the design profession and its activities.

The objectives of this thesis are

- **TO DEFINE WHAT CONSTITUTES USER EXPERIENCE;**
- **TO PROPOSE AND TEST TOOLS TO CONCEIVE USER EXPERIENCE;**
- **TO PROPOSE AND TEST METHODS TO MEASURE THE USER EXPERIENCE POTENTIAL OF EARLY CONCEPTS;**
- **TO APPLY KNOWN METHODS TO MEASURE THE USER EXPERIENCE OF INTERACTIONS.**

RESEARCH QUESTION

Designers have long focused on form-giving. Today they are asked to design an experience for the user, in order to achieve consumer products that attract and convince users on a highly competitive market. User Experience results from the interplay of a wide range of dimensions like form, colour, material, texture, as well as sensorial and semantic qualities, placed in a certain use context. User Experience has become an important subject for design researchers and product manufactures. A wide range of User Experience evaluation methods for products in advanced development stages is already available. Most of the current research analyses and describes User Experience. Only few tools or methods for User Experience conception have been proposed so far.

The research objective is to propose methods and tools to designers that help them to improve their design concepts with regard to the potential User Experience.

This thesis therefore asks, **HOW TO BRING USER EXPERIENCE TO EARLY PRODUCT DESIGN?**

CONTRIBUTIONS

This thesis contributes to design theory and design practice with the following 5 elements:

- **A LIST OF USER EXPERIENCE DIMENSIONS AS A TOOL FOR CONCEPT GENERATION**

Through an analysis of existing models, completed with findings from the studies, this thesis arrives at a complex listing of dimensions from the product, the user and the use context that together form the User Experience. The list is designated to design practice and design education to raise awareness of otherwise easily neglected design dimensions during the early conception. It is also meant as an orientation to define the design priorities of each project.

- **A MODEL OF USER EXPERIENCE**

This thesis proposes a new model that illustrates the main mechanisms of User Experience and the course of information processing between the human and the product. It includes the two time components of User Experience. On the one hand, we see information circulating and being modified between the user and the product for each interaction sequence. On the other hand the model is superimposed with itself which indicates that even the same interaction sequence will not be perceived identically at a later point in use over time.

- **CRITERIA FOR THE USER EXPERIENCE EVALUATION OF EARLY CONCEPTS**

The studies of this thesis show that it is possible to evaluate the User Experience potential of early concepts. This finding significantly enriches the effectiveness of early conception with regard to User Experience. In order to enable stakeholders of conception to undertake UX evaluations on concepts this thesis also furnishes a manageable list of criteria of which these applicable to the stage of the concept have to be selected before undertaking the evaluation.

- **CONCEPT GENERATION WITH WORD-BASED TOOLS**

The experimental terrain of this thesis is the development of a design software that is based on conception words linked to each other (Skippi project). The findings of the studies served to develop specifications for the development of the software. In a later step the studies also helped to analyse the effectiveness of the tool and the interface design. The study results show that designers easily adopt such a word-based tool in addition to their regular design tools. Inspiration words help them to widen the horizon of ideas but also to be more precise on a wider range of User Experience dimensions starting from the very early product design.

- **DESIGNING USER EXPERIENCE THROUGH GESTURES**

The perception of static properties like colours, forms and materials has been extensively investigated in the field of design research. This thesis shows the high impact of dynamic properties like interaction gestures on User Experience. To facilitate the conception of interaction gestures, the tool ‘body storming’ was tested and validated in this thesis. Motion tracking is furthermore proposed as a new means of behavioural measurements in the field of User Experience evaluation.

ORIGINALITY

The originality of this thesis lies in the following 4 points:

- **THE POSITIONING OF THE TOPIC: USER EXPERIENCE IN PRODUCT CONCEPTION**

For the first time, for the emerging topic of User Experience is addressed through the angle of early product design. As two novelties, User Experience evaluations were applied on early concepts and on interactive products in the studies of this thesis.

- **THE APPLICATION OF UNCONVENTIONAL DESIGN TOOLS: WORDS AND BODY**

In two of the studies, the designers were invited to generate concepts through word maps and with the help of a word-link based software, instead of using their habitual tool sketches. In the third study, stakeholders of conception tested body movements as a new tool to conceive interaction gestures, instead of doing a classical brainstorming.

- **THE COMBINATION OF TWO PHASES: CONCEPT GENERATION AND CONCEPT EVALUATION, AND WITH IT TWO POPULATIONS: CONCEPTION PROFESSIONALS AND POTENTIAL USERS IN THE STUDIES ON USER EXPERIENCE.**

The conception process combines phases of concept generation and phases of concept evaluation. These two phases are present in the studies of this thesis. First concepts are generated by professional designers and then the outcome is evaluated by potential users. This allows working on both UX generation and UX evaluation during early conception.

- **THE APPLICATION OF CREATIVITY TECHNIQUES AND METHODS OF HUMAN SCIENCE IN THE STUDIES.**

For the studies on concept generation various creativity tools like word/mind mapping and body storming furnished the sought information. The methods chosen for the evaluations, like focus group, semi-guided questionnaire, observation and physiological measurements were adapted from the human sciences in order to fit the design context.

STRUCTURE OF THE DOCUMENT

This thesis is structured into the following 6 chapters:

- **CHAPTER 1: RESEARCH CONTEXT**

This chapter introduces the global topic – User Experience and product conception. The emergence of the User Experience subject is explained through societal and technological evolutions. It is then positioned in the context of conception science and design research.

- **CHAPTER 2: STATE OF THE ART**

The state of the art in chapter 2 provides an overview on dimensions and mechanisms of User Experience and on existing tools and methods that can be adapted for User Experience conception. The overview on UX dimensions is compiled from existing models and from design related domains on human perception. The tools and methods are gathered for the four activities of conception: Information, Generation, Evaluation and Communication.

- **CHAPTER 3: RESEARCH QUESTION, HYPOTHESIS AND SUB-HYPOTHESES**

In chapter 3 the research question is formulated and the hypothesis and sub-hypotheses of this thesis are developed. The thesis asks **HOW TO BRING USER EXPERIENCE TO EARLY PRODUCT DESIGN?** To answer this question it is assumed that **TO DESIGN FOR USER EXPERIENCE, DESIGNERS NEED TO ADDRESS A**

WIDE RANGE OF DIMENSIONS DURING EARLY CONCEPT GENERATION AND EVALUATION (Hypothesis). The three sub-hypotheses are related to **TOOLS FOR USER EXPERIENCE GENERATION** (Sub-hypothesis A), to **USER EXPERIENCE EVALUATIONS OF EARLY CONCEPTS** (Sub-hypothesis B) and to **USER EXPERIENCE EVALUATIONS OF DYNAMICALLY CHANGING DIMENSIONS** like gestures (Sub-hypothesis C).

- **CHAPTER 4: EMPIRICAL STUDIES**

Three studies are conducted in order to explore the hypothesis and sub-hypotheses. Chapter 4 describes these studies with their respective objectives, participants, research methods, results and discussion. Study 1 addresses the main hypothesis and has for goal to establish an overview on dimensions of User Experience. Study 2 serves to test a word-based design tool (Skippi) on its impact on User Experience generation (sub-hypothesis A) and to apply User Experience evaluations on early design concepts (sub-hypothesis B). Study 3 has for objective to test the tool body storming for the generation of interaction gestures (sub-hypothesis A) and to evaluate the final User Experience with these gestures (sub-hypothesis C).

- **CHAPTER 5: CONTRIBUTIONS**

Chapter 5 presents this thesis' contributions that resulted from the empirical studies in chapter 4. The contributions include insights for design research as well as recommendations and tools for design practice.

- **CHAPTER 6: PERSPECTIVES**

The final chapter shows limits of the findings and suggests how research activities on the research question of 'User Experience in early product design' could be pursued in order to overcome these limitations.

1 Research Context: User Experience and Product Conception

This second chapter introduces the societal, industrial and academic context of this thesis. The topic User Experience is influenced by changes in society, findings of academia and industrial developments (Image 1). The first section addresses social and technological evolutions over the last century that brought the human into the centre of product development (1.1). The second part gives an overview on existing models of product development and in particular the conception process with its stakeholders and their activities (1.2). The third part lists activities world-wide of research groups who seek to develop methods and tools for the integration of the user perception in product conception (1.3).

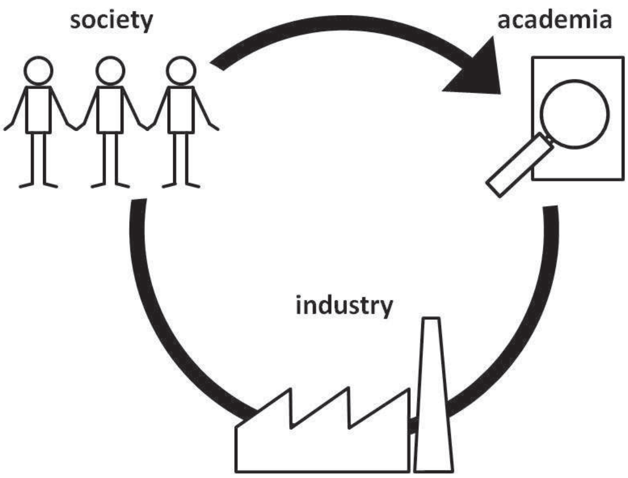


Image 1: User Experience from three perspectives.

1.1 The societal and technological evolution of consumer products

Technological advancements over the course of the 20th century have lead to a large range of electronic consumer products that in turn strongly influenced the people's lifestyle. While work before meant physical labour, today the work life of many is dominated by computer-supported activities. While communication was only possible face to face or with long delays through letters, today a return to a life without mobile communication devices that allow instant information exchange all over the globe is unthinkable for most of us. This section gives an overview of these technological and societal changes. Through it we will see how the **User Experience** moved into the centre of consumer product development.

1.1.1 From manufacturing to mass production

When Konosuke Matsushita opened a tiny workshop in 1918, he had just identified a business opportunity in Japanese homes. At this time there was only one socket per room. Most people needed to unplug their lamp in order to use other devices. His idea was to produce multi-sockets. From there on his vision became to produce electrical products at a cheap price so that everybody could profit from the electrification. He expanded to bicycle lamps, irons, and later washing machines and radios. The means of mass production allowed making these items at a low price. That gave more and more people access to a wide range of consumer products. Starting from one-man garage businesses Matsushita became Panasonic and grew quickly into a global player with thousands of employees around 1960 (Panasonic, 2012). Long gone are the days when an entrepreneur like Matsushita had a simple product idea that he could sell in its original form over many years. Today a company like Panasonic is producing all kinds of consumer goods from home appliances to mobile phones. Companies like Samsung, Philips, Haier or Siemens supply the market with the same products and compete for the same costumers. They refine their array of products on an ongoing basis to secure their market position. New products and services need to catch the consumer attention and established products have to evolve quickly to stay up-to-date.

1.1.2 From consumers to prosumers

In the second half of the 20th century electronics made their way into the world of consumer products. The first consumer electronics were based on analogue technologies. Today micro-processors are integrated in many consumer products and allow the user insight into the product status (Saffer, 2009). With the birth of the World Wide Web in the 1990ies, digital technology entered peoples' everyday life through PCs and mobile phones. These radically altered human communication, entertainment, and life management.

When we look at products designed around 1960 like the world receiver by Dieter Rams for Braun, we see one product that served one function: to play back analogue radio waves with news and music from around the world. 50 years later, the sources to access world-wide information have increased significantly. Digital products like Smart Phones provide a connection to the World Wide Web anytime anyplace. They facilitate access to merely all existing international radio stations, newspapers and podcasts. They serve many functions like communication through mailing, SMS, telephone, social networks, or recording instants in form of photos with the inbuilt camera. Thanks to digital technology, consumer electronics have rapidly evolved from one product equal one function to multifunctional products. Consumer electronics today converge communication, information and entertainment (D. Lim, 2003).

A survey on French consumer's favourite brands in 2011 substantiates the pertinence of products of numeric nature. Next to classic manufacturers like IKEA or Decathlon a great amount of service providers are in the top positions, among them Google and Microsoft, followed by Amazon, Apple, Samsung, and Sony (Burnett & Fran, 2011). The most popular consumer electronics among American adolescent's and adult's in 2010 were PCs, TVs, Smartphones, ipad, and various game consoles (Nielsen Company, 2010) (Image 3).

IMAGE 2: FAVOURITE BRANDS IN FRANCE 2011

IMAGE 3: PRODUCT BUYING DESIRES OF AMERICAN ADOLESCENTS AND ADULTS IN 2010.

All these products originated in the web 2.0 or are strongly related to it in their actual use. The term web 2.0 refers to a cumulative change in the use of the internet from the early years of 2000. Users left the passive consumption mode and strove to individually share and create own contents. Today consumers take on a more and more active role in product development. Toffler coined the term 'prosumer' which refers to engaged consumers who whether propose solutions themselves, or use applications or platforms to create own contents (photo books, video clips, blogs etc.) (Gerhardt, 2008; Hughes, 2010).

Even non-electronic products are influenced by the growing knowledge share via the internet that enables consumers to create objects themselves, e.g. through 3D printing. The relation between humans and products is evolving. The satisfaction of needs on the commodity level is taken for granted in more and more countries. Freed of worries on basic needs, people desire products that also enable them to attain values like relatedness, meaning, stimulation, competence, security, and popularity (Hassenzahl, Diefenbach, & Göritz, 2010). Consumers choose products that fit their lifestyle, and find own ways to use of them. They decide for one product over another if it offers some 'added value'. Value can be added through lower cost or higher performance, improved usability, but even more importantly through engaging interaction and visionary use scenarios (Jacobs, 2007).

> *"[…] interactions that enable an individual customer to co-create unique experiences with the company are the key to unlocking new sources of competitive advantage."* (Prahalad & Ramaswamy, 2004)

Therefore, one key challenge for companies today is to conceive meaningful interactions between the user and the product.

1.1.3 From Product Design to User Experience Design

Product design has long focused on the form-giving of materialised products. While engineers dealt with functions, components and performance, product designers were mainly asked to work on form, colour, texture and material (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004). Now microcontrollers have considerably enriched the capabilities of products to process the user input and to respond with discrete output behaviour (Lim & Kim, 2011) and therefore to adapt their behaviour to the context of use and user actions (Djajadiningrat et al., 2004).

The user perception of such **DYNAMICALLY CHANGING PRODUCTS** goes far beyond good form-giving. Hassenzahl illustrates this with the example of the Philips Wake-Up Light: "…it substantially changes the way one wakes up. It changes the experience. The object itself, its form, is rather unremarkable" (Hassenzahl, Eckoldt, & Thielsch, 2010). Schuster Smith showed that interaction impacts the affective experience. She compared expression ratings of juicers before and after use and found that for novice users the ratings changed in a negative direction. Her findings also hint that people evaluate a product design based on past experiences (Schuster Smith, 2008).

Even though people might not expect great emotional stimulation from all products, it cannot be neglected that each artefact causes a reaction in its user - at a minimum indifference or rejection. Thus all goods and services made for consumers have to respond to some kind of physiological, psychological or social human need (D. Lim, 2003). Today form-giving is only one of various issues that product design needs to address. The challenge for product developers is to switch their focus from material product dimensions to the perception of the user – the so-called **USER EXPERIENCE**.

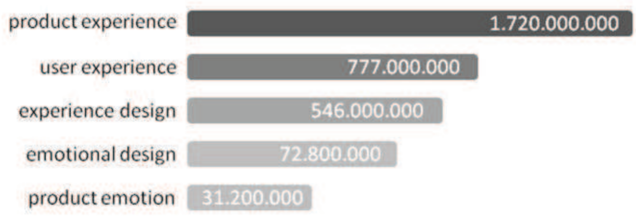


IMAGE 4: NUMBER OF HITS PER TERM ON GOOGLE.

The growing importance of User Experience can also be seen by the high number of search results found on google when looking at terms related to User Experience (Image 4). User Experience is a term that embraces a wide range of notions from the psychology to the business point of view. It is related to usability, interface design, customer satisfaction, etc. (Roto, Law, Vermeeren, & Hoonhout, 2011) It encompasses “A person’s perceptions and responses that result from the use or anticipated use of a product, system or service” ISO 9241-210 (2010). In this definition appear the human and the product with each ones capabilities that can be addressed through design (Djajadiningrat et al., 2004). The focus of this thesis therefore lies on **USER EXPERIENCE DESIGN,** and more specifically for dynamically changing products.

1.2 The Development of Consumer Products

In the first section of this chapter the societal and technological context of this thesis' research topic **User Experience Design** were introduced. In this second section this research is positioned on the theoretical side in the field of product development.

1.2.1 The product development process

The development of a new product is usually initiated by an identified market demand. Firstly the conditions of the market and the industrial partners are being analysed. Subsequently to a positive conclusion of the discovery phase, the project is planned. The development starts with the definition of the final product. In the following conception phase, different professions (design, engineering, and marketing) explore various design directions and step by step narrow down the scope of chosen solutions in more and more detail. Certain ideas advance while others are suppressed on the way. It is an iterative process during which functional and aesthetical properties have to be outbalanced and validated by the various stakeholders. Once the concept is finalised, the product enters the phase of development. Here problems of feasibility and financial constraints have to be resolved without too much deformation of the initial concept until the product is ready to go into mass production. Even after launched on the market, product support handles technical amendments or visual brush-ups if are necessary. The company might also continue the development of additional equipment for the product. That initiates a new project (Ullman, 2010).

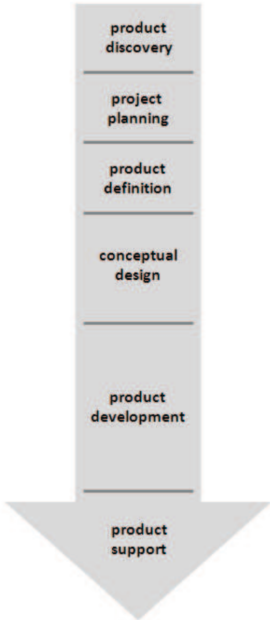


Image 5 : The product development process adapted from Ullmann 2010.

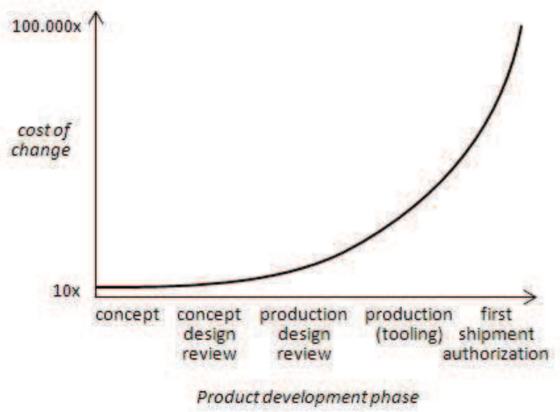


Image 6: Cost of design changes in relation to the product development phase (traditional development) (Folkestad & Johnson, 2001)

In the classic product development process costs and delays increase rapidly the later modifications are undertaken. Their impact can be kept relatively low if amendments occur during the early conception phase. They rise significantly once production has started (Image 6). It is therefore important to take as many factors as possible into account during the early conception cycles. The stakeholders of product conception need tools and strategies that help them to organise all available information and synchronise their procedures from the early phases of product development and onward. This research focuses on the **CONCEPTION PHASE** and its crucial role **AT THE BEGINNING OF THE PRODUCT DEVELOPMENT.**

1.2.2 THE DESIGN CONCEPTION PROCESS IN PRODUCT DEVELOPMENT

Several researchers in the field of industrial engineering formalised the course of product conception. It is commonly called ‘the design process’ and described as an iterative process with alternating activities of diverging and converging character. Aoussat identified 4 main activities that have to be undertaken during conception: the translation of needs, the interpretation of needs, the product definition, and the product validation (Aoussat, Christofol, & Le Coq, 2000).

IMAGE 7: THE STAGES OF THE CONCEPTION PROCESS BY AOUSSAT

Bouchard as well as Cross propose to distinguish four phases of the conception process: Information/Exploration, Generation, Decision/Evaluation, and Communication (Image 8). During the information/exploration phase, designers gather the information related to the brief as well as complementary data from various sources of inspiration. The generation phase consists in the creation of solution ideas, mainly through physical 2D (sketches, renderings) and 3D (CAD models, mock-ups) representations. The evaluation and decision phase serves to select the most appropriate solution(s) among the generated ideas. Various methodological tools are available for this analytical phase. Quality Function Development or Functional Analysis help to define evaluation criteria. Semantic differentiation or semantic mapping allow positioning the solutions in relation to each other. Finally the chosen solution needs to be communicated to the design team and to clients in order to prepare the launch of the product development phase (Bouchard & Aoussat, 1999; Cross, 2008). Cross placed a feedback loop between generation and evaluation of design solutions. Bouchard identified an overlapping and repetition of all four phases.

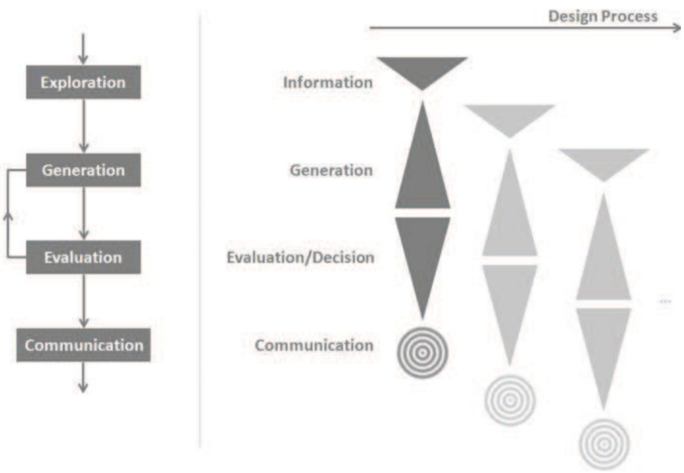


IMAGE 8: DESCRIPTION OF THE DESIGN ACTIVITY BY CROSS (LEFT) AND BOUCHARD (RIGHT).

1.2.3 The stakeholders of product conception

The early product development is marked by a great degree of uncertainty and plentiful opportunities. Therefore the activities of product conception are usually handled by multiple stakeholders of different professions. Together they consider a wide range of dimensions, including the product functions, performance and quality objectives, economic and ergonomic issues, the brand image, use scenarios, the interplay with other products, the product life-cycle, the anticipated perception of the user and the society, etc. (Krippendorff, 2005). All of these factors might later lead to success or failure on the market. The professions involved in product conception are engineering, product design, ergonomics, and marketing. The marketer defines the target users, conducts benchmarks, brings in customer feedback, estimates the potential revenues, etc. The engineer selects technologies, components and their performance parameters that respond to the anticipated competitive level by the time of release. The designer is asked to propose an attractive design for the future product. The person in charge of ergonomics oversees usability issues of the design. All these people constitute the group in charge of product conception. Their work fields are not strictly separable, and work contents often overlap. For example the definition of functionalities depends on technical factors that are defined by engineers, user expectations that are compiled by marketers, as well as use scenarios that are envisioned by designers.

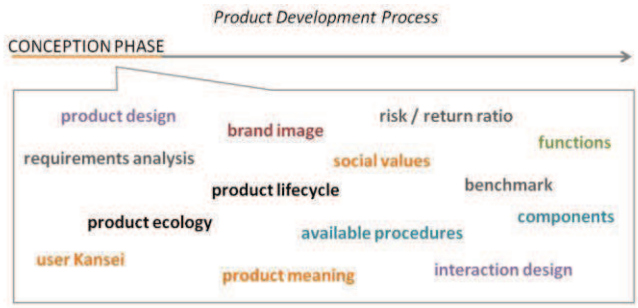


Image 9: Dimensions of product conception (non-exhaustive).

This research focuses particularly **ON THE ROLE OF THE DESIGNER** in the conception of consumer products. With the trend towards user-centred products, the role the designer has gained importance. It evolved from being the person in charge of 'making products look nice' to the one who translates user needs and desires into product solutions (Kim, 2011).

1.3 RESEARCH ON USER EXPERIENCE

In the first section of this chapter the societal and technological context of this thesis' research topic **USER EXPERIENCE DESIGN** were introduced. In the second section this research was positioned in **THE EARLY CONCEPTION PHASE OF PRODUCT DEVELOPMENT**. This third section presents which research entities worldwide seek to propose conception methods for User Experience Design. It furthermore introduces the activities of the Product Design and Innovation Laboratory that have led to this thesis.

1.3.1 LEADING RESEARCH GROUPS AROUND USER EXPERIENCE

As stated earlier, the experience of the user with the product has moved into the focus of consumer product conception. Numerous scholars around the world are today engaged in this subject. Their common goal is to achieve an improved product development process and products with a positive User Experience. They come from to the fields of product design, neuroscience or cognitive psychology, as well as industrial engineering and software engineering.

From the early 20th century onward **COGNITIVE PSYCHOLOGISTS** provided us with theories and models that explain the human perception of the environment (Gibson, 1986). They established a rich data base on human values and needs, as well as methods for their evaluation that today can serve design research (Scherer, 2005; Shalom H Schwartz, 2009).

In the 1970ies scholars of Design Engineering in Japan started to develop product conception tools that systematically take the user associations into account. They introduced the concept of **KANSEI ENGINEERING**. The Japanese word **KANSEI** is commonly translated as feeling, but it includes a wide range of sensorial and affective aspects. It also comprises semantics and meaning. The method measures the user cognitive and affective response to a product appearance. It enables designers to evaluate the Kansei evoked by certain product properties, so that they can adapt the design to the desired expression. Kansei Engineering techniques are mainly applied in East Asia (Japan and Taiwan) but they have found their way to some research groups in Europe (Sweden (Schütte, 2005), France (Mantelet, Bouchard, & Aoussat, 2003), Spain (Llinares & Page, 2008), and the Netherlands (Lévy, Kuenen, Overbeeke, Uchiyama, & Yamanaka, 2011)). The teams in France and the Netherlands speak of **KANSEI DESIGN.**

Another research branch that seeks to understand User Experience is software engineering. The emergence of consumer software, followed by a strong complexity of digital tools raised their consciousness for usability issues. The specialisation is called **HUMAN-MACHINE INTERACTION** (HMI). Here the group of Forlizzi at Carnegie Mellon in the US has mainly brought forward the research.

Furthermore the yearly Conference on Human Factors in Computing Systems (CHI) receives high interest from the UX community.

Another important movement is the newer research branch on **EMOTIONAL DESIGN**, mainly brought forward by cognitive psychologist Donald Norman and design researcher Pieter Desmet of TU Delft (Desmet, 2002; D. A. Norman, 2004). Their objective resembles the Kansei Engineers', but they focus on the human emotional reactions on product designs.

Other researchers seek to bring sensorial product dimensions into product conception. The so-called **SENSORIAL DESIGN** tries to understand the human perception of sensorial stimuli, followed by the systematic implementation of the insights through **AFFECTIVE ENGINEERING**.

Researchers from the different here listed domains all contribute to a better understanding of User Experience. Today the term itself starts to be a research branch. Besides "**USER EXPERIENCE**" (Bruseberg & McDonagh, 2001; Garrett, 2010; Roto et al., 2011), we also read the terms "**PRODUCT EXPERIENCE**" (Schifferstein & Hekkert, 2008), or "**EXPERIENCE DESIGN**" (Hassenzahl, Eckoldt, & Thielsch, 2009). They can be grouped under the term **USER EXPERIENCE DESIGN**. Most researchers that work explicitly on User Experience are active in the US and in Western Europe (UK, the Netherlands, Germany).

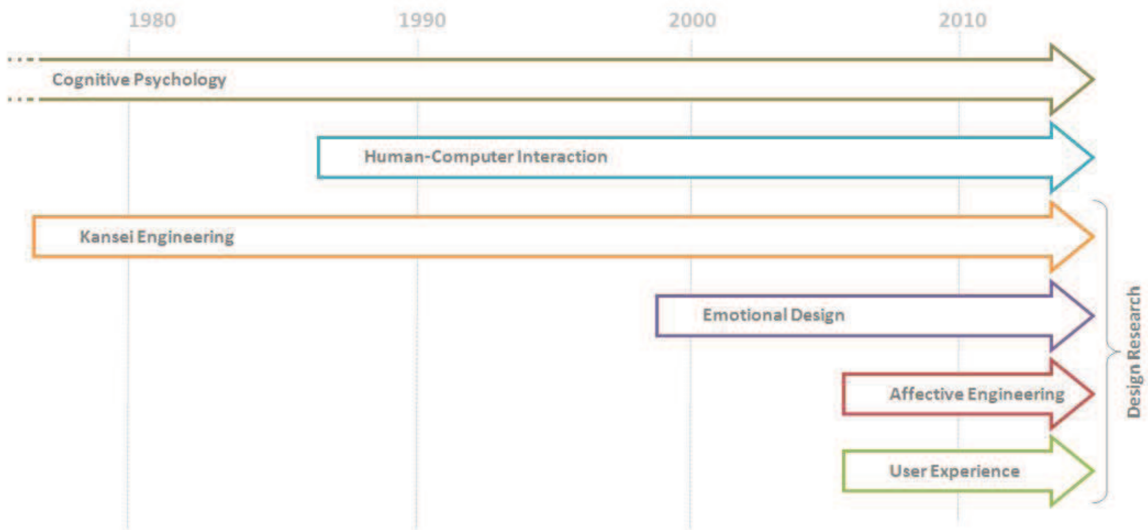


IMAGE 10: EVOLUTION OF THE HUMAN-PRODUCT RELATED RESEARCH DOMAINS.

The common goal of all these research branches is to enrich the human **ERLEBEN** (experience) of or with the product that is stimulated by various different product dimensions. The following world map shows research institutes that currently develop theories and methods on user-product related issues.

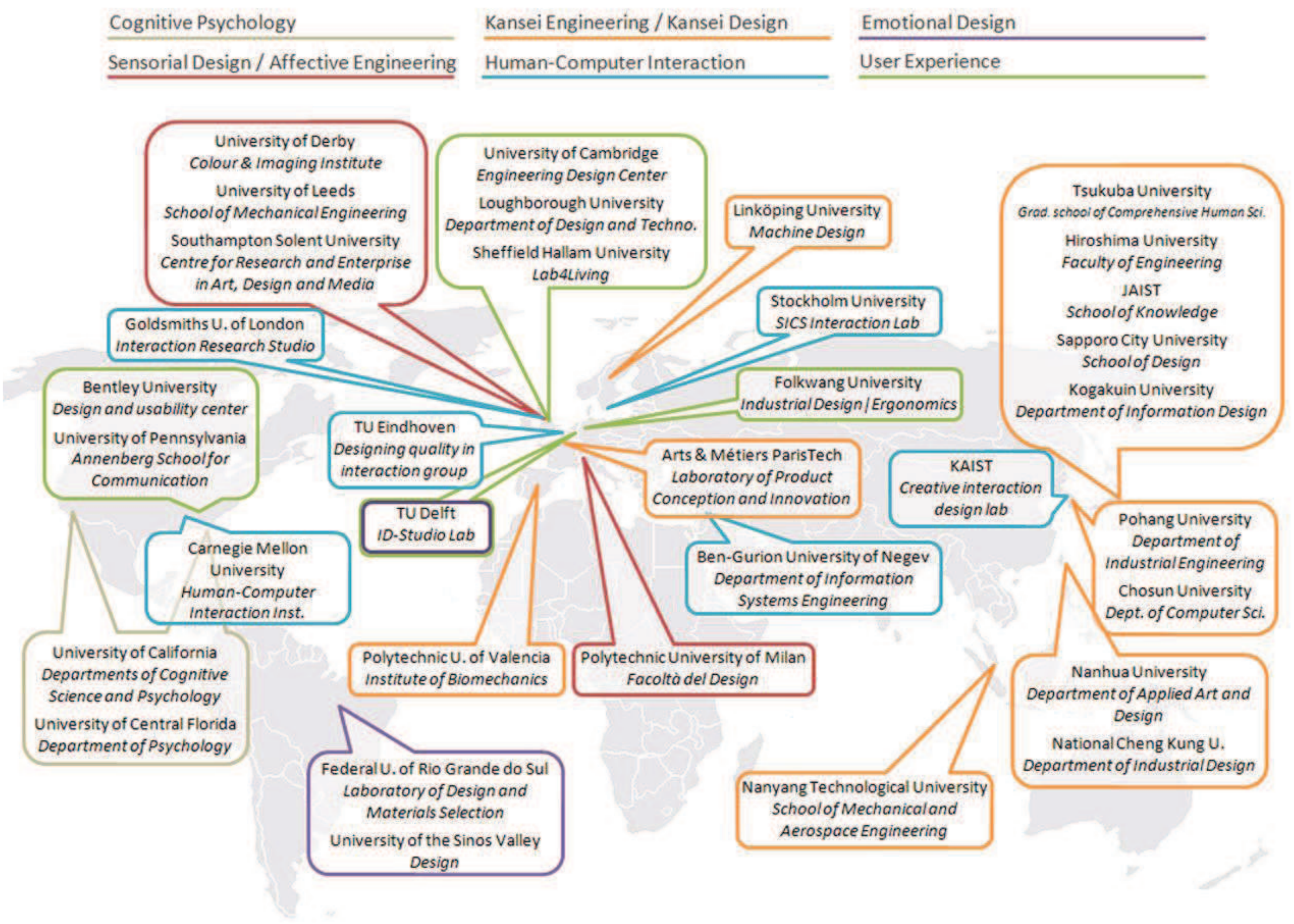


IMAGE 11: WORLD MAP OF DESIGN RESEARCH UNITS ON USER EXPERIENCE RELATED ISSUES FROM 2000 TO 2013 (NON-EXHAUSTIVE).

1.3.2 THE RESEARCH ENVIRONMENT OF THIS THESIS

This thesis is embedded in the research activities of the Product Design and Innovation Laboratory of Arts et Métiers ParisTech. The labs research activities have for objective to enhance the quality and output of the product conception process. Tools and methods are developed to support conception teams to come up with innovative product solutions. Such solutions are neither centred on technical constraints nor on pure styling factors. They have to give a holistic response to user expectations. The research activities point into three directions:

i. Design Project Engineering
ii. Models and Integration of Skills in Design Projects
iii. Product Representations.

The research activities on Design Project Engineering have for objective to develop methods and tools that assist the decision-making and the management of design projects. The second direction, Models and Integration of Skills in Design Projects, addresses the changing needs concerning professions and skills in product development with special regard to the end-user. The third direction of Product Representations explores different innovative formats to represent product concepts. Such include traditional techniques like sketches or CAD models, as well as new opportunities facilitated by technologies like Virtual Reality (LCPI, 2013). This thesis contributes the research direction two (Models and integration of skills in design projects). It builds on previous works of researchers in the Product Design and Innovation Laboratory who investigated issues of product design through proposals of conception methods and analysis of design conception activities.

The first thesis on this subject was presented by Bouchard in 1997 who modelled the design process in the automobile industry (Bouchard, 1997). The next thesis was undertaken by Lim in 2003. She proposed a model for user centred conception that integrates methods and tools of cognitive ergonomics (D. Lim, 2003). Mantelet investigated and developed product conception methods that take the consumer emotion into account (Mantelet, 2006). Mougenot analysed and modelled the exploration process as part of the early product design with the goal to enhance creativity (Mougenot, 2008). Kim examined cognitive and affective processes of designers in the early stages of design (Kim, 2011). Rieuf assessed the potential of Virtual Reality tools for the early design process. He worked on 3D mood boards and a system for 3D sketching (Rieuf, 2013). Ocnarescu showed that aesthetic experiences elicited by the implication of design in product conception processes create better conditions for innovation (Ocnarescu, 2013). Among these seven theses, three (Kim, 2011; Mantelet, 2006; Mougenot, 2008) were conducted in the context of multidisciplinary research projects supported by the European commission or the French ministry of research. These projects were:

- KENSYS European project: The development of a Kansei Engineering System that integrates user preferences and emotional responses during the design process. (2003-2006; 1,41M€)
- TRENDS European project: The development of an image retrieval software that works through analysis of image contents and lexical content semantics. (2006-2008; 5,0M€)
- GENIUS ANR project: The development of a system for the early design phase that supports the generation of new shapes. (2008-2011; 1,8M€)

The research conducted in this thesis is likewise part of an interdisciplinary research project:

- SKIPPI ANR project: The development of a system that stimulates and synchronises the multidisciplinary early conception activities through intelligent links in a rich lexical data base. (2011-2013; 1,3M€)

The project provided the study terrain for this thesis. In return, the research insights influenced the development of the system. More details on Skippi will be given in section 4.2.

1.4 Summary of the research context

Since the end of the last century the world of consumer products has evolved rapidly. The reasons were the evolution of microprocessors and in particular the emergence of devices that provide ubiquitous accessibility to the World Wide Web. As a consequence we now have access to more and more products that have the capability to adapt their behaviour to the user and/or the environment. This has enabled the user to be more than a mere consumer. Today the user is also the creator of his own experience with products.

Facing a strongly competitive market, product developers are therefore challenged to propose products that correspond perfectly to user needs and desires and that provide an added value. To be able to do so, product developers need to understand the ways in which humans perceive and interact with products. Research groups all over the developed world and in emerging countries like Brazil and Taiwan devote increasing effort in the investigation of the User Experience with products. Some focus on the emotional impact, others try to amplify the employment of sensorial triggers and many deal with usability issues.

Yet the comprehension of some User Experience dimensions alone is not sufficient. The gained insights need to be translated into products. In order to limit the risk of failure on the market, the User Experience needs to become part of early product design. Here the designer plays a particular role to secure the adaptation of the User Experience in product development. In order to enable designers to propose User Experience rich products, methods for the generation and evaluation of User Experience are necessary. The following chapter presents the state of the art on User Experience dimensions, as well as User Experience conception methods from design research and neighbouring disciplines.

2 STATE OF THE ART: USER EXPERIENCE – DIMENSIONS, TOOLS AND METHODS

This thesis is part of design research with a focus on the conception and evaluation of User Experience (UX) for dynamically changing products. This second chapter gives an overview on research on User Experience from two different angles:

i. **THE DIMENSIONS AND MECHANISMS OF UX:** User Experience is not the result of one single product property but of the interplay of various dimensions. In order to establish an overview on these we will take a look at **EXISTING MODELS OF USER EXPERIENCE**. Furthermore, insights from design related domains on **HUMAN PERCEPTION**, as well as emerging dimensions of **PRODUCT APPEARANCE AND BEHAVIOUR** are added. As a third point, the **TEMPORALITY OF UX** will be discussed. The findings are gathered in a proposal for **A MODEL OF USER EXPERIENCE**.

ii. **TOOLS AND METHODS FOR UX CONCEPTION:** The creation of User Experience starts with the early product design. This second part presents a selection of tools and methods that designers can make use of in the four phases of conception – information, generation, evaluation and communication – in order to achieve concepts with a good User Experience potential.

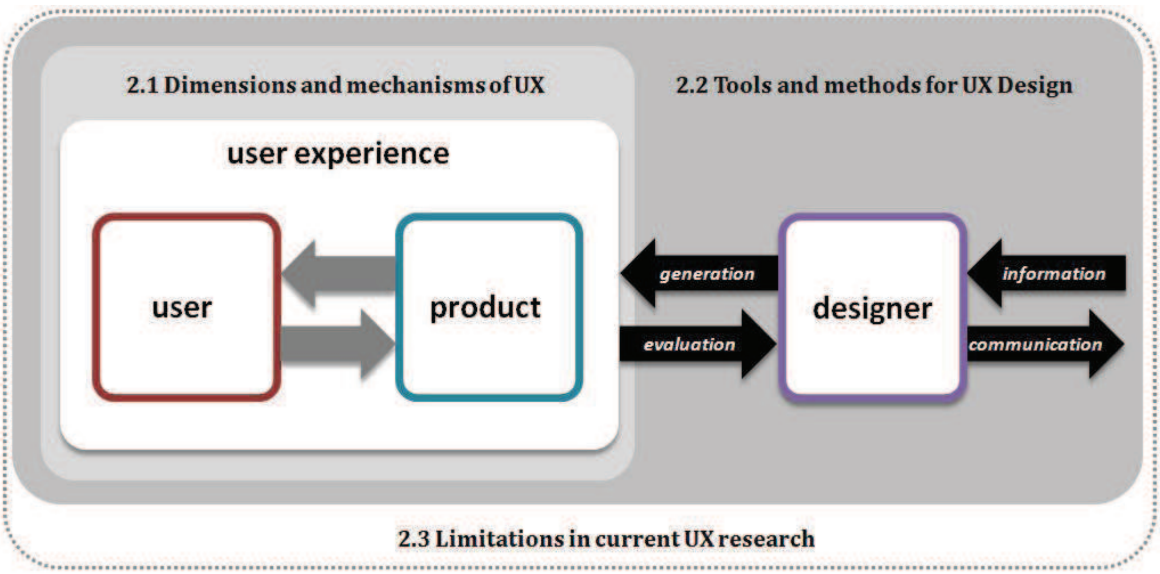


IMAGE 12: STRUCTURE OF THE LITERATURE REVIEW.

The objectives of this literature review are:

- to provide an overview on theories related to User Experience,
- to present User Experience conception tools and methods and
- to highlight gaps in current User Experience research, tools and methods.

2.1 Dimensions and mechanisms of User Experience

User Experience results from a multitude of product properties (Schifferstein & Hekkert, 2008) that are the expertise of different disciplines (Bernhaupt, Obrist, & Tscheligi, 2006). As Forlizzi and Ford put it, in order to understand "what influences experience", we first of all have to "think about the components of a user-product interaction, and what surrounds it" (Forlizzi & Ford, 2000). This section gathers knowledge from Design Research as well as Cognitive Psychology in order to understand the mechanisms of User Experience and the dimensions that form it. First of all a typology of User Experience (2.1.1) is defined. Then various existing models on User Experience are presented (2.1.2), followed by a detailed look into dimensions of human perception (2.1.3) and dimensions of products (2.1.4).

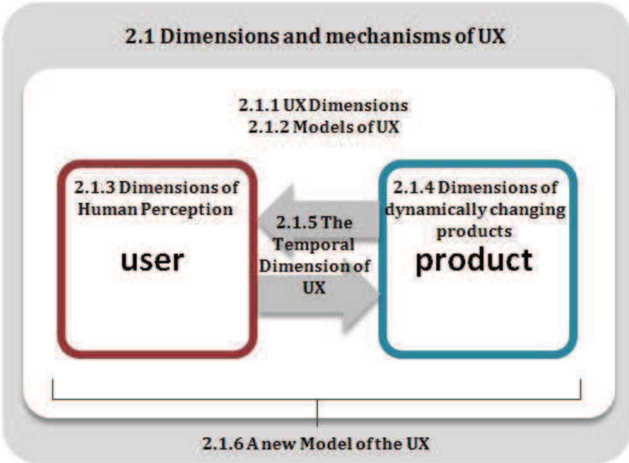


IMAGE 13: TOPICS OF LITERATURE REVIEW PART 1.

2.1.1 User Experience Dimensions

Design researchers in the fields of "Kansei Engineering" (Tomico, Mizutani, Levy, Takahiro, & Cho, 2008), "Emotional Design" (Desmet & Hekkert, 2007) and "Human-Machine-Interaction" (Forlizzi & Ford, 2000) study the user-product interplay. User Experience is a multidimensional quality (Bargas-Avila & Hornbæk, 2011). A review of UX papers revealed the dimensions listed in Table 1 as contents of current User Experience research. This list already shows an incoherence of the terms and their limits within the community. It does not sufficiently show what dimensions constitute User Experience. This subsection therefore analyses the product design typology and existing models in order to constitute a holistic picture of the dimensions of User Experience.

TABLE 1: DIMENSIONS IN UX RESEARCH (BARGAS-AVILA & HORNBÆK, 2011)

UX dimension	N	%
Generic UX	27	41
Affect, emotion	16	24
Enjoyment, fun	11	17
Aesthetics, appeal	10	15
Hedonic quality	9	14
Engagement, flow	8	12
Motivation	5	8
Enchantment	4	6
Frustration	3	5
Other constructs	15	23

2.1.1.1 Typologies of design dimensions

In current design research exist different typologies to class product properties, each adapted to a different purpose. For example: The differentiation between abstract and concrete attributes or low, middle, high level attributes is useful for the conception of the product. Let us take a more precise look into these typologies.

2.1.1.1.1 Abstract & concrete

Snelders characterises products through abstract attributes of higher order and concrete attributes of lower order. Concrete attributes are materialised through form, colours, materials, textures, etc. The concrete attributes carry a meaning for the user in form of semantics, symbols, emotions, and sensations. These are called abstract attributes. While the perception of abstract attributes might differ strongly between humans, the perception of concrete attributes is mostly equal between persons of different background. In user centred design, abstract attributes define the design objective. The product designer then materialises this objective through concrete attributes (Snelders, 2003).

IMAGE 14: ABSTRACT (RED) AND CONCRETE (BLUE) PRODUCT

2.1.1.1.2 Intangible & tangible

Analogous to abstract and concrete, there also appear the terms intangible and tangible product attributes. Design intentions are considered as intangible. They describe functional and psycho-sociological aspects of design that are relevant for the user. They are verbally formulated as symbols, analogies, values, semantics, etc. During the design process the designer transforms intangible thoughts step-by-step into the tangible features form, colour, material, etc. through mental and physical representations (Bouchard, Kim, & Aoussat, 2009; Y. Lim & Kim, 2011).

2.1.1.1.3 High level & middle level & low level

Bouchard proposes to distinguish three levels of information: high, middle and low. Such levels of information come from the field of artificial intelligence where specific algorithms need to be developed for each category (Bouchard, Kim, et al., 2009).

- High-level information is quite abstract and includes sociological values, semantic descriptors, styling descriptors, and emotional reaction on the design.
- Middle-level information holds abstract as well as concrete attributes at the same time; for example sector names, or patterns.
- Low-level information is very specific like shape, colour and texture related data.

2.1.1.1.4 Hedonic & pragmatic

This typology is proposed by Hassenzahl with regard to the main product functions. The term pragmatic refers to product attributes that define the product functionality for the purpose of manipulation – like utility and usability. A purely pragmatic product simply fulfils a behavioural goal, e.g. cutting paper for a pair of scissors. Hedonic attributes on the other hand are strongly related to the user personality, his stimulation, identification and the evocation of memories (Hassenzahl, 2003). They include emotions the person feels while using the product, the fit of the product with his values, the meaning the product holds for him, etc. A purely hedonic product, like a souvenir or photo, might have no pragmatic value but can be very important to the person.

2.1.1.1.5 Sensory & arbitrary

From the point of view of design, it is also interesting to distinguish between sensory aspects of designs that are equally understood by all humans independent from their cultural background, and arbitrary aspects that have been learned (Ware, 2012). The differentiation is relevant when testing the effectiveness of a design.

2.1.1.2 Attributes, characteristics, features, dimensions, properties…

In this overview of typologies we come across the terms product **ATTRIBUTE** and **ASPECT**. Further terms that we read in design research are

PROPERTY	(Akay & Henson, 2010; Blijlevens, Creusen, & Schoormans, 2009; Bouchard, Kim, et al., 2009; Desmet & Hekkert, 2007; Elvin Karana, Hekkert, & Kandachar, 2009; Y. Lim, Lee, & Lee, 2009; Nico H. Frijda, 1988)
DIMENSION	(Bouchard, Kim, et al., 2009)
CHARACTERISTIC	(Akay & Henson, 2010; Hassenzahl, 2004; E Karana, Hekkert, & Kandachar, 2008; Lévy, Yamanaka, Ono, & Watanabe, 2009; Ross & Wensveen, 2010; Schütte, 2005; Yanagisawa & Takatsuji, 2012)
FEATURE	(Guo, Asano, Asano, & Kurita, 2012; Hassenzahl, 2004; Scherer, 2004; Schütte, 2005)

Hassenzahl relates these terms in the following way: "…color and layout (i.e., product features) of a particular Web site may be new to a user and thus perceived as novel (i.e., a product attribute). […] A product character is a bundle of attributes, such as innovative, comprehensible, professional" (Hassenzahl, 2004). In Visual Thesaurus (Thinkmap, 2013) both characteristics and features are defined as "a prominent attribute or aspect of something". Characteristics and aspects are there defined as "a distinguishing quality". An attribute is a "characteristic of an entity". And attribute, dimension, and property are "a construct whereby objects can be distinguished". Visual Thesaurus draws a strong relation between property, dimension and attribute on the one hand, and feature with characteristic on the other hand (see Image 16).

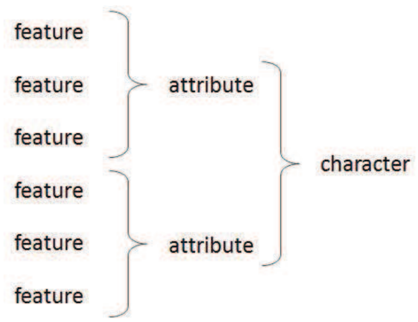


Image 15: Typology of product descriptors (Hassenzahl 2004).

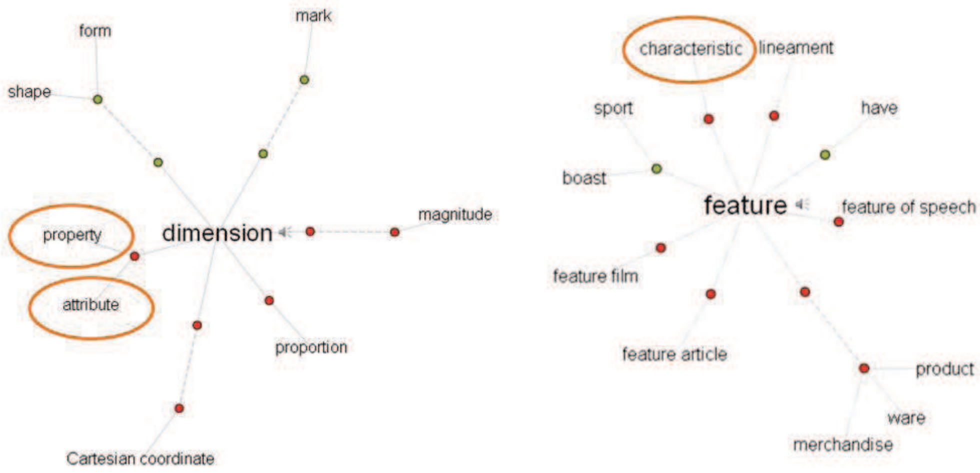


IMAGE 16: VISUAL THESAURUS OF PRODUCT DESCRIPTORS.

The following typology to describe User Experience was chosen for this thesis: The object defines the type of product in question. This object is constituted of various design **DIMENSIONS**, e.g. the surface colour(s), the surface material(s), texture(s), etc. Each dimension can have different **PROPERTIES**, e.g. the colour can be red or green or blue, the material of the surface can be wood or plastic or metal. The colour red itself is defined through the **SUB-PROPERTIES** saturation, hue, and lightness; for an acoustic dimension, properties can be intensity and duration (Scherer, 2004).

(object)		dimension		property		(sub-)property
Chair	>	Colour	>	Red	>	Saturation
				Blue		Hue
				Green		Lightness
				White		
				Silver		
		Material	>	Wood	>	Oak
				Plastic		Birch
				Metal		Beech

There are not always 3 levels of description. Certain properties might be already bijective while some sub-properties might be further declined. For all dimensions that are directly materialised in the product design, like form, colour, material, and texture, the term **CONCRETE DIMENSIONS** is adopted. They are of objective nature and their conception follows common principles, for example the theory of Gestalt and the rules of colour harmony established over the last centuries including theories of Goethe, Chevreul, Ostwald, Munsell, Itten, Moon and Spencer, etc. (Luo, 2006). Otherwise they can be selected from data banks (“CES Selector,” 2010) based on objective criteria. Users perceive concrete dimension properties and will accord different meanings and emotions to them (Crilly, Moultrie, & Clarkson, 2004; Desmet & Hekkert, 2007). They will here be called attributed properties of **ABSTRACT DIMENSIONS**. To bring properties of abstract dimensions into a product, they have to be translated into properties of concrete dimensions (Snelders, 2003). A User Experience is generated through the fit between abstract and concrete dimensions in a specific context (Roto et al., 2011).

2.1.2 Models of User Experience

Over the last decade, researchers proposed first models related to User Experience. In the following a selection of relevant contributions from the main actors in the domains Kansei Engineering, Human-Computer Interaction, Emotional Design, and User Experience is presented in chronological order. None of these models exhaustively illustrates all dimensions and mechanisms of User Experience. Each has been created to illustrate a slightly different view point and includes only some dimensions. However, in their totality, they bring us closer to a holistic view on dimensions that play part in the experience of the user with a product. All found models place the user and the product on two opposite sides. The information circulates in a context space between user and product. Some researchers add the designer/manufacturer with his intention as another pole.

The first model on User Experience was proposed by Forlizzi and Ford in the year 2000. It is a simple schema including basic factors that influence the experience (Image 17). The user is placed on one side, the product on the other. Both are enclosed by the context of use as well as social and cultural factors. The experience of the user is conditioned by his **EMOTIONS**, his **VALUES**, and his **PRIOR EXPERIENCES**. The product is characterised through its **FORM LANGUAGES**, its **FEATURES**, its **AESTHETIC QUALITIES**, and its **USEFULNESS**. This schema is far from exhaustive, but lists very relevant dimensions. It is one of the first proposals in the field on which other researchers have built their models.

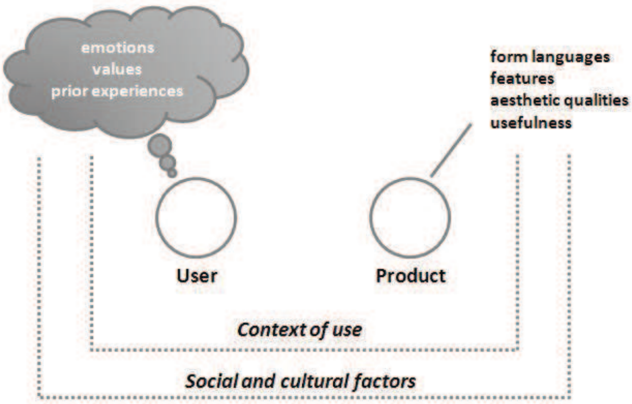


IMAGE 17: INFLUENCES ON EXPERIENCE (FORLIZZI & FORD, 2000)

In 2003, Hassenzahl presented his overview on the key elements of User Experience (Image 19). His model looks at User Experience from the designer perspective on one side and the user perspective on the other side. The intended product character, in between these two, is formed by two types of attributes: pragmatic attributes (related to the product manipulation) and hedonic attributes (including stimulation, identification, and evocation). The designer conceives product features like **CONTENT, PRESENTATION, FUNCTIONALITY**, and **INTERACTION** to create the product character. The user perceives the product character in a specific situation and reacts to it with consequences in form of **APPEAL, PLEASURE**, and **SATISFACTION**. This model is interesting for product development since it clearly distinguishes what the designer can practically conceive while keeping in mind what the user can perceive.

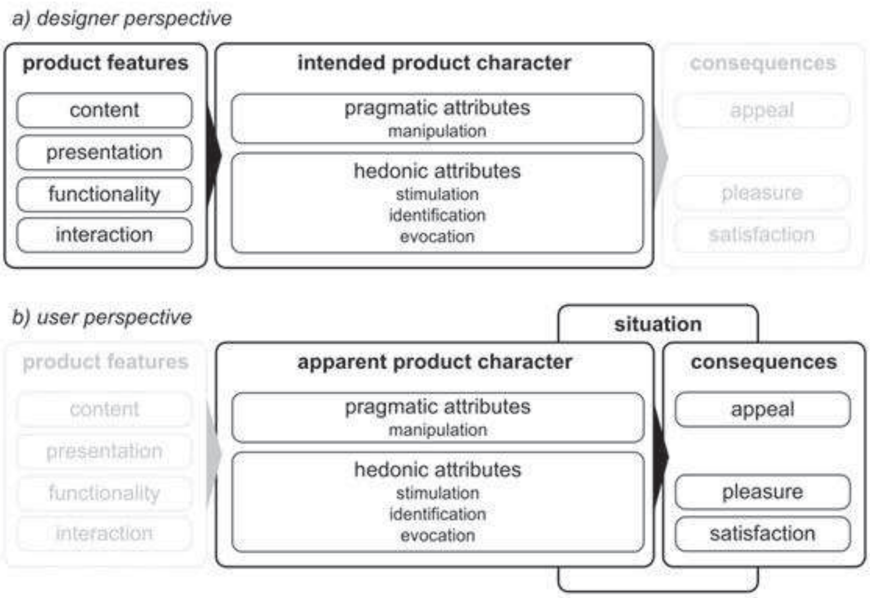


IMAGE 19: KEY ELEMENTS OF THE MODEL OF USER EXPERIENCE FROM (A) A DESIGNER PERSPECTIVE AND (B) A USER PERSPECTIVE (HASSENZAHL, 2003)

In 2004 Crilly, Moultrie, and Clarkson introduced a complex framework that focuses on the consumer response to visual stimuli in product design (Image 18). They underwent a profound literature review and assembled various theories on product appearance. They consider the visual dimensions the key components of User Experience. Similar to Hassenzahl, there are three actors in the model: the design team with its intention, the product, and the consumer. The latter two are enclosed by the context of consumption. The product is characterised through the visual attributes **GEOMETRY, DIMENSIONS, TEXTURES, MATERIALS, COLOURS, GRAPHICS,** and **DETAILS**. The consumer perceives those

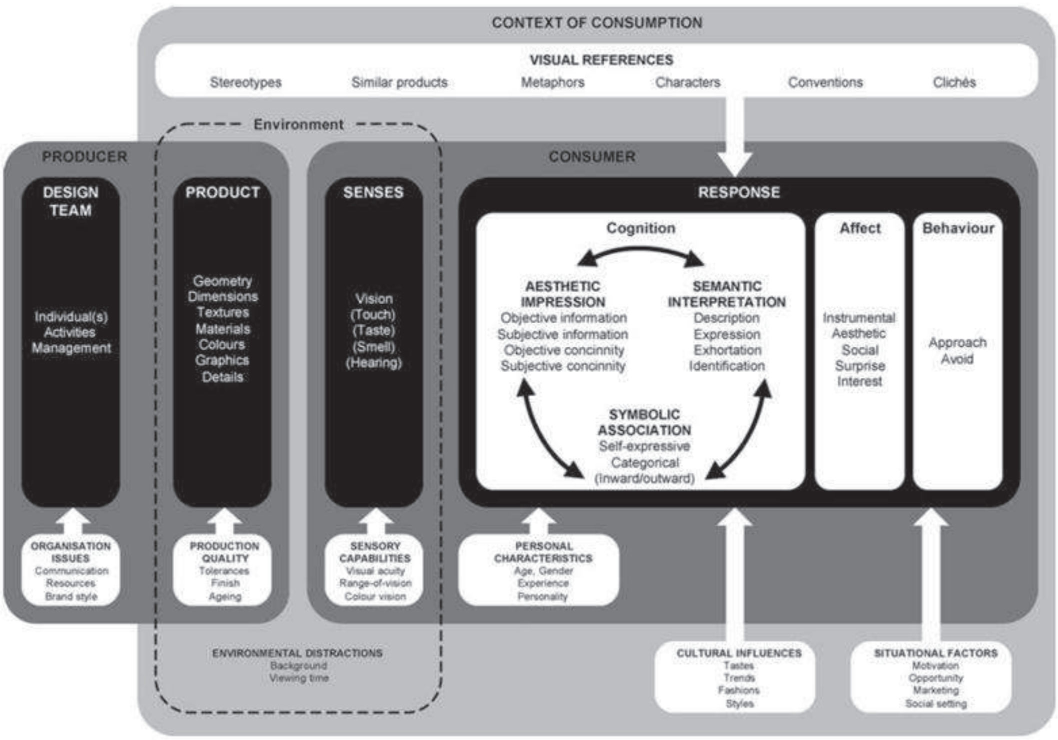


IMAGE 18: FRAMEWORK FOR CONSUMER RESPONSE TO THE VISUAL DOMAIN IN PRODUCT DESIGN (CRILLY ET AL., 2004)

through his senses. The following consumer response is repartitioned into three parts: **COGNITION** (aesthetic impression, semantic impression, symbolic impression), **AFFECT** (instrumental, aesthetic, social, surprise, interest), and **BEHAVIOUR** (approach and avoid). Even though this framework was created with regard to the visual dimension only, many of its contents also widely apply to the other sensorial dimensions.

The models of Hassenzahl and Crilly, Moultrie, and Clarkson treat the user-product relation in one direction: how does the user perceive the product. They work well if the scope is limited to static product designs. However, dynamically changing products work in two directions from the product to the user and from the user to the product. Consequently temporal changes in perception cannot be explained with these two models. The basic model of Forlizzi and Ford leaves this option open.

In the intro of their book on 'Product Experience', Schifferstein and Hekkert present their synthetic view on human-product interaction. On the one hand there is the human with **ITS MOTOR, SENSORY, COGNITIVE SYSTEM** capabilities and the according **SKILLS**, on the other hand is the product with its properties of **STRUCTURE, MATERIAL**, etc. and its according **SENSORS** and **POSSIBILITIES OF ACTION**. The interaction happens between the human skills and the product sensory properties and behaviours (Schifferstein & Hekkert, 2008).

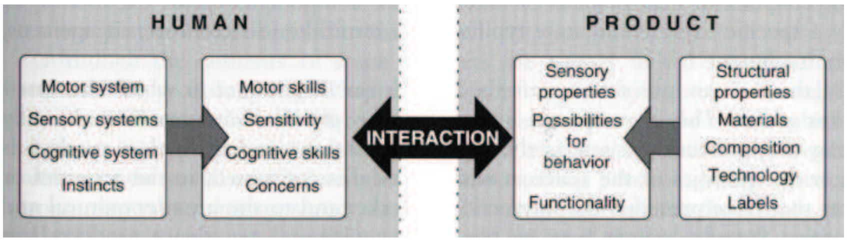


IMAGE 20: MODEL OF HUMAN–PRODUCT INTERACTION BY SCHIFFERSTEIN, HEKKERT (2008).

Locher, Overbeeke, and Wensveen's model from 2009 visualises a cycle between the user and the product. Their Framework for Aesthetic Experience describes the coupling of user actions and product functions (Image 21). They too put the human and its context on one side, the artefact and its context on the other. An interaction space spans between the two. The artefact context is defined through **PRODUCT CHARACTERISTICS**, and **SITUATIONAL CHARACTERISTICS**. Many attributes are assigned to the person, among them his **GENERAL KNOWLEDGE, LEVEL OF AESTHETIC SOPHISTICATION, PERSONAL TASTE, COGNITIVE STATE, AFFECTIVE STATE, PERSONALITY, MOTIVATION, CULTURAL BACKGROUND,** and **BODY SKILLS**. The central executive processes the functional and augmented information coming from the artefact. For the information treatment, it refers to activated memory contents, and encodes spatial-temporal changes. What follows are actions of the person's sensory-motor system which influence the artefact. Locher, Overbeeke, and Wensveen take into consideration that interaction between the person and the artefact is a continually changing process that works in two directions. The artefacts appearance stimulates a multitude of reactions in the person. It can convey **AESTHETIC** and **SYMBOLIC VALUES**, and communicate **FUNCTIONAL CHARACTERISTICS, PRODUCT CATEGORIZATIONS**. The person's cognitive structure contains **SEMANTIC, EPISODIC**, and **STRATEGIC** information that allows him to interpret the stimuli from the artefact.

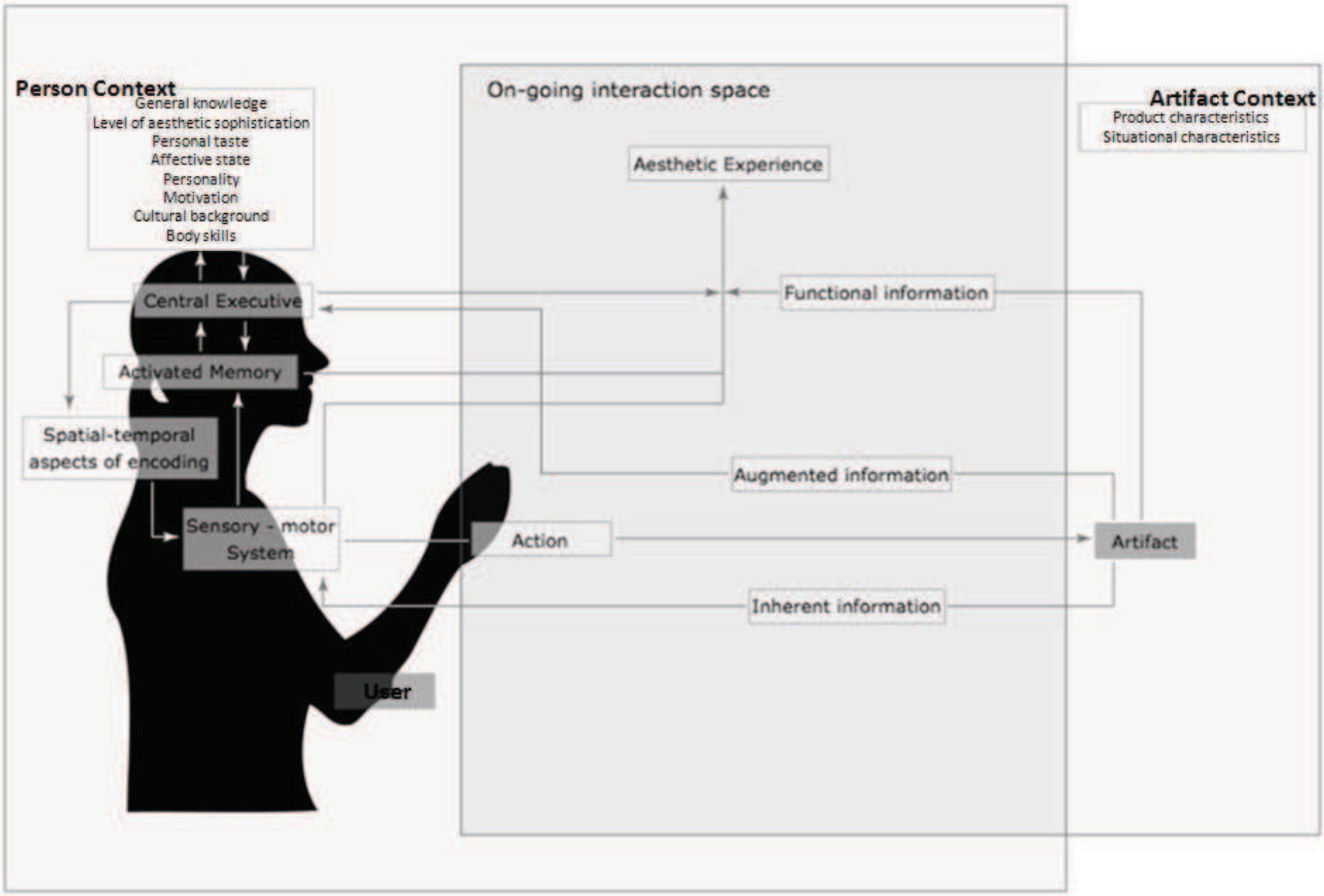


IMAGE 21: FRAMEWORK FOR AESTHETIC EXPERIENCE (LOCHER ET AL., 2009)

A very first model that illustrates use sequences is Krippendorff's 'Interaction protocol of an interface'. It describes User Experience through the interaction between the user and the artefact over time (Image 22) as a reciprocal cause-effect.

> *"[…] in an interface, user concepts penetrate the domain of a machine to the extent that the machine affects them and relevant parts of the structure of the machine enter human cognition as needed to inform actions."* (Krippendorff, 2005) *(p. 79)*

In his model human agency and material artefacts are separated. Both sides are capable of **SENSING INPUTS** and showing **ACTIONS (OUTPUT)**. On the user side the level of **MEANING** is added between sensing and action. External factors from the context of use (**EXTERNALITIES**) potentially impact the actions.

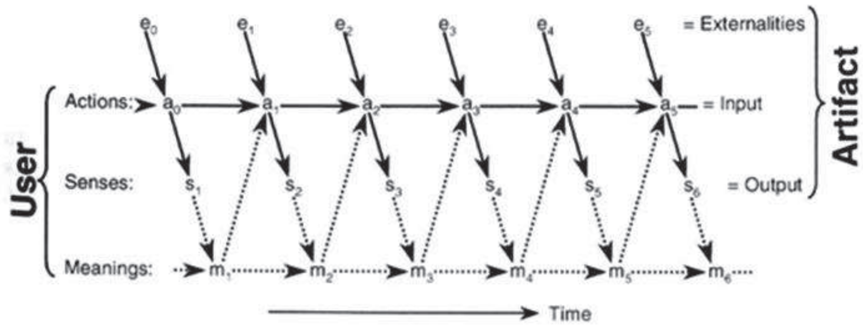


IMAGE 22: INTERACTION PROTOCOL OF AN INTERFACE BY KRIPPENDORFF 2005

Various models on human-product experience have been proposed over the last ten years. Together they hint at a wide range of factors that need to be taken into consideration when designing for User Experience. Even though, the models are each quite comprehensible, they do not sufficiently inform designers. Everybody will agree that a product that evokes pleasure will be experienced as a positive User Experience. However, without understanding more about cognitive and affective mechanisms it is difficult for designers to actually design positive user experiences. We therefore leave the field of design research and consult disciplines like cognitive psychology for a more profound understanding of the human perceptive and effective capabilities.

2.1.3 DIMENSIONS OF HUMAN PERCEPTION

Research on User Experience is a relatively young discipline. Yet its principles are based on the human perception of objects, a mechanism that has been investigated by Cognitive Psychology, Neuroscience, Sociology, Semiotics, and Philosophy for more than a century. Design research can access this knowledge to understand how humans perceive and interact with products.

One of the first formalisations on human perception was Uexküll's 'Scheme for a Circular Feedback' (Wirkkreis) from 1920 (Image 23). According to it, the nervous system interacts with the environment through sensory inputs and motor outputs. Organisms hold **RECEPTORS TO SENSE** changes of the **INDICATOR** (their environment) in order to anticipate and coordinate actions that help them to fulfil their goals (e.g. nutrition, reproduction, belonging). These **SENSORY RECEPTORS** constantly adapt their states upon interaction with the object. Inside the

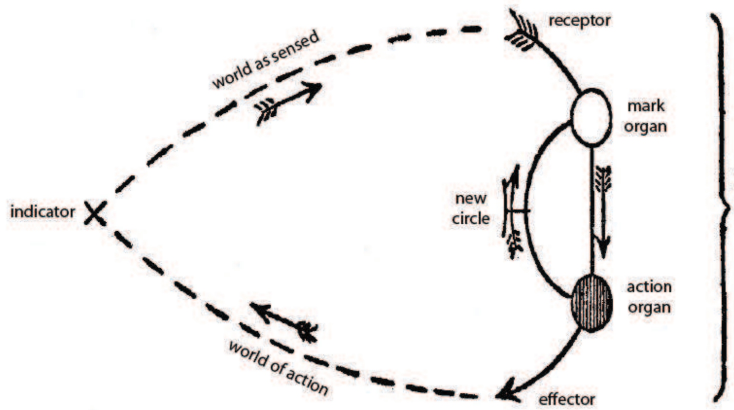


IMAGE 23: UEXKÜLL'S SCHEME FOR A CIRCULAR FEEDBACK (CARIANI, 2001).

human nervous system, the information circulates between **SENSORS** (the mark organ) and **EFFECTORS** (the action organ). On an abstract level one can model the path information takes inside the nervous system as perception loops through the memory. Each internal loop serves a different function: measurement, computation, prediction, evaluation, and action. The memory contents continually modify themselves as a response to new experiences. Sensed patterns are compared to previous patterns and templates are created or altered. The nervous system then determines which actions to take in response to the sensed information (Axelrod, 1973; Cariani, 2001). The action organs (e.g. muscles) act as **EFFECTORS** that can alter the state of the **INDICATOR** (the environment or the object they interact with). The human learns to understand an unfamiliar object by interacting with it (Russell, 2003).

Gibson enriched this model through the so-called affordances approach. Thereupon we do not perceive characteristics of the environment but rather opportunities for action, so called affordances, like climb-ability, pull-ability, etc. When people sense their surroundings they recognise coherent patterns of objects or events that have some meaning to them (Russell, 2003). *"The psychologists assume that objects are composed of their qualities. But I now suggest that what we perceive when we look at objects are their affordances, not their qualities."* (Gibson, 1986)(p. 134) This is important for User Experience design, since it means visual properties like form or colour do not become stimuli just by themselves but through the affordance they communicate. Gibson's direct perception approach applies to the physical world but it has its limits for the indirect nature of digital representations (Ware, 2012). Gibson furthermore set the ground for the Enaction theory according to which perception does not work through the analysis of sensorial information only. Certain properties only become stimuli when modifications to their original state appear. The sensorial information therefore needs to be seen in relation to spatiality and temporality. Perception is based on successive reception and actions (Lenay, 2006). Lenay points out that to perceive an object does not necessarily mean to recognise it. For conscious recognition a certain action strategy is required. Furthermore, it can be assumed that there are percept-action mechanisms adapted to special purposes and computational strategies that serve general purposes. Those for special purposes are evolutionary specialisations of genetic codes shared among a species, for example for communication or reproduction. General-purpose mechanisms serve to recognise variable aspects of the environment (e.g. changing light or sound conditions) of which the species has no control. Both together allow the human or organism to recognise invariant properties (like forms) under varying conditions (Cariani, 2001).

Sensing, cognition and affect, and action are embedded in neural discharge activities. Neuroscientists do not yet agree on the brain mechanism involved (Cariani, 2001) but there exist various models that describe each of these dimensions. In the following we look at the details of human perception based on the 3 levels defined by Uexküll: the **HUMAN SENSES** (reception), **THE HUMAN COGNITION & AFFECT** (the inner world) and the **HUMAN RESPONSES** (effect).

2.1.3.1 THE HUMAN SENSES

In order to perceive their surroundings, humans dispose of a limited range of physiological capacities (sensors) to capture information. They can be classified into exteroceptive, proprioceptive, interoceptive senses (LaMuth, 2011) and chronoception.

senses	definition
EXTEROCEPTIVE SENSES	Capture stimuli that are external to the organism (Oxford dictionary), in order to keep him aware of the environmental changes. They are *visual* (the eyes / ophthalmoception), *auditory* (the ears and bones / audioception), *gustatory* (the tongue with its taste buds / gustaoception), *olfactory* (the nose / olfacoception), and *somesthetic.* The somesthetic senses form a complex system able to sense *heat or cold* (thermoreceptors), *pain* (nociceptors), *pressure* (pacinian corpuscles), and *touch* (mechanoreceptors) (Amsel, 2005).
PROPRIOCEPTIVE SENSES	Arise from the spatial body orientation. They include the sense of *balance* (vestibular input from the inner ear/equilibrioception)*, position* (limb and joint afferents/ stretch receptors), and *movement* (muscles for kinesthesioception).
INTEROCEPTIVE SENSES	Relate to stimuli that are produced within the organism from the *visceral, digestive,* and *autonomic* systems to secure bodily functions. They work through *chemoreceptors* that regulate hunger, thirst, body temperature, blood pressure, and sexual behaviour.
CHRONOCEPTION	Humans also have limited capabilities to sense of time. However the perception of event duration is subjective and variable. There is no direct sensor for time, it is mostly reconstructed from other sensed information (Tangient LLC, 2013).

Humans are also capable of **CROSS-SENSORY TRANSFERS**. For example people who lose sight can partially substitute the visual sense with enhanced auditory and tactile senses. Furthermore sensory substitution devices can be employed as a new means to acquire the non accessible information to compensate the loss of one sense (Bach-y-Rita & W. Kercel, 2003; Lenay, Gapenne, Hanneton, Marque, & Christelle Genouëlle, 2003). **SYNAESTHESIA** is a phenomenon "*in which stimulation of one sensory modality causes unusual experiences in a second, unstimulated modality*" (Hubbard & Ramachandran, 2005) like letters or numbers that are associated with colours (grapheme-colour synaesthesia), sounds that induce colours (Grossenbacher & Lovelace, 2001), or lexical-gustatory synaesthesia where sounds evoke a taste (Ward & Simner, 2003). Real synaesthesia happens involuntary and concerns about 4 % of the population (Simner et al., 2006).

This is a very brief overview on the type of information a human is able to capture. Product Design so far exploit only few of these capabilities, concentrated on the visual and as an emerging trend the tactile and the olfactory senses. To address a wider spectrum of sensors holds a high potential for

User Experience Design. For example, if a design seeks to address the visual domain, its shape and colour are of course the main factors but designers could also work on shadows and light or movement. Or when touch becomes part of design considerations, not only the texture structure but also the felt temperature of material or the weight of the object are interesting dimensions that humans can sense and appreciate.

2.1.3.2 THE HUMAN COGNITION AND AFFECT

Once stimulus information has been captured by the human senses, it enters the "inner world" of the human that prepares his motor responses to this stimulus. The sensorial information takes two distinct neuronal pathways: the ventral system with the main function of identification and the dorsal for the control of motor behaviour (J. Norman, 2002).As Russell (2003) states, cognitive events are essentially related to an object/a situation/something. Humans experience emotional episodes induced by an object but also independently of any stimulus. Cognition and affect are two closely related mechanisms of perception. Cognition enables the human to understand his environment, affect allows him to judge what he perceives (Bonnardel, 2012). To this day neuroscientists are still discordant whether both are distinct or if cognition is included in the affective process. But they agree that affect has a cognitive component (Bonnardel, 2012; Lane, Nadel, Allen, & Kaszniak, 2000; Russell, 2003; Scherer, 2004). Russell gives the example of experiencing "pride". To be proud means to feel good about one's self. While "feeling good" is an affect, the object "about one's self" is a cognitive element. Helander and Khalid suggest that humans treat stimuli parallel on the affective and on the cognitive level (see Image 24). In their model, affect is intuitive and experiential and leads to reactions like **EMOTIONS, SENTIMENTS** and **ATTITUDES.** Cognition is the analytical, rational part of information treatment. It creates lasting **KNOWLEDGE, MEANINGS** *and* **BELIEFS** (Khalid, 2006).

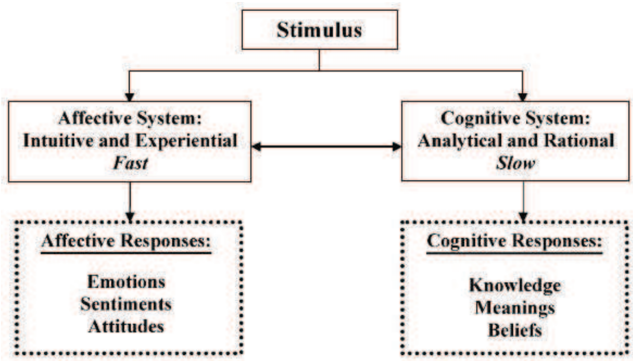


IMAGE 24: COUPLING OF AFFECT AND COGNITION (KHALID, 2006).

To understand cognitive and affective mechanisms of human perception is important for the User Experience Design. Several cognitive and affective components are intentionally or unintentionally addressed by a product design. The better we understand these mechanisms the more consciously we can design objects for the desired cognitive and affective response.

2.1.3.2.1 Human Cognition

Cognitive processes work via three different semiotic pathways. Neural assemblies of the sensory and the motor system link the external information with the brain on a **SEMANTIC** level (relations of symbols to the external world). The **SYNTACTIC** circuit (relations of symbols to other symbols) comes into play for prediction, planning, and coordination of outputs. Evaluation based on the human motivations/goals happens on the **PRAGMATIC** level (relations of symbols to system-purposes) (Cariani, 2001).

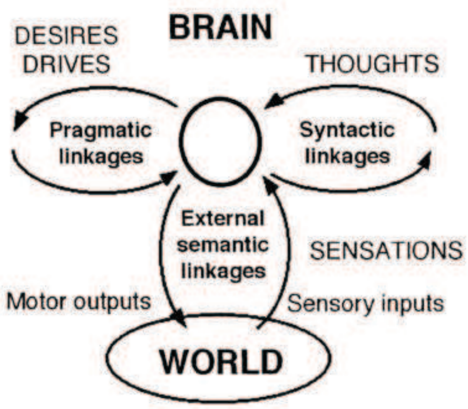


Image 25: Semiotics of brain states (Cariani 2001).

Another way to model the process of cognition is the Schema Model (Image 26). It describes how human's process new information in order to make sense of it. According to this theory any new information is out-balanced with patterns that have been used in the past. By doing so the old patterns are reinforced or modified. At the beginning stands a message (a stimulus) that holds different types of information on several cases at a specific instance in time (e.g. the current condition of an object property like the fill level of a glass). The information also has a known source. The human has built schemas to interpret information. The information processing succeeds the following way: When a message is received, the human seeks first to find an already available interpretation of this case. If that exits, he will

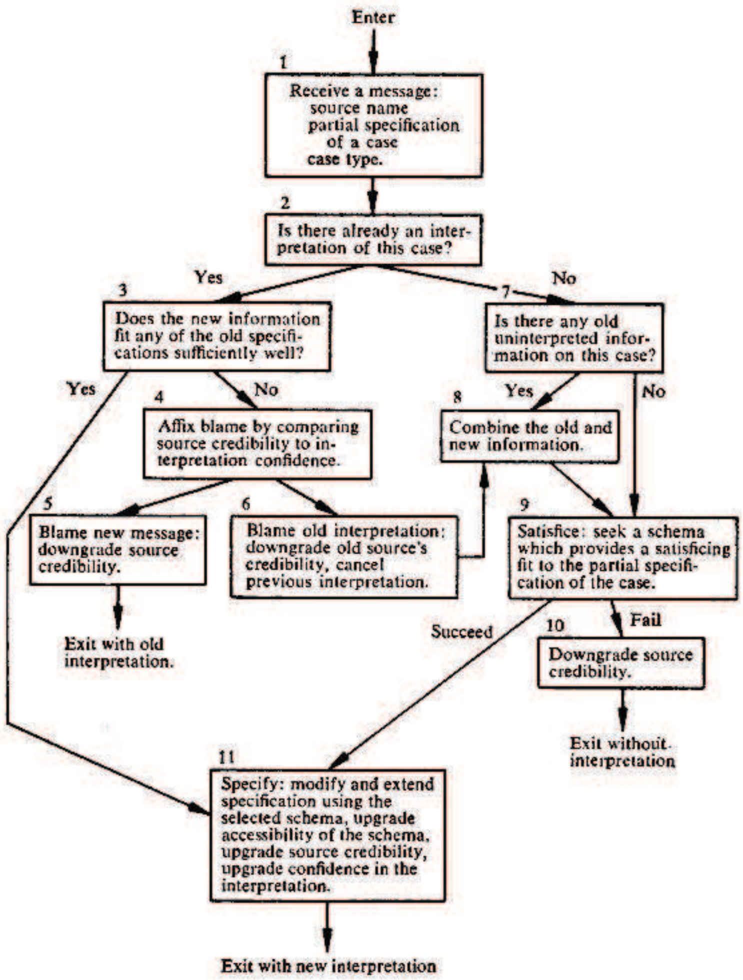


Image 26: Schema Model: An Information Processing Model of Perception and Cognition (Axelrod, 1973).

verify if the new information is in accordance with the old interpretation. If that is the case this interpretation will be reinforced and the behaviour is equivalent. If the new information does not fit old interpretations, he first questions the credibility of the source. If it is low, he will keep the old interpretation. If the source credibility is high, he will have to amend the old interpretation. The same is necessary if no interpretation exists so far. In this case other schemas are sought to help with the interpretation. The human will try one schema after another starting with the schemas that are easiest to reach / that have served often. If he finds a satisfying interpretation with the help of a schema, the applied schema will become more easily accessible and the source credibility will be upgraded. If no schema can be found to interpret the information, the source credibility will be downgraded and no interpretation is done (Axelrod, 1973).

Another perspective on cognition, that is interesting for User Experience Design, comes from Rasmussen (1983). His model is based on three layers of performance: **SKILL-**based, **RULE-**based, and **KNOWLEDGE-**based behaviour. The cognitive load depends on the type of perceived data.

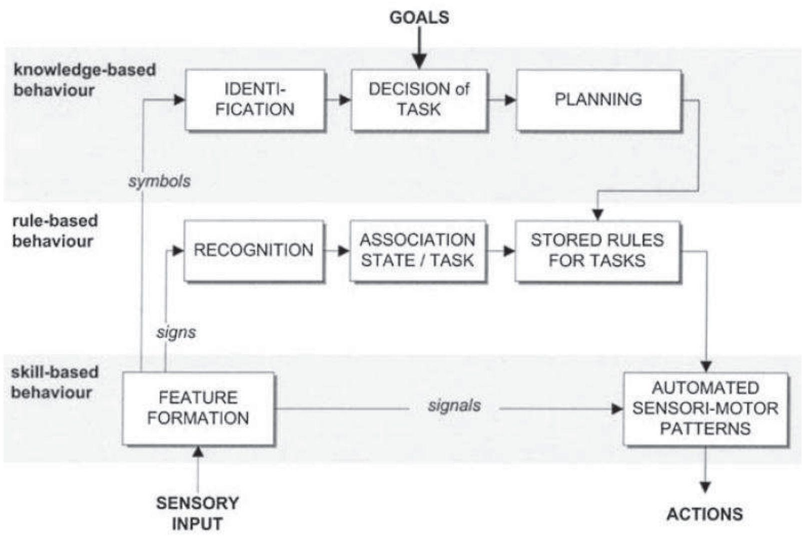


IMAGE 27: THREE LEVELS OF PERCEPTION, AFTER RASMUSSEN (1983).

i. Basic feature information (like spatial changes) constitutes a signal that can directly trigger a motor response. The response is a learned skill that can be carried out without thought.
ii. If the perceived feature does not directly address a skill but is in accordance with a specific situation/task/goal of the human, it becomes a sign to which the human can respond through action sequences that he has learned at one point in his life, so-called rules.
iii. If the stimulus is relevant for the situation and of novelty, the user needs to constitute a new mental model of the problem based on his available knowledge in order to respond adequately. The stimulus in this case becomes a symbol.

For the Interaction Design the difference between signal, sign and symbol is relevant. In emergency situations the stimulus emitted by the product needs to be a signal, so that the operator will not have to reflect about his reaction. If this is not possible, the designed sign needs to be easily comprehensible and the learning process has to be designed with it (Rasmussen, 1983).

All these models look at cognition from a different angle. Cariani distinguishes three types of symbols that humans can process, Rasmussen makes a difference in the complexity of information that has to be processed, and Axelrod describes the cognitive process as a flowchart in which arriving information is compared to available data.

2.1.3.2.2 Human Affect

Contrary to cognitive processes the affective part of information processing is still little understood and models are more based on folk than on scientific concepts (Russell, 2003). Some researchers call it affect, others talk about emotions. Yet emotions are not equivalent with affect. Emotions are one part of affects.

> *"…what we loosely call "emotions" are responses to events that are important to the individual [...] "emotions" are subjective experiences. Their core is the experience of pleasure or pain."* (Nico H. Frijda, 1988)

Wundt was the first to propose an emotion model that had three continuous dimensions: **PLEASANT–UNPLEASANT (VALENCE), TENSION–RELAXATION (TENSION),** and **EXCITEMENT–CALM (AROUSAL)** (Wilhelm Max Wundt, 1914). Models that built on it are for example Russell's circle of core affects (Image 28) with the two poles **'ACTIVATION – DEACTIVATION' AND 'DISPLEASURE – PLEASURE'** or Plutchik's wheel of emotions (Plutchik, 1991) that forms a cone. All emotions of **LOW INTENSITY** meet at the neutral tip point. The **HIGHEST INTENSITY** is on the flat side (Image 29).

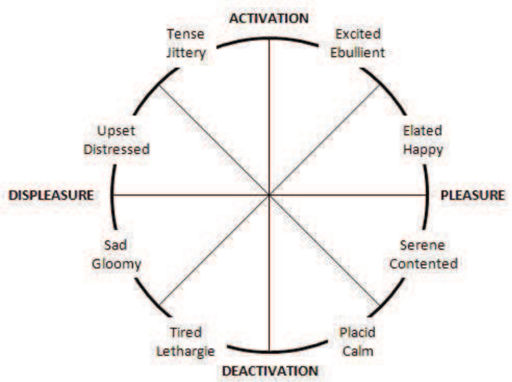


Image 28: Core Affects (Russell 2003).

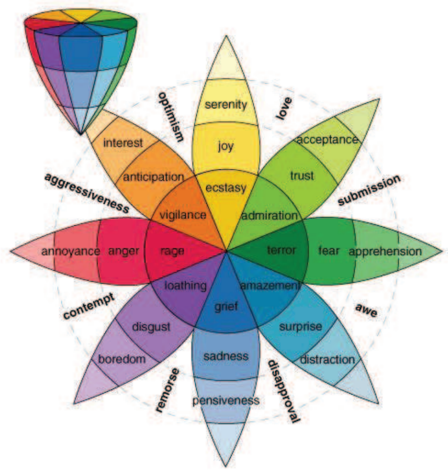


Image 29: Wheel of emotions (Plutchik 1991).

Studies suggest that unpleasant stimuli are more arousing than pleasant ones (Bradley & Lang, 2000). It has also been shown that events that are accompanied by strong arousal are better remembered. However this seems to be stronger for negative than for positive valence (Kensinger, 2009).

As a synthesis of the types of affects defined by Scherer (2004) and Russel (2003), the following 6 affective phenomena can be distinguished:

affect type	definition
Core Affect (mood)	Diffuse affect states of low intensity, usually rather long lasting, independent of an object/person/event (irritable, depressed, cheerful, buoyant, etc.).
Attributed Affect	Core affect attributed to an object/person/event.
Utilitarian Emotions	Brief episodes of synchronised response "of all or most of the five organismic subsystems" to an external or internal stimulus event that is relevant to the organism, personal goals and bodily needs (fear, anger, sadness, joy, disgust, etc.).
Aesthetic Emotions	Brief episodes experienced through evaluations of sensorial stimuli on their intrinsic qualities, irrespective of bodily needs, current goals or social concerns, addressed to a cause like a piece of art, a design, music, etc. (being full of wonder, admiration, fascination, ecstasy, harmony, rapture, etc.).
Preferences	Stable evaluative judgements on the pleasantness of a stimulus (like/dislike, positive/negative).
Attitudes/values	Enduring beliefs or predispositions towards an object or a person (loving, hating, desiring, rejecting, etc.). They are based on values that are "desirable, trans-situational goals […] that serve as guiding principles in people's lives" (S. H. Schwartz & Sagiv, 1995).
Affect Dispositions	Stable personality traits that lead a person to frequently experience certain moods and to react with similar emotions and behaviours on certain types of objects, persons or events (nervous, anxious, reckless, jealous, etc.).
Interpersonal stances	Affective style adopted by the person in a specific social situation (distant, open-hearted, supportive, etc.).

Affect dispositions, attitudes/values, and **preferences** are rather stable elements of human affect. They slowly evolve over the person's lifetime as a result of interaction with his environment (Desmet & Hekkert, 2007). **Core affects** can last for a day, some days or even weeks. **Attributed affects** alter instantly with each new stimulus that appears (Image 30).

The long-lasting affect components influence the experienced temporary core affects and attributed affects. **Preferences, attitudes/values**, and **affect dispositions** are always present, but only addressed once there is an external stimulus to be evaluated. Contrary to that, humans always experience some state of **core affect**, even if they are not conscious about it. **Core affect** is an intrinsic state of the human. It describes a mood or a lasting state that occurs during emotion-rich events. At any time anybody is able to define his core affect state.

Image 30: Affects over time.

Products can be an external cause that alters core affect (Russell, 2003). When the human perceives an external stimulus an **emotional episode** starts. **Emotional episodes** are evoked by the **affective**

QUALITY that is a property of a stimulus. AFFECTIVE QUALITY of a stimulus can be perceived as pleasant or unpleasant, and activating or deactivating. The perception of the affective quality of a stimulus does not necessarily change the core affect. Both can be experienced at the same time even in a non-congruent way. Somebody who feels depressed will confirm the beauty of a landscape, and yet still feel sad. An AFFECTIVE QUALITY, that is perceived by the humans is called ATTRIBUTED AFFECT (Russell, 2003). Scherer's UTILITARIAN OR AESTHETIC EMOTIONS can be considered as two different types of ATTRIBUTED AFFECTS.

Design evaluations should try to distinguish between attributed affects and core affects in order to draw relevant conclusions for design modifications. People are able to evaluate AFFECTIVE QUALITIES of objects or events even without being in the real situation through anticipation (Russell, 2003). However, CORE AFFECT can only be affected when the human experiences the real interaction. Otherwise there is the risk of misinterpretation caused by misattribution or mood-congruent judgement. MISATTRIBUTION means that the core affect evoked by one source is mistakenly attributed to the wrong object (Schwarz & Clore, 1983). MOOD-CONGRUENT JUDGMENT has for effect that a person who is feeling happy processes more positive information of the stimulus and therefore rates it more positively than she would if she was in a gloomy mood (Bower & Forgas, 2012). Negative moods are more easily attributed to an external cause than positive moods (Schwarz & Clore, 1983).

To evaluate the affective quality of a product it might therefore be useful to measure first the CORE AFFECT of the test person, and then the quality the person attributes to the product. When we downgrade the ATTRIBUTED QUALITY for persons with a highly positive core affect and upgrade it for those with a negative core affect we might get an overall idea of the actual AFFECTIVE QUALITY of the product. It is also relevant to understand the VALUES (already considered by (Bouchard, Mantelet, et al., 2009)), PREFERENCES, and DISPOSITION of a person to position her evaluation of a design.

Now that we have seen human senses and human cognitive and affective treatments of stimuli, we take a look at the effector end (von Uexküll, 1926) of human perception: the Human Responses.

2.1.3.3 HUMAN RESPONSES

After stimuli sensing and information processing, human responses constitute the third element of the human percept-action loop. The word effect was used by Uexküll in the context of his circular feedback (Image 23). It embraces the terms behaviour, action, and response. The Oxford dictionary defines *effect* as "a change which is a result or consequence of an action or other cause"; *behaviour* as "the way in which an animal or person behaves in response to a particular situation or stimulus"; *action* as "the fact or process of doing something, typically to achieve an aim", and *response* as "a reaction to something " or (in Psychology & Physiology) as "an excitation of a nerve impulse caused by a change or event; a physical reaction to a specific stimulus or situation". The meanings of these terms overlap but each also excludes certain aspects of the others. For example behaviour and action are only related to controllable events. But human responses can also be of uncontrollable nature, notably when they are bodily symptoms. This thesis will hence speak of 'human responses to a stimulus'. The responses can be of three different types **PHYSIOLOGICAL/SOMATIC, MOTOR, MOTIVATIONAL** (Scherer, 2004, 2005).

effect type	definition
PHYSIOLOGICAL EFFECTS bodily symptoms	Responses of the human metabolism. Symptoms are temperature sensations as a consequence of blood circulation (red cheeks, cold hands, pale face), respiratory accelerations/decelerations, cardiovascular accelerations/decelerations, muscle tension (weak limbs, trembling, relaxing), constriction in internal organs (stomach ache, lump in the throat), and body fluids (transpiration, salvia, odorant) (Scherer, 2004). These responses happen when events appear that disturb the ongoing body state. They have for purpose to set the human body in the condition necessary to cope with the situation. An augmented blood rate for example prepares the body to run away from an aggressor. They can also be an unconscious means of communication.
MOTOR EFFECTS facial, gestural, posture, vocal (action)	Occur on three different body parts: the limbs (gestural, postural), the face (mimic), and the speech organs (vocal). Gestures, postures, mimics and voice are more or less controllable means of human communication that enable the human to visually and audibly show the outsider in which state the situation put them and how they will react (Scherer, 2004). Values that distinguish motor effects are the speed, the amplitude, the frequency/rhythm, pauses, and patterns. The meanings of facial expressions have been subject of research in psychology from Darwin, to Paul Ekman, and Nico H. Frijda.
MOTIVATIONAL EFFECTS action tendencies and readiness (behaviour)	Stable action tendencies towards a specific object or situation (Scherer, 2005), in general approach or withdrawal (Russell, 2003). Become visible in human comportment. The person directs her attention to the subject, like somebody who always buys a specific brand or acts with consciousness on the environmental impact of his behaviour.

Human responses that users show to products can be observed or measured (see 2.2.3.). They therefore provide rather objective data to researchers. However, even though these responses are the result of cognitive and affective judgements, "no specific action or action tendency is produced by or is necessary for a specific emotion" (Russell, 2003). That means an observed behaviour does not represent one specific affect felt by the person. The researchers need to look at the totality of responses and the person's subjective self-evaluations in order to draw conclusions on her experience.

2.1.3.4 CONCLUSION

Section 2.1.3 provided an introduction on the mechanisms of human perception. Firstly we saw that humans dispose of a wide range of sensors that can capture stimuli information. Here lies a first entry point for original ideas to design for User Experience.

Secondly we saw that the stimuli information is processed through a complex interplay of human cognition and affect. To address certain cognitive responses, designers can work on a semantic expression of a product. Designs can also transport a certain affective quality. However, the designer cannot control all individual dimensions of human perception. Somebody's current mood or previous memories are outside of the design scope. Nevertheless, there might be a huge potential for smart products that know to adapt their properties to the user's individual affective disposition and knowledge.

Thirdly a range of human responses was introduced. They can be of physiological, behavioural or motivational nature. A design that causes reactions on each of these three levels is likely to be more engaging than one that only addresses one level. Furthermore, product developers might think about ways to enable their products to not only react on behavioural but also on physiological effects. In order to do so, the designer needs information about the product dimensions and capacities that he can influence through his design. This is therefore the topic of the next section.

2.1.4 Dimensions of dynamically changing products

Hassenzahl assigns four major functions to products: 1. enable people to manipulate their environment, 2. stimulate personal development, 3. express identity, and 4. evoke memories (Hassenzahl, 2003). To do so, products must possess certain properties that facilitate these functions. The models on User Experience in 2.1.2 contain various design dimensions including functionalities, form, colour, material, texture, etc. They are classical contents of product design and will not be further discussed here. It seems more interesting to look at properties that enable the product to react to stimuli from the user and/or the environment. Today products too can have sensing capabilities that facilitate intelligent responses to user actions and they might come with properties that allow a flexible behaviour. In the following, an analogy is therefore drawn with the human perception-action system and potential sensory and responsive capabilities of products are presented.

2.1.4.1 Product sensors

In order to react to user inputs, products need to be capable of perceiving his actions. Classic consumer products (furniture or decoration, or the external parts of industrial designs of a car chassis, telephone housing, etc.) are usually not equipped with sensors. Nowadays there are more and more products that show a dynamic reaction to user inputs through tactile or graphic user interfaces. These products come equipped with a great variety of sensors, depending on the product type and behavioural objective. Such sensors can be classified into the following types (Robotworx, n.d.).

TABLE 2: TYPES OF SENSORS FOR CONSUMER PRODUCTS (NON EXHAUSTIVE).

Sensors categories	Sensors types	Definition
PHYSICAL SENSORS	Active sensors	emits some form of energy, ultrasonic, laser, infrared
	Passive sensors	receive energy, example: a camera
LOGICAL SENSORS		supplies robot with a percept from the physical sensor
PROPRIOCEPTIVE SENSORS		monitor self maintenance, control internal status. for battery monitoring, heat monitoring. Examples: Global Positioning System (GPS), Inertial Navigation System (INS), Shaft/rotary Encoder, Compass, Inclinometer
EXTEROCEPTIVE SENSORS	Contact Sensors	Emit a signal on physical contact, can measure the interaction force and torque, Tactile sensors, conductivity (linear, circular, discontinued)
	Range Sensors	measure distance to an object two principles: time-of-flight and triangulation (reflection, sonar, capacity)
	Vision Sensors	extracting, characterizing and interpreting visual information
EXPROPRIOCEPTIVE SENSORS		combination of proprioceptive and exteroceptive monitoring; measure the relative position through directional sensors, measure difference between internal and external heart. Examples: panning sonar sensors, force sensors.
FORCE SENSORS		measure torque or force or weight

Today product designers have access to a wide range of sensors and actuators (for behavioural response) that are easy to employ in the phases of rapid prototyping– nearly like a pen for sketching or some 3D software for modelling. There are for example the Arduino kits (Arduino, 2012) or Phidgets (Phidgets, 2012) with MAX/MSP, Processing or Adobe Flash with ActionScript that allow designers the modelling of interactive behaviour coupled with sensing technology. These techniques find their way into design education and now that design graduates master them, they begin to enrich the interactivity of products and with it the User Experience (Helm, Aprile, & Keyson, 2008).

2.1.4.2 PRODUCT RESPONSES

All externally perceivable product dimensions potentially are stimuli for the user. Classic stimuli are related to product **APPEARANCE***:* form, colour, material, and texture. Today intelligent technologies have found their way into consumer products. The products are more and more connected to a network, pro-active and capable of adaption to the context (Ross & Wensveen, 2010). The design of intelligent products goes beyond traditional product design (Ross & Wensveen, 2010) and can even be independent of physical materials (Y. Lim et al., 2009). To conceive intelligent products, designers require "a new language of form that incorporates the dynamics of behavior" (Ross & Wensveen, 2010). **DYNAMIC BEHAVIOUR** means that the product adapts its **APPEARANCE** properties to the situation. It may for example alter the orientation of some of its components (like Nabaztag moving his ears) or its colour (e.g. clicked links). These changes can be instantaneously or follow a fixed pattern. Lin and Cheng defined 6 types of interactive behaviours (Lin & Cheng, 2011):

behaviour type	definition
TEMPORAL INDEX	Product display varying sates without user actions (e.g. wrist watch).
REGRESSIVE LOGIC	Two states of the product. The user's action changes the state. A reversion of the same action reinstalls the original state (e.g. on/off switch).
REITERATIVE LOGIC	Like regressive logic but to reinstall original state, user action is repeated, not reversed (e.g. PC power button).
TEMPORAL RECOVERY	User action causes state change. Product automatically returns to original state after a while (e.g. musical box).
SUCCESSIVE LOGIC	Sequence of more than two states. Different user actions cause different states. At one point of sequence original state reappears (e.g. wing cork screw).
SPATIAL SUPERIMPOSITION	Similar to successive logic but based on spatial clues that do not necessarily correspond to user expectations.

Shape change is a specific behaviour that waits to be exploited by Product Designers. They can be changes of **ORIENTATION, FORM, VOLUME, TEXTURE, VISCOSITY, SPATIAL CHANGES,** as well as **ADDITION** or **SUBTRACTION** of elements or changes of **PERMEABILITY** (Kirkegaard Rasmussen, Pedersen, Petersen, & Hornbæk, 2012). Researchers from Human-Computer Interaction have experimented with dynamic **SPATIAL DISTRIBUTION** and **MOTION PATTERNS** on animated displays. They designed abstract animations that were projected on a wall in a community space. The animation patterns responded to voices and movements of people in the space. The designed patterns suggested happiness, curiosity, or fear through their spatial distribution and motion. The researchers found that even very simple patterns can express complex meanings that people interpret on a social dimension (approaching, avoiding, etc.). (Mutlu, Forlizzi, Nourbakhsh, & Hodgins, 2006).

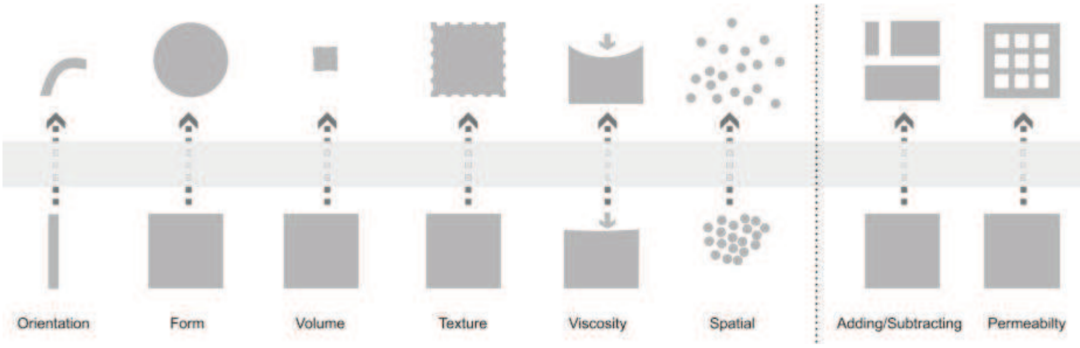


IMAGE 32: TYPES OF SHAPE CHANGE (KIRKEGAARD RASMUSSEN ET AL., 2012)

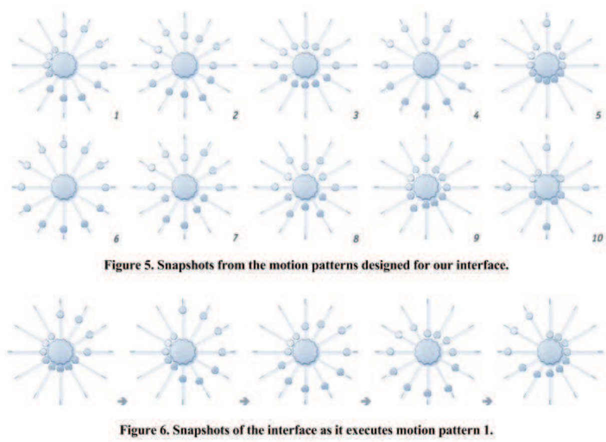


IMAGE 31: ABSTRACT SOCIAL INTERFACE BY MUTLU ET AL. (2006).

Lim et al. too seek to define a vocabulary to describe interactivity properties for graphical interfaces. They found the following properties as descriptors of interactive behaviour (Y. Lim et al., 2009):

- **Concurrency** (concurrent – sequential)
- **Continuity** (continuous – discrete)
- **Expectedness** (expected – unexpected)
- **Movement range** (narrow range – wide range)
- **Movement speed** (fast – slow)
- **Proximity** (precise – proximate)
- **Response speed** (delayed – prompt)

Building on the works of these researchers, the following product dimensions can potentially show dynamic behaviour (see Table 3). The behaviours of these listed dimensions apply primarily to physical products. Their range for graphical interfaces on digital displays is limited since here "interaction as a separable entity to be designed, detached from embodied physical materials" (Y. Lim et al., 2009).

Table 3: Possibilities of dynamic behaviour for product dimensions (non exhaustive).

Dimension	Property	Behaviour
Material	(depending on the material)	elasticity, colour, temperature, conductivity…(Ashby & Johnson, 2010)
Colour		hue, saturation, lightness
Texture	visual texture tactile texture	smoothness, transparency…
Illumination		intensity, colour, movement pattern, fade pattern
Sound (Özcan, 2008)	volume	increase or decrease
	timbre	change type
	pitch	increase or decrease
	melody / pattern	change in a pattern or randomly
	spatiality (source)	orientation change
Form		geometrically defined free-forms adapt to human dimensions (ergonomic)
	Body volume	increase or decrease
Orientation		between two states or seamlessly 360°, on 3 spatial axes
Permeability		binary or seamlessly from complete permeability to impermeable
Spatial distribution		of product elements in the available space systematic (meaningful) or random way; the product itsself can change its position in the room/space
Components		can be added/subtracted
Functionality		can change when the purpose is distorted, e.g. a bottle becomes a vase, a chair used as a ladder
Language style		casual / formal style natural / artificial style (Blanchy, 2010)

2.1.4.3 Conclusion

Products are constituted of a wide range of design dimensions. They define the product appearance as well as its behaviour. To this day product design is often seen as something static. But products can be equipped for dynamic behaviours. Designers have the possibility to explore for example form changes thanks to flexible materials, or spatiality and motion changes on graphic interfaces in order to communicate with the user or to adjust their behaviour to the context of use. To design adaptive behaviour, product designers need knowledge about the different types of human or environmental responses that a product can capture if equipped with the corresponding sensors.

2.1.5 The Temporal Dimension of User Experience

A final dimension that has been identified as a particularly important factor of User Experience is time. It will be discussed in this final part on User Experience dimensions.

2.1.5.1 User Experience over time

According to Norman, when humans perceive products, information processing happens on three levels: the *visceral* level, the *behavioural* level, and the *reflective* level. The visceral level refers to initial reactions on a stimulus, the so-called instinct. The human makes fast judgements about the product. Is it good or bad, safe or dangerous? The behavioural level relates to the product use and its performance. It is experienced during interaction with the object. What are its functions? How usable is it? What is the physical feedback? On the third reflective level, humans give a meaning to the product and eventually identify with it. This level can still be active when the product does not exist anymore. An event can trigger memories of the object and evoke feelings (D. A. Norman, 2004).

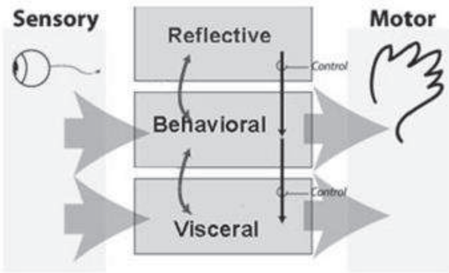


Image 33: Norman's three levels of information processing.

Hassenzahl demands a "longitudinal approach" to User Experience design. He distinguishes between a micro (an hour of usage), meso (a few weeks of usage), and macro (years of usage) perspective on the User Experience with a product. Roto et al. identified four types of User Experience over time: the anticipated UX (before usage), the momentary UX (during usage), the episodic UX (after usage), and the cumulative UX (multiple periods of usage over time) (Roto et al., 2011).

From the product conception point of view, there are two different types of temporality that can be effectively shaped by the designer: The use sequence of the actual interaction and eventually the cumulative UX of the product usage over a long time:

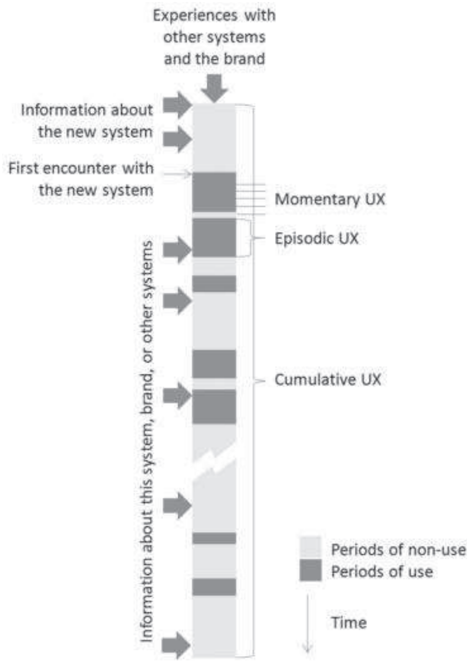


Image 34: UX over time with periods of use and non-use (Roto et al. 2011).

2.1.5.1.1 Use sequences

A dynamically changing product is conceived as a continuous cycle of sensing and response on the human and on the product side. The human as well as the artefact are both capable of sensing inputs, processing this data, and responding with distinct behaviour (output actions). The data circulates between the human and the artefact and is transformed (Krippendorff, 2005).

Lin and Cheng used the model of Krippendorff to prove semantic shifts in human-product interaction sequences. They chose seven lamps with the representation of five use stages for each one. They then showed the images of interaction to test persons who were asked to rate surprise and pleasure on a seven point scale after each sequence picture. The results show that a change of semantics leads to a change of emotions over the different interaction steps (Lin & Cheng, 2011).

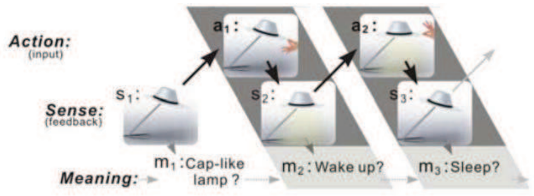


IMAGE 35: USE SEQUENCE OF A LAMP, MAPPED ON KRIPPENDORFF'S INTERACTION PROTOCOL (LIN AND CHENG 2011).

2.1.5.1.2 LONG-TERM UX

An interactive product might show reoccurring response patterns to user actions, but the user might respond differently to those after a while. Surprise can only be triggered once. Excitement changes into comfort once the user gets familiar with the product. Even when the product disappears from sight, the memory of it can still trigger emotions (D. A. Norman, 2004).

Locher, Overbeeke, and Wensveen mention two stages of interaction: the *initial glance* and the *visual scrutiny/focal analysis*. Both are descriptive for the very early moments of contact with an artefact (Locher, Overbeeke, & Wensveen, 2009). Karapanos et al. undertook a long-term study with iphone users from the intention of purchase until a few months of usage. They proved a shift in User Experience over time and identified four phases: *anticipation, orientation, incorporation,* and *identification*. *Anticipation* raises the person's expectations towards the product. During *orientation* the basic responses of the product are learned. Once users handle the product with ease and have decided over its usefulness, it gets *incorporated* on a long-term. Users eventually show emotional attachment and *identify* with the product. They are also able to assign different product qualities to each phase. During the orientation phase, stimulation and learnability are appreciated by the participants. This leads to a certain familiarity with the product. In the following incorporation phase usefulness and long-term usability are important. A functional dependency of the user on the product appears.

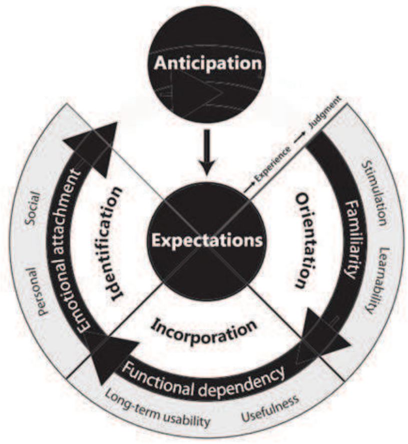


IMAGE 36: TEMPORALITY OF EXPERIENCE BY KARAPANOS ET AL. (2009)

Finally the user enters the phase of identification where he shows an emotional attachment to the product (Karapanos, Zimmerman, Forlizzi, & Martens, 2009).

2.1.5.2 Conclusion

Besides human perception as well as product sensing, appearance and behaviour, temporality could be identified as another important dimension of User Experience. Designers need to anticipate the temporal course of use sequences as well as the potential development of the User Experience over the time of product use during their conception work. In the following a model of User Experience that assembles the findings from this first part of the literature review is presented.

2.1.6 A Model of User Experience

In accordance with the other beforehand presented models, this model too separates the human with his perception – human sensors, affect & cognition, human responses – and the product with its capabilities – product sensors, product properties, product responses – are separated. In this context, a *sensor* is an agent “which detects or measures a physical property” (Oxford dictionary), a *response* is a bodily process occurring due to the effect of an antecedent sensorial event.

On a concrete level a product is characterised by its functional properties, its appearance, its sensorial properties and its behaviour. On an abstract level it has certain pragmatic and hedonic (affective, semantic, aesthetic) qualities. A human-product interaction happens when either the product captures certain behaviours of the human or if the human is stimulated by certain concrete properties of the product. Such a stimulus is influenced by the context of use. Parts of the stimulus information from the product reach the human sensors for exteroception (visual, auditory, gustatory, olfactory, and somesthetic (heat or cold, pain, pressure, touch), proprioception (balance, position, and movement), or interoception (hunger, thirst, temperature, etc.) (LaMuth, 2011). Once stimulus information has been captured, it enters human cognition and affect. The two mechanisms operate simultaneously. Cognition enables the human to understand his environment, affect allows him to judge what he perceives (Bonnardel, 2012). Cognition and affect react on the stimulus event based on event-independent information that is already present in the human memory and the human’s personality.

Cognitive processes work via three semiotic pathways. Neural assemblies link the external information with the brain on a semantic level. The syntactic circuit comes into play for prediction, planning, and coordination of outputs. Evaluation based on the human motivations/goals happens on the pragmatic level (Cariani, 2001). The stable memory contents – skills, rules, and knowledge (Rasmussen, 1983) – continually alter with new experiences. Sensed patterns are compared to previous patterns and templates are created or altered (Axelrod, 1973; Cariani, 2001).

Affect has a cognitive component too (Bonnardel, 2012; Lane et al., 2000; Russell, 2003; Scherer, 2004). The model distinguishes stable personality traits and the values of the human on the one side and attributed affect as a reaction on the stimulus on the other side. The attributed affect might or might not influence the core affect of the human (Russell, 2003; Scherer, 2004).

Based on the result of the affective or cognitive process, the nervous system determines which actions to take in response to the stimulus information. The action organs are muscles, voice, and physiological reactions. They can potentially alter the state of the product, if the product is equipped with the necessary sensors to detect this human response. Depending on its capabilities, it responds with changes in functional, behavioural, sensorial properties or appearance. The human again perceives these changes through his sensors and this new stimulus might initiate other responses from his part.

Stimulus information circulates between the human and the product while each changes its state. This can happen in a use sequence as well as over multiple use sequences spread over a long time. The human and eventually even the product will never react in exactly the same way. The affective response evoked by a specific property at first sight, will be less pronounced when the interaction is repeated and might disappear completely (Karapanos et al., 2009).

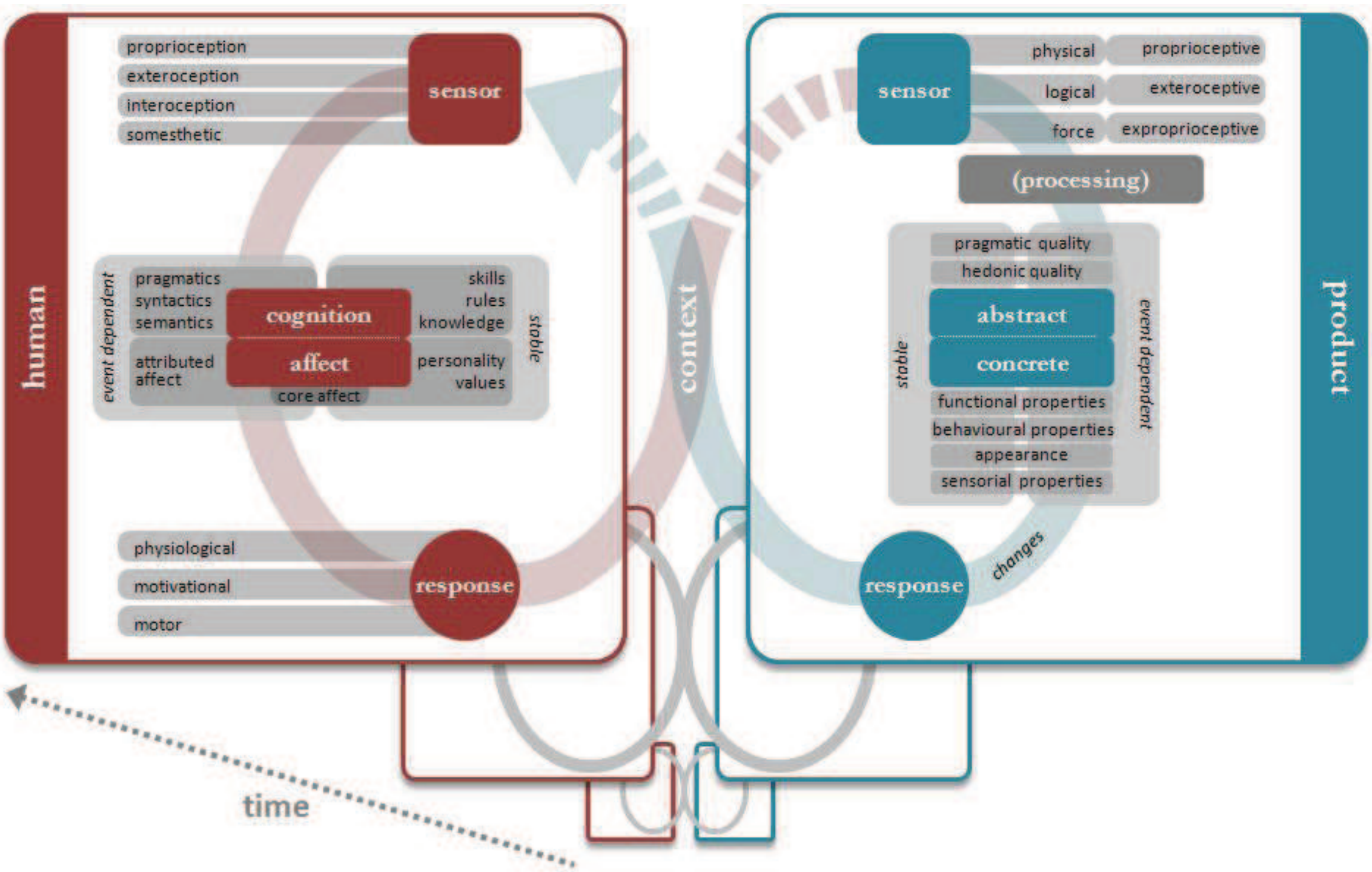


IMAGE 37: A MODEL OF HUMAN-PRODUCT INTERACTION FOR DYNAMICALLY CHANGING PRODUCTS.

2.1.7 Summary of chapter 2.1

Chapter 2.1 gave an overview on the complexity of dimensions that together form the User Experience. We have seen that User Experience is the result of the interplay between the properties of the product (its appearance, behaviour and sensory capacities) and the user who senses, then perceives the stimulus event and finally responds to it driven by his stable values, preferences, knowledge, etc. User Experience is furthermore not a static instant but has a time component. It evolves through use sequences in which the product properties and the user states alter and it also undergoes changes over a long time of product use.

The gathered knowledge on the mechanisms of User Experience should inform designers and enable them to consciously consider User Experience issues during their design activity. It could be seen that the complexity of User Experience dimensions is very high. In order to approach the relevant User Experience dimensions for each project, designers need UX conception tools and methods. The next section will therefore present a compilation of existing tools for User Experience Design.

2.2 Tools and Methods for User Experience Design

A successful product that evokes a desirable User Experience is the result of a well-conducted product conception process. As introduced in 1.2.2, the conception process can be divided into 4 types of activities that overlap and iterate between each other: information, idea generation, idea evaluation and communication (Bouchard & Aoussat, 1999; Cross, 2008). In order to undertake these activities, designers need tools and methods. A tools is “a thing used to help perform a job” and a method is a “systematic or established procedure for accomplishing or approaching something” (Oxford University Press, n.d.). A method can employ various tools. Traditional Design tools are sketching, rendering, physical modelling, and nowadays also 3D modelling, tools for animation of scenarios and lately tools like Arduino for interactive prototyping. This section introduces User Experience Design tools for each of the four conception activities.

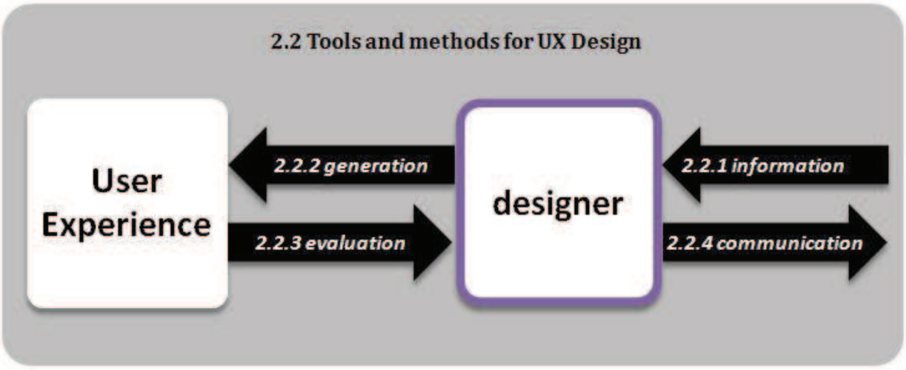


Image 38: Topics of SoA part 2.

The most common tools in the User Experience domain are listed in Table 4. Since the field of User Experience originated in Ergonomics with issues of usability measurement, most tools have been developed for product evaluation. Design research has developed various tools for UX information gathering itself. We will see that for the moment there are only few tools that help with the generation of User Experience rich designs. As communication tools can be considered the various types of intermediate representations that appear during the design process. Some tools can be used for information gathering as well as evaluation and communication.

Table 4: UX data collection methods (Bargas-Avila & Hornbæk, 2011). (N=occurrence)

collection method	N	%
Questionnaires	35	53
Interviews (semi-structured)	13	20
User observation (live)	11	17
Video recordings	11	17
Focus groups	10	15
Interviews (open)	8	12
Diaries	7	11
Probes	6	9
Collage or drawings	5	8
Photographs	5	8
Body movements	3	5
Psychophysiological measures	3	5
Other methods	18	27

2.2.1 Tools to gather UX Information

In order to design products that evoke a certain User Experience, designers seek to understand as much as possible about the future user and the possible context of use before starting concept generation. Such information can address different levels of knowledge, from explicit, to observable, to tacit and finally latent. Explicit is what users say, observable is what they do and tacit and latent is what users know, feel or dream (Bordegoni, 2011; Visser, 2009). Depending on the choice of tool, one can obtain more or less profound knowledge on user needs, desires, etc. Table 5 gives an overview on information gathering tools with their respective advantages and disadvantages.

Table 5: Overview on information gathering tools for UX Design (non exhaustive).

Information type	Tool	How it is done?	What type of data?	+ Advantages - Disadvantages
Explicit	**Interview**	A conversation between researcher and user, guided or not by a list of questions.	Qualitative data in form of verbal accounts	+ clear answers to research questions - users only give information about issues that are asked; built on assumptions of the researcher
	Focus group	A moderator leads a group of selected users through a group discussion on specific topics and with various activities.	Qualitative data in form of verbal accounts and sometimes filmed behaviours	+ more diverse points of view than interview; comments of the other participants might lead to awake tacit information - need to constitute a group; users mainly give information about issues that are asked; built on assumptions of the researcher
Observable/ Ethnography	**Diary / Journal**	Participants record their experiences/activities over a certain time.	Qualitative data, usually in written form, with photos or videos. Captures direct user's actions, feelings and personal observations	+ field setting; long time application - subjective point of view
	Observation	Follow people in their natural living or work environment	Qualitative data, usually in written form, with photos or as video recordings. Captures user's direct actions, feelings and personal observations	+ field setting - subjective point of view ; the presence of the researcher influences the behaviour of the person
Tacit / latent	**Role-Play**	The researcher immerses in the field situation and records his experiences.	Experiences registered in the memory of the researchers. Can also be in written form, with photos or videos. Captures direct actions, feelings and personal observations of the researcher	+ field setting; might emerge issues that have not been pointed out by experts since they are habits - subjective point of view; capacities of reliving a professional situation are limited by researchers skills and talent (especially for sport or work context).
	Generative Sessions	Participants receive trigger materials and create collages or word maps on a specific subject with them.	Collages, word maps, mind maps, etc.	+ users get to express issues that they are not able to express through words; allows insights into deep level information - subjective choice and preparation of the material; risk of wrong interpretation
	Probes	Small objects that transport a certain research question. The objects are handed to users who provide responses by filling in the probes.	Objects with verbal accounts, images, drawings, etc.	+ users are inspired to reflect on and to respond about very personal experiences; allows insights into deep level information - subjective design of the probes; risk of wrong interpretation
Transversal	**Day in the life scenarios**	Identify daily activities through a questionnaire and illustrate the course of the day in a narrative	Storyboard with images and text that illustrate the day of the user	+ easily accessible and easily communicated - very basic level of information; biased by the focus points of the researcher und scenarios creator
	Personas	Interpretation of gathered user information into segmented representations of fictitious users with different behaviours, attitudes, desires.	Representation of a fictitious person's profile in form of images and text	+ easily accessible and easily communicated - high creational effort; needs know-how

Classical methods are field studies with interviews or Focus Groups (Bruseberg & McDonagh, 2001) and applied ethnography. Interviews and Focus Groups provide direct answers to the researchers' questions but might also miss inspiring points since they are very much built on the researchers' assumptions. During field studies the researchers visit the living or product-related context like user home or work place. Such methods are called "ethnographic" because the researchers observe the user activities, taste, habits, etc. in an unaltered context. The observations can also happen indirectly through dairies and camera journals (IDEO, 2013). However, "designers seem to be overwhelmed by the information generated by the real life observation technique" (J. Lee, Popovic, & Lee, 2005). Marketing therefore translates the gathered information from the interviews and observations into "Day in the life" scenarios (Moll, 2006). The scenarios illustrate the user's course of the day. While the classical methods seek to understand the current conditions, designers also need information that helps them to project the future and to come up with unexpected ideas. Design has therefore developed own tools to gather tacit and latent information. These tools give the future user an active role. Among them are Design Probes (B. Gaver, Dunne, & Pacenti, 1999; Wallace, McCarthy, Wright, & Olivier, 2013), Generative Sessions that work with trigger images and/or words (Stappers & Sanders, 2003) or Role-Play (IDEO, 2013).

Image 39: 3 examples of tools to gather information for UX design
user's diary (Cense, n.d.), Design Probes (Wallace et al., 2013) and collage (Naranjo-Bock, 2012).

Design Probes are small, materialised objects. Their design is related to the researched issue. They pose "a question through gentle, provocative, creative means" to which the users respond "through the act of completing the probe creatively" (Wallace et al., 2013). In Generative Sessions, the participants create their own collages or mind maps. Role-play enables the design team to experience the context of the product. It provides the designer with empathy for the user and helps to identify relevant issues that can be addressed by design. Similar to 'day in the life scenarios', the so-called Personas are largely employed in industrial design and marketing to arrange the found information into a format that can easily be exploited in the following design generation, evaluation and communication. Personas are fictitious profiles of persons. Each persona is characterised by certain behaviours, attitudes, values that were beforehand identified through the mentioned tools (Pruitt & Adlin, 2006).

IMAGE 40: LEVELS OF INFORMATION AND TOOLS TO ACCESS THEM. ADAPTED FROM VISSER (2009).

2.2.2 TOOLS AND METHODS FOR UX GENERATION

Once information about the user and use context is gathered, the identified needs and desires need to be translated into design dimensions. The review of current UX research papers does not explicitly point at generative tools and methods for User Experience Design. However, one can find tools and methods in the fields of Engineering and User-Centred Design that have been developed to bring the User Experience into the generative phase of conception. Table 6 gives an overview on tools/methods applicable for UX generation. They are further discussed in the following.

TABLE 6: OVERVIEW ON CONCEPT GENERATION TOOLS OR METHODS FOR UX DESIGN (NON EXHAUSTIVE).

Design dimension	Tool/Method	How it is done? / examples	+ Advantages - Disadvantages
Kansei (semantic, sensation, attributed affect, etc.) with form, colour and/or texture	**Kansei Engineering Systems**	Design variations evaluated on Semantic Differential Scales by a large user panel. A database stores evaluations and generates design.	+ a complete UX generation method - decomposition of design dimensions but sum of dimensions is not necessarily the UX of the whole product
	Kansei Design Systems	Software systems designated to designers for inspiration and concretisation of ideas.	+ engaging interactions, original proposals from the artificially intelligent system - each system addresses a specific activity in the concept generation
used to find original solutions	**Creativity tools** **Innovation tools**	Systematic methods that lead from a problem to a technical solution by for example resolving contradictions via TRIZ, C-K Theory…	+ non-experts can generate innovative solutions - laborious in preparation and execution
	Creativity tools	Group sessions to generate many ideas from which certain are further developed into concepts. Purge, Brainstorming, Brain writing, Body storming, etc.	+ relatively easy to put into place; group dynamic makes emerge ideas that built on each other - results need treatment and interpretation for transfer into concepts
	Co-creation	Tools that enable users to give input to the concept generation. Card sort, cognitive maps, scenario testing, word-concept associations.	+ playful and engaging tools - results need treatment and interpretation for transfer into concepts
Product behaviour	**Quick Prototyping**	Quick ways of prototyping with paper or other materials can be combined to Experience prototypes with Arduino or other tools.	+ allow testing ideas during generation - certain prototyping or programming skills necessary; need of imaginative capacities in order to judge what can be judged
Materials with production processes, sensorial qualities, semantics, affects	**Material libraries**	Virtual (CES) or physical spaces (Materio) that assemble information and samples of materials.	+ extensive source of information - access to most libraries limited
Usability	**Tools from Ergonomics**	Anthropometric guidelines that direct the design generation, Empathy Tools that allow the designer to live the handicap of his users.	+ help the designer to be less self-centred in his design reasoning and to better understand his users needs and capacities - not so fun to use; do not inform about compensation strategies of the handicapped users

2.2.2.1 KANSEI ENGINEERING SYSTEMS

In the 1970ies Japanese researchers sought to create a methodology for the integration of meaning in early product development. This new discipline was called **KANSEI ENGINEERING** (Nagamachi & Lokman, 2010). The Japanese word **KANSEI** is commonly translated as "feeling", but it includes a wide range of words related to semantic descriptors, emotions and sensations. Kansei Engineering allows product designers to evaluate the meaning evoked by certain product properties, in order to enable them to adapt their design to a desired expression. Once a database is established, Kansei systems can directly generate forms following the choice of Kansei words. The classic Kansei Engineering proceeds in the following steps:

i. At the beginning a word base for the Semantic Differentials is constituted. The researchers collect terms that are representative for the product and its sector through brainstorming, journals, websites, etc. They select the most adapted words and create opposed word pairs.
ii. As a second step, rules for the repartition of the product components have to be deducted. One can evaluate the totality of the design or separate parts of it.
iii. A large number of participants evaluate the product or its components on the Kansei expression of its properties – like form or colour – with a questionnaire that contains the previously defined Semantic Differentials (see 2.2.3.1.1).
iv. The results are treated through statistical analysis of the word ratings in relation to the evaluated attributes.
v. In order to exploit the results of the analytical part in further projects, the data is stored in a data base that is integrated in a Kansei Engineering System. Such a system links Kansei words with forms or colours. It can be used as a design tool.

There exist different types of Kansei Engineering Systems. The basic version facilitates the input of words. It then calculates which design elements from the data base correspond to these words and displays the according design. A Hybrid Kansei System allows two directions of use: "forward" – the user enters Kansei words and sees the fitting design – or "backward" – the user presents a design to the systems and receives an evaluation (Matsubara & Nagamachi, 1997).

In Japan and Taiwan, various Kansei Engineering Systems have been developed to automatically support the design process (Shih-Wen Hsiao, Chiu, & Chen, 2008; Matsubara & Nagamachi, 1997; Shibata & Miyakawa, 2003; Tsai & Chou, 2007; Wang, 2011). Sophisticated systems contain interfaces that enable designers to manipulate the Kansei of the design instantly through e.g. form or colour modifications. There are systems that integrate virtual reality and provide a 3-dimensional visualisation of the design (Shibata & Miyakawa, 2003). Today subjective questionnaire are coupled with more objective means like physiological measurements (Lévy et al., 2009).

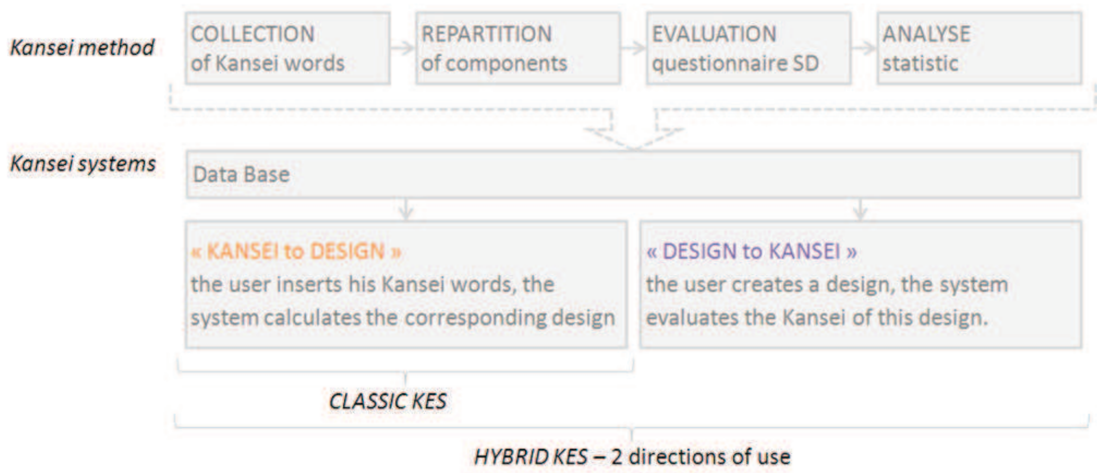


IMAGE 41: KANSEI ENGINEERING METHOD AND KANSEI ENGINEERING SYSTEMS.

Kansei Engineering have already been employed in various sectors, including mobile communication (Hong, Han, & Kim, 2008; Lai, Lin, Yeh, & Wei, 2006; Yang, 2011), transportation interior design (Guerin, 2004; Tanoue, Ishizaka, & Nagamachi, 1997), architecture (Llinares & Page, 2008, 2011; Shibata & Miyakawa, 2003), tools and technical elements (Schütte & Eklund, 2005; Wang, 2011), shoe design (Alcantara, Artacho, Gonzalez, & Garcia, 2005; Bouchard, Mantelet, et al., 2009; Ishihara, Ishihara, Nagamachi, & Matsubara, 1997) etc.

2.2.2.2 KANSEI DESIGN SYSTEMS

While Kansei Engineering seeks to automate the whole design work, in its European branch – the Kansei Design – it is still the designer who proposes the concepts and not the system. Kansei Design develops a variety of tools that designers can use during concept generation in order to translate abstract dimensions into concrete forms, colours, textures, etc. Examples for Kansei Design Systems are the projects 'Trends' and 'Genius'. 'Trends' is a system for image retrieval. From a chosen image, Trends displays other images with a similar expression. It allows to categorize images and to reveal design trends. Image palettes with colour, texture and form information can be extracted (Bouchard, 2008). 'Genius' is a system that automatically generates shapes from inspirational data. It also allows sketching and the identification of 'good shapes' (Omhover, 2011). 'Skippi', the project that provides the experimental terrain for this research, too is a system for concept generation (Bouchard, 2013). It will be introduced in 4.2.

IMAGE 42: SCREENSHOT OF THE TRENDS-SYSTEM (BOUCHARD, 2008).

2.2.2.3 Creativity tools

Innovation tools include TRIZ and the C-K Theory. TRIZ establishes contradictory requirements for which solutions are sought. This leads to innovative solutions (Shulyak, 1997). In the C-K Theory ideas evolve between the two spaces concept and knowledge in the course of the concept generation. Concepts inspire other concepts that need an investigation on the knowledge level. Knowledge leads to other knowledge and can again inspire new concepts (Hatchuel, 2002).

There also exist various tools that stimulate the ideation in early concept generation, such as mind maps, purge, brainstorming, inspirational scenarios, inversion, angel's and devil's advocate, idea sheets etc. (PSA Peugot Citroën, n.d.) or body storming to define behaviour based concepts (IDEO, 2013). Creativity sessions are a conception method that is undertaken with several conception team members. Ideally they apply several of the mentioned techniques to first diverge and later converge their ideas.

Another way to bring the User Experience into early conception is by inviting users to join the generation process at certain points. This is called co-creation/co-design or participatory design. The objective is not an outsourcing of design activities to customers but rather to initiate a dialogue between the designer and the user (Prahalad & Ramaswamy, 2004; Sanders & Stappers, 2008). Since ordinary users are not trained in designing, co-creation needs tools to facilitate the interaction between the conception team and the users. In design practice, we find tools like card sort, cognitive maps, scenario testing, and word-concept associations (IDEO, 2013).

2.2.2.4 Quick prototyping tools

Intermediate representations tools in the classical design process have been sketching, rendering and 3D CAD modelling. Today designers use many more types of representations in order to advance the conception. Among them are paper or 'Quick-and-Dirty' prototyping and scale modelling (IDEO, 2013) that use available materials to quickly test forms and interactions. Especially tools like Arduino (Arduino, 2012) now provide designers a way to easily integrate interactivity into their early prototypes. This enables them to test the User Experience of the idea in the use context (IDEO, 2013).

2.2.2.5 Material libraries

Today more and more designers use actual or virtual material libraries like CES (Grantadesign, 2010). Such libraries help engineers and designers with the choice of materials and production methods. However, most of them only contain technical data that limits their usefulness for designers (Rognoli, 2010). A few that web based libraries that can serve designers are Innovatèque (FCBA, 2011), Material Explorer (Bezooyen, 2001) or Rematerialise (The Rematerialise Project, n.d.). They include information on texture, transparency, brilliance, rigidity, temperature, and odour in the search criteria (Ramalhete, Senos, & Aguiar, 2010). However, none provides knowledge about the meaning users attribute to materials. This starts to be a topic of design research (Ashby & Johnson, 2010; Elvin Karana, 2010a). Amaral compared material libraries in France and Brazil and found only one out of eight that provided information on associated emotions (Amaral, Silva, Bouchard, Jr, & Omhover, 2012). Today he works on a data base that links materials with semantics, attributed affect and sensorial qualities that will be integrated in the Kansei Design System Skippi.

2.2.2.6 Tools from Ergonomics

Finally various usability tools are available for product conception. Among them anthropometric guidelines (Neufert & Neufert, 2012) as well as empathy tools that designers can wear in order to understand the obstacles for certain users (elderly, pregnant women, visually impaired, etc.) (i-design, n.d.; Panasonic Inc., 2012).

2.2.2.7 Summary of UX Generation Tools

Searching UX generation tools and methods does not point straight forward to certain techniques. On a second look it is possible to find some that have the potential to contribute UX design in the generative phase. The overview provided here is most likely not exhaustive and should continue to grow in the coming years.

2.2.3 Tools and Methods for UX Evaluation

This section presents tools that can be employed by researchers and practitioners to test whether or not a design evokes the desired experience for the user. The techniques presented here have their origin in the fields of ergonomics, Kansei Engineering, Emotional Design, and Marketing. Bradley and Lang (2000) draw our attention to the fact that user emotional responses on stimuli can be measured on three dimensions: language events, physiological events, and behavioural events. These three types structure this overview, but the language category is extended to cognitive responses in a wider sense (Kim, 2011; Rieuf, 2013). In following will therefore be presented:

i. Measurements of cognitive user responses.
ii. Measurements of behavioural user responses.
iii. Measurements of the physiologic user responses.

2.2.3.1 Measurements of cognitive user responses

Following Khalid (2006), the cognitive response of the human is formed by three different aspects: the **knowledge** we have to judge the information, the **values** that form our principles of evaluation, and finally the **meaning** we accord to the information. We furthermore saw that **affect** too has a cognitive component. Let us look into the respective evaluation tools for meaning, values, attitudes and affect. Table 7 gives an overview on the tools that will be discussed.

TABLE 7: OVERVIEW ON TYPES OF COGNITIVE MEASUREMENTS FOR DESIGN RESEARCH.

Indicator	Tool	How it is done?	What type of data?	+ Advantages - Disadvantages
Meaning / semantics	**Word-pair questionnaires**	Participants rate their impression of a design in between word-pairs.	A set of words, rated on Semantic or Likert Scales	+ easy to process; inexpensive - translation in languages
Value	**Value rankings**	Participants rank values based on lists, e.g. Rokeach values	Ranking list of value words	+ easy to process; inexpensive - translation in languages
	Sentence completion	Participants add missing words in sentences. The chosen words indicate certain values.	Unpredictable amount of words	+ unconscious results; individual word choice - high treatment effort; translation in languages; data difficult to compare
	Word-pair questionnaires	(see above)		
Attitude/ Preferences	**Word-pair questionnaires**	(see above)		
Affect	**Word-pair questionnaires**	(see above)		
	Emotion Wheel	Participants mark their feeling in a two-dimensional space between the axes valence and arousal.	A x-y position in the 2-dimensional affect space	+ very easy tool - unspecific information
	Affect Label coder	Verbalisations are analysed on the appearance of certain emotion indicating words.	Unpredictable amount of words, that can be classified automatically through word stem coding	+ individual word choice - high treatment effort; translation in languages; data difficult to compare
	Image-based scales	Participants rate their impression of a design on images that express different affective states.	A set of selected images/animations	+ relatively easy to process inexpensive; universal principle - Attributed affect not always clearly distinguishable from core affect

2.2.3.1.1 MEANING AND SEMANTICS

Krippendorff, Norman, Hassenzahl and many other design researchers agree that the most important aspect of User Experience today is **MEANING**. This is a very abstract and individual concept, often difficult to predict by product developers.

When Charles Osgood introduced his Semantic Differentials in 1957, he had found a tool that allows psychologists and today design researchers to measure meaning that people accord to their environment or to product designs (Osgood, Suci, & Tannenbaum, 1957). The method of Semantic Differentials is based on self-evaluation questionnaires. The participant is confronted with a list of opposed word pairs with a scale of 5 or 7 steps between the two poles (adjective pairs like: static – dynamic, comforting – disturbing, etc.). In order to get meaningful answers, the choice of words pairs needs to be adapted to the context of the questionnaire. The person rates the product or the situation through each pair. As a result the researchers get a range of words that apply or not to the research object. If these tests are repeated with a great test population some generic aspects of the meaning accorded to the object become visible (Osgood et al., 1957).

IMAGE 43: EXAMPLE FOR SEMANTIC DIFFERENTIAL SCALE.

A similar method is the rating scale of Likert. Here each question is answered with the rating choice between five states of agreement: 1. I strongly disagree, 2. I disagree, 3. I neither agree nor disagree, 4. I agree, and 5. I strongly agree.

IMAGE 44: EXAMPLE FOR LIKERT SCALE.

Design researchers employ semantic evaluations to test the emotional effect of colours or colour combinations (Ou, Luo, Woodcock, & Wright, 2004a, 2004b, 2004c). Materials too have become another dimension evaluated on its meaning (E Karana et al., 2008; Elvin Karana et al., 2009; Elvin Karana, Hekkert, & Kandachar, 2010; Elvin Karana, 2010a, 2010b). And with materials comes the latest trend of predicting user responses to textures (Akay & Henson, 2010; Elkharraz, Thumfart, Akay, Eitzinger, & Henson, 2010; Guo et al., 2012; Henson & Lillford, 2010; Yanagisawa & Takatsuji, 2012; Zuo, Hope, Castle, & Jones, 2001; Zuo & Jones, 2005).

2.2.3.1.2 VALUES

When designers conceive products they indirectly address people's values through the product appearance, function, performance, etc. When users evaluate designs they do so with regard to their own values. Therefore designers must understand the values of their target users (Nurkka, Kujala, & Kemppainen, 2009). Bouchard has shown a correlation between meaning (semantic ratings) that people assign to designs and their moral concepts/their **VALUES** (Bouchard, 1997).

The social psychologist Milton Rokeach established a questionnaire on human **VALUES** that consists of two lists: **TERMINAL VALUES** and **INSTRUMENTAL VALUES** (Rokeach, 1973). Terminal values are goals that the human wants to attain over the course of his life-time. Instrumental values are preferable modes

TABLE 8: TERMINAL AND INSTRUMENTAL HUMAN VALUES (ROKEACH, 1973).

Terminal Values	Instrumental Values
A world at Peace (free of war and conflict)	Ambitious (hard-working, aspiring)
Family Security (taking care of loved ones)	Broadminded (open-minded)
Freedom (independence, free choice)	Capable (competent, effective)
Equality (brotherhood, equal opportunity for all)	Cheerful (light-hearted, joyful)
Self-respect (self esteem)	Clean (neat, tidy)
Happiness (contentedness)	Courageous (standing up for your beliefs)
Wisdom (a mature understanding of life)	Forgiving (willing to pardon others)
National security (protection from attack)	Helpful (working for the welfare of others)
Salvation (saved, eternal life)	Honest (sincere, truthful)
True friendship (close companionship)	Imaginative (daring, creative)
A sense of accomplishment (a lasting contribution)	Independent (self-reliant, self-sufficient)
Inner Harmony (freedom from inner conflict)	Intellectual (intelligent, reflective)
A comfortable life (a prosperous life)	Logical (consistent, rational)
Mature love (sexual and spiritual intimacy)	Loving (affectionate, tender)
A world of beauty (beauty of nature and the arts)	Obedient (dutiful, respectful)
Pleasure (an enjoyable leisurely life)	Polite (courteous, well-mannered)
Social recognition (respect, admiration)	Responsible (dependable, reliable)
An exciting life (a stimulating active life)	Self -controlled (restrained, self-discipline)

of behaviour that enable the human to achieve his terminal values. People are asked to rank the values in each of the lists Table 8.

Schwartz identified 10 types of motivational **VALUES** (universalism, benevolence, conformity, tradition, security, power, achievement, hedonism, stimulation, and self-direction) that drive human actions (S. H. Schwartz & Sagiv, 1995). They can be mapped between the two axes ‘openness to change – conservation’ and ‘self-enhancement – self-transcendence’ (Image 45). These 10 categories have been confirmed through surveys (Schwartz Value Survey SVS) and a portrait based values questionnaire (PVQ) in 68 countries (Shalom H Schwartz, 2009).

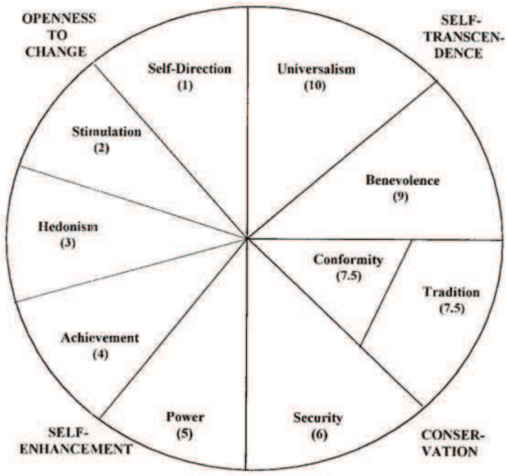


IMAGE 45: MODEL OF RELATIONS BETWEEN MOTIVATIONAL VALUES (SCHWARTZ 2001).

The design agency designaffairs uses the evaluation tool SimuPro® to assess the coherence between the brand values of their clients and the values transported by the design of the products. They ask the client as well as costumers to rate contrary values on an interval scale, for example is the brand more associated with ‘control’ or ‘enjoyment’, and ‘protection’ or ‘attack’. The most important values are than clustered under the three poles “maintain”, “challenge”, and “experience”. Visually one can see if the positioning of the brand and the positioning of the user judgments of the product fit or if they are at contrary ends. In the latter case strategies are discussed how to change the

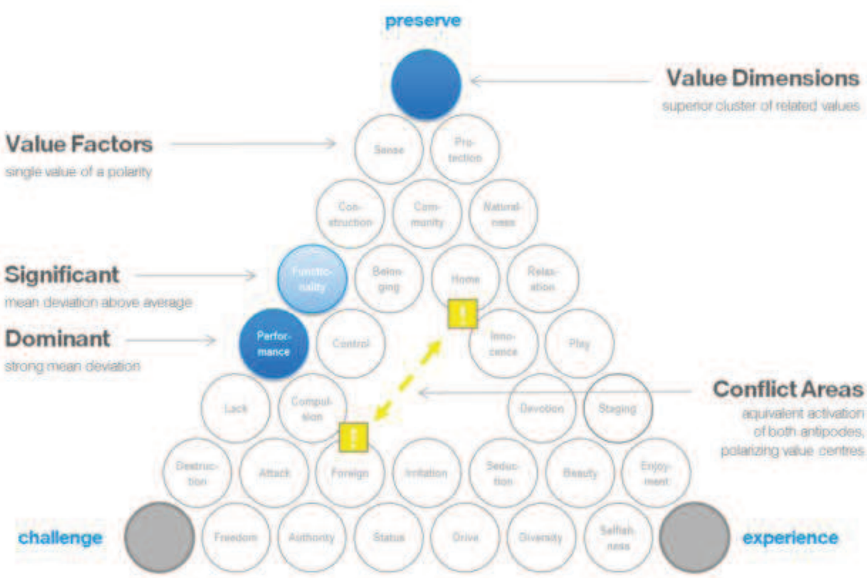


IMAGE 46: SIMUPRO®, A DESIGN STRATEGY TOOL FOR THE EVALUATION OF VALUES (DESIGNAFFAIRS GMBH 2013).

product design in order to make it fit with the brand values (Designaffairs GmbH, 2013).

Complementary to surveys, there are also projective techniques that are employed to indirectly access information about the person's actual values and feelings (Nurkka et al., 2009). Nurka, Kujala, and Kemppainen identified five types of projective techniques: *"association (connecting the research object with words, images, or thoughts); completion (finishing sentences, stories, or arguments); construction (answering questions about the feelings, beliefs, or behaviours of other people […]); choice ordering (ranking product benefits); and expressive (role-playing, storytelling, drawing)."* They applied sentence completion as a tool for the evaluation of values and meaning.

2.2.3.1.3 Attitude/Preferences

Previous questionnaire-based studies on product emotions by colleagues have shown that the test person's **attitude** towards a product type or brand has a great influence on the rating of the product design. If people dislike the brand, they tend to chose negative ratings, regardless of the actual product design. The same was seen for people who are completely uninterested in the product type (Wu, 2011). To integrate user values in questionnaires will help to better position the responses. In addition, the reliability of the obtained data increases if questionnaires also evaluate the preferences of the person on the subject of evaluation ("I usually prefer QWERTY to full keyboards.") and their attitudes towards this type of product or the brand ("For me, tablet PCs have no added value.").

2.2.3.1.4 Affect

To assess affects/emotions evoked by a product design, one can simply ask people to give self-accounts on their feelings. But if more objective and comparable data is required, lexical methods like Semantic Differentials can be employed. Mayer and Gaschke say that core affect is constituted of the mood we experience directly and a meta-level of experience with our thoughts and feelings about this mood. In order to measure core affect including meta-experiences, they developed a word based Brief Mood Introspection Scale (Image 47) (Mayer & Gaschke, 1988). The ratings allow conclusions on the levels of activation and pleasure.

	definitely do not feel	do not feel	slightly feel	definitely feel
Lively				x
Happy			x	
Sad	x			
Tired		x		
Caring				x
Content			x	
Gloomy	x			
Jittery		x		
Drowsy	x			
Grouchy	x			
Peppy			x	
Nervous		x		
Calm		x		
Loving				x
Fed up	x			
Active				x

Overall, my mood is:

Very Unpleasant *Very Pleasant*

-10 −9 −8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8 9 10

Image 47: Brief Mood Introspection Scale after Mayer and Gaschke (1988).

Furthermore, there are the extensive works of the Geneva Emotion Research Group who developed several tools that serve to analyse human emotions. Among them the Geneva Affect Label Coder, a tool based on a list of 36 affective states and their synonyms in English, French, and German, as well as the Geneva Emotion Wheel which, similarly to Russell's Core Affects circle, positions all emotions between the two poles 'unpleasant – pleasant' and 'low control – high control' (Scherer, 2005).

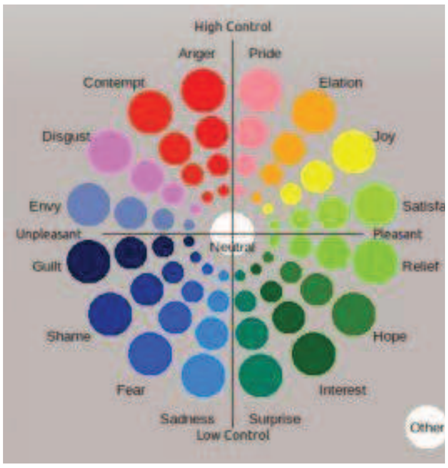


Image 48: The Geneva Emotion Wheel (Scherer 2005).

All so far introduced techniques are based on words. Russell reminds us that words can never be exact descriptors of an emotion. Each language sets the limits of a word differently, or has a more or less precise vocabulary. Even though the concepts are similar, they are not equal between cultures. Concepts like fear, anger, etc. remain folk concepts (Russell, 2003). Misinterpretations also occur when questionnaires are translated into other languages. It is not always possible to find the adequate term in another language. Furthermore word-based questionnaires exclude people with low literacy like children.

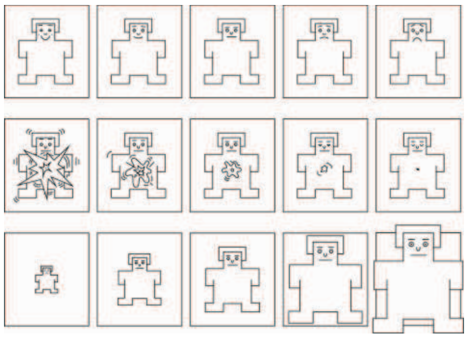


Image 50: The Self-Assessment Manikin (SAM) to rate the affective dimensions of valence (top panel), arousal (middle panel), and dominance (bottom panel).

To overcome these limitations, Bradley and Lang proposed a picture based evaluation instrument, called Self-Assessment Manikin SAM. It illustrates Wundt's three affect dimensions: **VALENCE (PLEASURE), TENSION (DOMINANCE),** and **AROUSAL.** Besides testing which emotion is triggered by the design (appraisal), the levels of arousal and dominance are equally important aspects to test, since they indicate the relevance of the found appraisal (Bradley & Lang, 1994). However, people have some difficulty to distinguish tension from arousal. That is why today most SAM questionnaires only include valence and arousal (Scherer, 2005). The test person chooses the character that corresponds to his feeling on each level. The SAM method is inexpensive, quick and easy. It has therefore found its way from psychology to design research (Kim, 2011; Mantelet, Bouchard, & Aoussat, 2003).


Image 49: PrEmo®, animated character for emotion assessment.

Another character-based tool is called PrEmo®. An animated character plays 14 emotional responses (7 positive and 7 negative) through his facial and gestural expression. The test person rates on a five point scale on much she feels the same after contact with the product (Desmet, 2002; SusaGroup, 2012). The SAM and PrEmo® are both visual tools that bring a playful and universal component to affect evaluation.

2.2.3.1.5 Usability, utility and satisfaction

Finally it is also possible to gather self-reflective evaluations by simply asking potential users or experts their opinion about the product, prototype or concept. To do so a frequent tool is the constitution of a focus group that together, under direction of a moderator, analysis and discusses the object of evaluation. Another tool is an informal expert review. This is an option that allows identifying avoidable problems very early in the design process at a low cost (Vredenburg, Mao, Smith, & Carey, 2002).

2.2.3.1.6 Conclusion

We have seen various tools of cognitive evaluation techniques that have found their way into design research. They allow researchers to access conscious aspects of user responses. Most of them are inexpensive, easy to apply and to exploit. Their disadvantage is that they only cover what people explicitly say. The words to choose from do not always reflect the exact feeling of the participant. Moreover people often say one thing but act differently from what they say, the so-called value-action gap (Blake, 1999). To investigate user behaviour with products can therefore add important insights to our understanding of the human-product interplay. Methods and tools to undertake behavioural measurements are presented in the following subsection.

2.2.3.2 Measurements of behavioural user responses

Long before the term User Experience emerged, the discipline of ergonomics already advocated the usability of tools and architecture for humans. The dimensions of the human body and its capabilities have always been the main orientation for ergonomic designs. Today, in the context of digital interfaces, the three principles of ergonomics are: effectiveness, efficiency, and satisfaction (ISO 9241-11). Behavioural measures, also called behaviometrics, can furnish different types of information to the design researcher. First of all they provide information about classical issues of usability. They are furthermore employed to get insights about the attractiveness of a product, how use habits develop over time (Karapanos, Zimmerman, Forlizzi, & Martens, 2010) and how involved the person is with the product (Insko, 2003). Table 9 gives an overview on current techniques that are available for design research and that will be discussed here.

Table 9: Overview on types of behavioural measurements for design research.

Indicator	Tool	How it is done?	What type of data?	+ Advantages - Disadvantages
Visual cues	**Eye Tracking**	Visually records eye movement through a head-mounted camera.	Follow the regard direction of the user gives insights about the points of interest of a design.	+ bit invasive; continuous data - only for visual stimuli; handling of the equipment
	Face Tracking	Records facial mimic, marker-based or markerless e.g. through a web camera.	Recognises facial expressions that indicate emotional responses	+ little or non-invasive; continuous data - handling of the equipment
	Posture / Gesture Recognition	Recognises body postures marker-based or markerless	automatically decoded video data	+ little or non-invasive; - handling of the equipment
	Motion Pattern Recognition	Recognises body motion patterns, marker-based or markerless	automatically decoded video data	+ non- invasive; continuous data - handling of the equipment
Audible cues	**Voice, rhythm, pitch, melody**	Audio records	Changes can indicate arousal states	+ natural, spontaneous - coding effort
	Vocal expressions	Audio records	Audio data	+ natural, spontaneous - coding effort
Observation	**Diary Method**	Participants record their experiences/activities at fixed points over time. A beeper or a SMS can indicate the moments.	Usually in written form, with photos or as video recordings. Captures direct actions, feelings and personal observations of user	+ field setting; long time application - subjective point of view
	Observation	Follow people in their natural living or work environment	Usually in written form, with photos or videos. Captures direct actions, feelings and personal observations of user	+ field setting - subjective point of view ; the presence of the researcher influences the behaviour of the person
	Action Research	The researcher immerses in the field situation and records his experiences.	Registered in the researcher's memory. Can be in written form, with photos or videos. Captures direct actions, feelings and personal observations of researcher	+ field setting - subjective point of view
Performance	**Task success, Time-on-task, Errors, Learnability**	(see literature on usability)		

2.2.3.2.1 Measuring motor responses/actions

Behavioural measurements mainly address issues of usability. Tullis and Albert (2008) give an overview on standard techniques of the discipline that are applied on consumer electronics and websites, too. Task analysis is one means to measure usability. One can observe the effectiveness (does the user reach the goal?) and measure the efficiency (the time and complexity of steps taken to accomplish the task). Satisfaction is not assessed through behavioural measurements. Here they recommend subjective evaluations in questionnaires or interviews (Tullis & Albert, 2008).

It is also interesting for a designer to find out which properties of his design proposal actually enter the user perception. Did he see a specific feature? Did he recognise a specific smell or sound? Is he able to distinguish a certain colour contrast? Salvia et al. (2010) used eye tracking in order to follow the path of the participants' regard while looking at textiles. This data allowed them to see from which characteristics people predicted sensorial properties of tissues (Salvia, Rognoli, Malvoni, & Levi, 2010).

Behavioural responses can also simply be observed. One can film the person in interaction with the object and analyse his actions or one can ask people to write down in a diary what they have been doing/how/with which object etc. at defined moments (Csikszentmihalyi, 1990; Karapanos et al., 2010). One can enter the field and follow the subject's activities, postures, verbalisations, etc. or one can even put himself in the situation and observe own behaviours, so-called Action research. However, even though behaviour is observed, the choice of the noted aspects is selective and therefore not objective.

2.2.3.2.2 Measuring affective behavioural responses

Desmet and Hekkert state that affective experiences are accompanied by facial, vocal, and postural expressions and that they “initiate behavioural tendencies like approach, inaction, avoidance, and attack” (Desmet & Hekkert, 2007). Today we dispose of powerful tools to measure behavioural responses of the eyes, the face, the body posture, or the body movement. Freeman et al. (2000) showed that postural responses happen unconsciously and can therefore be a good indicator for the involvement of the person with the product interaction. This was shown in an VR environment where people adapted their posture to only virtually happening events (Freeman, Avons, Meddis, Pearson, & Ijsselsteijn, 2000). Kim gathered vocal expressions from Designers as indicators for specific emotional states, like verbal acknowledgement, surprise, laughter, and uncertainty (Kim, 2011). It is imaginable that similar reactions occur when users interact with products.

2.2.3.2.3 Conclusion

Behavioural measures are less subjective than cognitive measures. The can be used to capture unconscious affective reactions (like facial expressions) as well as planned actions (moving from point A to B). The disadvantage of behavioural measurements is the complexity of the data that often needs manual treatment and coding after the session. When looking at human behaviour, we should not forget that humans have acquired the capability to delay, inhibit or even suppress response behaviours. If necessary, we can feel anger, yet say “everything is great” and react with a (forced) smile instead of an angry face. Some visual cues might therefore be misleading. But even though the instinctive behaviour (the angry face) is suppressed, the cardio-vascular system does prepare the defending action. “Emotions are often dispositions to action, rather than the actions themselves” (Bradley & Lang, 2000). There lies the interest of adding physiological measurements to the scope of methods. They can add objectivity to self reports and behavioural measurements.

2.2.3.3 Measurements of the physiologic user responses

Physiologic measurements come from the medical sector and are usually applied to assess the functioning of the major organ systems (Cohen, 2007). Neuroscience today can analyse processes in the brain and the zones of the brain that are active during a stimulus event which allows conclusions on the type of triggered process. Psychologists have found that physiological measures can also be indicators for affective states of the human and more specifically for valence and arousal (Bradley & Lang, 2000).

TABLE 10: OVERVIEW ON TYPES OF PHYSIOLOGICAL MEASUREMENTS FOR DESIGN RESEARCH

(BRADLEY & LANG, 2000; KIM, 2011; SCHERER, 2005) (NEDERKOORN, DE WIT, SMULDERS, & JANSEN, 2001) (BRADLEY & LANG, 2000; KIM, 2011; NEDERKOORN ET AL., 2001; SCHERER, 2005).

System	Indicator	Tool	How it is done?	What type of data?	+ Advantages - Disadvantages
Central nervous system	Activated brain area	**Functional Magnetic Resonance Imaging (fMRI)**	Magnetic fields influence orientation of atoms. Detects changes in blood oxygenation and flow	Visualises activated brain areas; Indicator for valence and workload	+ non invasive; no radioactive tracer necessary - too low time resolution for continuous recording; voluminous equipment
		Near-infrared spectroscopy (NIRS)	A spectroscopic method to detect changes in blood haemoglobin concentrations with light photons	Indicator for neural activity	+ non invasive; lighter equipment than fMRI; even wireless - only in the cortical tissue, not all the brain
		Positron Emission Tomography (PET)	Injection of radioactive tracer, a scanner creates 3D images of tracer concentration	Visualises activated brain areas;	+ accurate - invasive, eventually harmful radioactive tracer necessary; expensive
		Electroencephalogram (EEG)	Electrical activity of brain measured via scalp surface electrodes	Visualises activity of different brain areas; Indicator for valence	+ high time resolution for continuous data recording - high complexity of the equipment
Peripheral system PNS – Autonomic Nervous System	Heart Rate	**Heart Rate (HR) / Electrocardiography (ECG)**	Photo-optical sensors applied to fingers. Monitor sphygmic systolic waves that indicate variation of blood flux/heart rate	In- or decreased heart rate is indicator for valence.	+ little invasive; significant results under controlled test conditions; easy to put into place; continuous data - highly sensitive to disturbances from posture, movement, respiration
		Blood Pressure Recording (BP)	Measures force of blood flow through an inflated cuff around the upper arm	Increased blood pressure is an indicator for arousal.	+ inexpensive; easy to put into place; continuous data - highly sensitive to disturbances from body movement, posture, respiration, etc.; low time resolution
	Respiration Rate	**Respiratory Rate Sensor or Stethoscope**	Count of breaths per minute through chest movement	Increased respiratory rate is an indicator for arousal and negative valence.	+ simple; reliable; continuous data - highly sensitive to disturbances from body movement, posture, respiration
	Body zone temperature	**Infrared Thermography**	Infrared camera films or photographs the person without direct body contact.	Records changes of skin temperature. Indicator for valence or arousal.	+ non-invasive; light equipment; continuous data - significance of the indicator so far only shown in one study
	Perspiration (wet hands)	**Electrodermal Response (EDR) / Galvanic Skin Response (GSR)**	Set of electrodes attached to two fingers. Changes skin resistance lead to variations in the electrical intensity.	Rising electrical current is indicator for arousal.	+ method proven to furnish significant results; relatively light equipment; little invasive; continuous data - not reliable for low arousals; more valid for men than women
	Salivation	**Absorption method**	Cotton rolls absorb the liquid	High amount of saliva indicates arousal	+ validity proven - not continuous; obtrusive object in mouth
		Swallow frequency (EMG)	Electrode on cheek over muscles digastricus, counts peaks in muscle activity	High amount of muscle activity indicates arousal	+ continuous - obtrusive but less than cotton roll
		Parotid gland (EMG)	Electrode on cheek over parotid gland, counting peaks in muscle activity	High amount of muscle activity indicates arousal	+ continuous - obtrusive but less than cotton roll
	Pupil dilation/ constriction	**Visual Eye Tracking**	Visually records eye and its movement	Changes in pupil dilation indicate interest in the object.	+ little invasive; continuous data - only for visual stimuli; manual data treatment; susceptible to light changes
Peripheral system PNS – Somatic Nervous System	Facial expression	**Electromyography (EMG)**	Surface electrodes on face measure electrical activity if muscle contracted	Indicator for valence	+ accurate data; continuous data - obtrusive equipment, especially in the face
		Corrugator EMG	Electrodes on Corrugator muscle capture eye brow movements.	Indicator for valence	(see above)
		Zygomatic EMG	Electrodes positioned on Zygomatic muscle involved in smiling.	Indicator for valence	(see above) - no bijective interpretation possible more valid for women than for men
	eye blinking/ startle reflex	**Orbicularis Oculi muscle EMG**	Electrodes beneath lower lid on the Orbicularis Oculi muscle. Measure the magnitude of the blink.	Indicator for valence and arousal	(see above)
	viewing time (and direction)	**Visual Eye Tracking**	(see above)	Indicator for presence of response to stimulus, indicator for valence	+ continuous data; data directly related to stimulus - only for visual stimuli, difficult to interpret on the physiological level
		Electrooculography (EOG)	Records eye movements, through pairs of electrodes placed next to eye.	Indicator for viewing time per direction.	+ continuous data; automatic data - obtrusive equipment

Design researchers have started to employ certain physiological measurements to assess affective responses of users on product designs. A human can show various physiologic reactions when experiencing emotions, among them changes of body temperature, heart rate, breath rhythm, sweating, etc. (Scherer, 2005), as well as sweat, tears, facial and other somatic muscle movement, respiration rate, etc. (Bradley & Lang, 2000). The advantage of physiological measurements in comparison with cognitive (self-reports, questionnaires, etc.) is that they deliver objective results, in real-time (Jenkins, Brown, & Rutterford, 2009).

Kim provided an overview on physiological measurement methods for design research (Kim, 2011). Here the scope of presented methods is enlarged. They are classed according to the system, subsystem and organic function to which they are related. Physiological methods can measure activities in the Central Nervous System CNS, as well as in the Peripheral Nervous System PNS. The CNS interprets received information to coordinate activities of limbs and organs. The PNS connects the CNS with the limbs and the bodily organs. Table 10 gives an overview on physiological measurements for design research.

2.2.3.3.1 Physiological Measurements for Design Research

To measure the activity of the brain three methods are currently accessible: **Functional magnetic Resonance Imaging (fMRI), Electroencephalogram (EEG)**, and **Positron Emission Tomography (PET)**. The measurements in the brain can be indicators for valence and arousal (Bradley & Lang, 2000). Their disadvantage is the complexity and the intrusiveness of the equipment to the evaluation context. To measure affective or cognitive reactions provoked in the Peripheral Nervous System PNS design researchers dispose of a wide range of lighter technologies. Most of them are related to functions of the Autonomic Nervous System that controls organs below the consciousness of the human. For example measures of the **Heart Rate (HR) / Electrocardiography (ECG),** the **Blood Pressure (BP)**, **facial muscle activity** or **Infrared Thermography ITR**. Most peripheral measures allow conclusions on valence levels. Only **Electrodermal Response (EDR)** is a useful measure for the level of arousal (Bradley & Lang, 2000). Skin conductance seems to increase linearly with the level of arousal, independent of valence. The drawback of peripheral physiological measurements lies in their easy disturbance by external factors. Especially Heart Rate measures can lead to wrong interpretations since an increased heart rate can also be caused by motor responses, respiration, or body posture instead of a positive valence. Furthermore the responses are often not linear. That makes the interpretation of purely physiological data of one measurement type impossible. For example the activity in the Zygomatic Muscle (smiling) increases, as expected, for very pleasant stimuli, but an increased activity can also be seen when subjects face very unpleasant stimuli (Bradley & Lang, 2000).

It is furthermore interesting that significant differences between the two genders occur for CNS as well as PNS measurements. **Zygomatic muscle activity** has been shown to be a valid indicator of valence for about 2/3 of the female participants but only 1/4 of the male participants. On the contrary **Electrodermal Responses** are stronger for men than for women (Bradley & Lang, 2000). The physiological responses change in different ways with increasing arousal. While the initial pattern might be the same for all test persons at the beginning of the stimulation, it can then evolve in different directions. Bradley and Lang speak of a "cascade of different response events" that together indicate the affective response on a stimuli.

We see a wide range of available methods and they start to find their way into design research, often as a combination of several physiological measurements. For example Galvanic Skin Response (GSR), with Heart rate (HR) and electromyography (EMG) of the face (smiling and frowning) (Mandryk & Atkins, 2007) or Infrared Thermography ITR, Electrogastrogram EEG, and Affective Self Reports (ASR) (Jenkins et al., 2009).

The greatest advantage of physiological measurements over self reports is that they enable researchers to model emotion during a User Experience continuously and objectively. However, for their application in the design context three issues need to be considered

1. Familiarity is perceived as pleasant (positive valence) (Sanabria Z., Cho, & Yamanaka, 2012) and "new information that fits well with already available schemas is usually judged "persuasive, accurate, and pleasant". While incongruous information causes physiological arousal" (Axelrod, 1973). That means users will always react with arousal to new, original designs the first time they encounter them in a test. And something that looks familiar will cause less arousal but higher valence. It is likely that the person will react with less arousal on a second sight and that high arousal at first sight does not necessarily indicate positive or negative valence.

2. Physiological measures provide objective results. However, for low intensities, the automated physiological responses (heart rate, perspiration, etc.) are much less discriminating than words a person would use to describe his affective state (Bradley & Lang, 2000). Since designs are susceptible to cause lower arousals than life threatening situations, the discriminatory potential of the physiological data needs careful validation.

3. The physiological method alone can provide information about the affective levels arousal and valence, but "the existence of physiological and expressive signatures for specific emotions remains a viable but unconfirmed hypothesis" (Russell, 2003). For this reason, combinations of various physiological methods (Jenkins et al., 2009), as well as with cognitive methods have proven useful to interpret the obtained physiological data on specific affects (Tomico et al., 2008). The latter are

called psycho-physiological measurements (Lévy et al., 2009). The combination of physiological data (heart rate variability and level, skin conductance variability), locomotion data and subjective aesthetic assessments (through questionnaire) in the context of artwork perception showed a significant correlation between the physiological measures and the aesthetic-emotional experience (Tschacher et al., 2012).

2.2.3.3.2 Conclusion on physiological measurements in design research

Design research today has started to employ a wide range of physiological measurements that furnish data on the user's arousal or valence evoked by a product or an interaction. They are the most objective type of measurement and most can be recorded continuously. However, there are several disadvantages too. The equipment is relatively complex and often costly. To this day not one specific physiological effect can be attributed to one affect. Furthermore many of the measurements are susceptible to disturbance from other bodily symptoms. It is therefore not recommended to draw conclusions from data acquired with a single physiological measurement type. The combination of results from physiological measurements paired with cognitive and behavioural measures, allows design researchers to interpret this data on the User Experience.

2.2.3.4 Conclusion on UX evaluation methods

We have seen three types of measurements – cognitive, behavioural, and physiological – that can be employed to evaluate user reactions on product design. Each of the methods has its limitations and is sensitive to external disturbances or internal manipulations. Insko proposes that the adapted measurement methods should be chosen based on the four criteria: reliability, validity, objectivity, and sensitivity (Insko, 2003).

In any case, reliable evaluation results cannot be provided through one single method alone. But to apply a maximum of different methods parallel is not a possible choice either for reasons of practicality, complexity (cost/time/equipment), and also disturbance of the test situation. Bradley and Lang (2000) advice that any experiment that seeks to evaluate emotional responses should include one measure from each of the three types: cognitive/language, physiology, and behavioural.

2.2.4 Representations for UX Communication

As described by Bouchard (1999), the information phase, the generation phase and the evaluation phase each have intermediate representations as outcome that can be used to communicate project information to the other stakeholders of the product development. All the previously seen tools can therefore furnish data and data visualisations that serve the communication of UX concepts. Some common representations today are mood boards, scenarios in form of storyboards or animations, personas from the information process, visual prototypes (sketches, renderings), shape prototypes

(3D CAD models, rapid prototyping models), functional prototypes, full physical prototypes or mixed prototypes that combine virtual and physical outcomes (Bordegoni, 2011; Ferrise, 2013) from the generative phase, as well as testimonies and statistics from the evaluation phase. **Erreur ! Source du renvoi introuvable.** shows examples of these intermediate representations for UX concept communication.

2.2.5 Conclusion of section 2.2

Section 2.2 presented a variety of tools and methods that already exist to support the User Experience Design process. To establish this overview was made difficult by the fact that they all appear fragmented in various papers without a clear discrimination to which conception activity the tool or method belongs. IDEO (2013) for example presents some information techniques together with evaluation techniques under the activity 'ask'. With regard to the needs of designers in practice, it seems more relevant to separate the tools according to the conception activities: inform, generate and evaluate. Even though the established lists are probably not exhaustive, one can say that today there already exist many tools for User Experience information gathering and for User Experience evaluation. However, we see that despite Kansei Engineering there are no tools or methods that have been specifically developed for User Experience generation. What's more, despite that fact that there are many evaluation methods, the range of regarded User Experience dimensions in research projects is still rather limited to product appearances. The following final part of this State of the Art will therefore summarise limitations encountered in current design research.

2.3 Limitations of current Design Research on User Experience

User Experience has found its way into design research by adopting methods from related domains like cognitive psychology and human-computer interaction. The literature review gave insights into the mechanisms and dimensions of User Experience. Furthermore, it also provided an overview on methods and tools for the information gathering, concept generation, concept evaluation and communication.

We saw that Kansei Engineering and Emotional Design have developed own tools to evaluate the User Experience. The approximately 50 here cited projects undertaken between 1997 and 2012 address the dimensions illustrated in Image 51. The most evaluated attributes are forms and colours. 40% of the analysed research papers looked at the Kansei of form factors, about 15% related Kansei with colours and 10% combined both, form and colour. An emerging topic is sensorial perception of materials and textures. Dynamically changing dimensions only start to appear as a topic in Design Research.

Limitation 1: **Evaluation methods from Kansei Engineering and Emotional Design have not yet been applied to dynamically changing properties.**

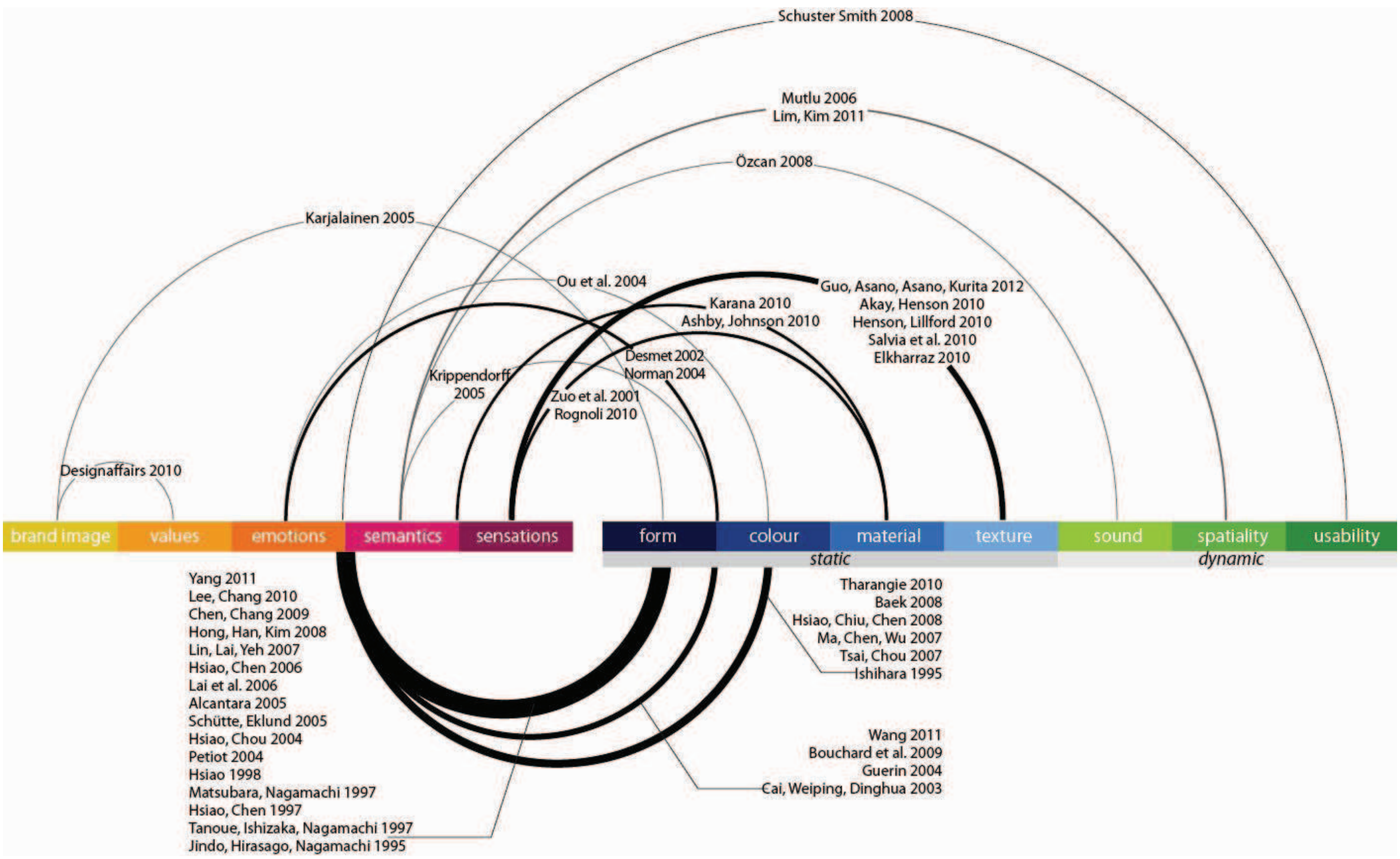


Image 51: Illustration of the User Experience dimensions in current studies (left: abstract dimensions, right: concrete dimensions); the arcs link the relation between the dimensions that are evaluated in the according paper.

The UX evaluations encountered in the cited projects are mostly done on images of finished products instead of concept representations or operable prototypes. This limits the possibilities to influence the design during the conception process.

Limitation 2: **User Experience evaluations have not yet been done on design concepts.**

Many studies measure emotions evoked by a product at the moment of first contact. Yet User Experience is not a static condition but a state of mind that changes over time. Design researchers have identified the importance of temporality in User Experience. Two temporal levels need to be addressed by designers: The momentary User Experience during single interaction sequences and the cumulative User Experience over various use episodes. Despite the growing interest in temporal changes of User Experience…

Limitation 3: **very few User Experience evaluations address the time dimension.**

User Experience has already been evaluated through various cognitive, physiological and behavioural measurements. We also see a great amount of tools that have been developed to gather information that should help designers to design for User Experience. However, among the methods there is…

Limitation 4: **A LACK OF TOOLS OR METHODS FOR THE GENERATION OF USER EXPERIENCE DURING PRODUCT CONCEPTION.**

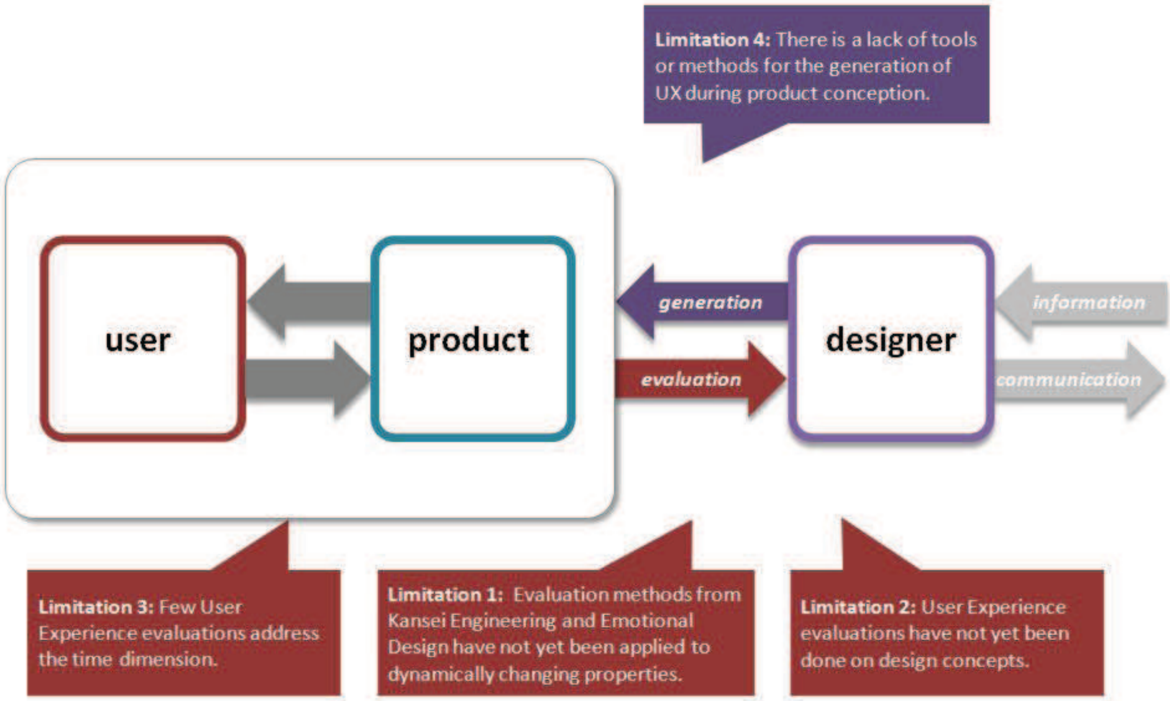


IMAGE 52: LIMITATIONS OF CURRENT RESEARCH ACTIVITIES, TOOLS AND METHODS FOR USER EXPERIENCE DESIGN.

This thesis seeks to contribute to the four identified limitations. It will therefore analyse the range of design dimension in practice, test two different concept generation tools, and apply evaluation tools on design concepts and on a dynamic user interface.

3 Research Question, hypothesis and sub-hypotheses

In this chapter, the research question of this thesis is formulated and the hypothesis with its sub-hypotheses that will be explored in the experimental part are developed. We have seen that current studies on User Experience focus on very few selected product properties and address evaluations of advanced product states. This thesis therefore seeks to **bring User Experience to early product design** and more precisely to concept **generation** and **evaluation** activities.

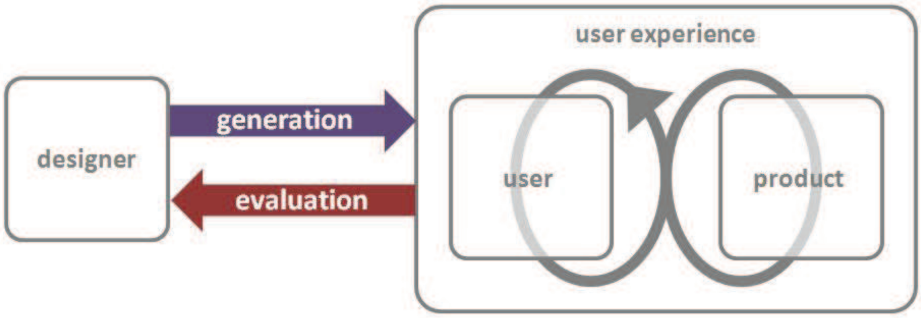


Image 53: Schema of the situation at the center of the research question.

3.1 RESEARCH QUESTION

Microprocessors have enriched the sensory and responsive capabilities of everyday products. This brought new opportunities as well as challenges to product designers. For centuries, people have created and refined products. A common understanding of Gestalt laws or colour harmonies has developed within and beyond cultural boarders. Designers have long been occupied mainly with form-giving. For that, their designs were based on knowledge of appearances. Today product designers are asked to design more than just good-looking products. They are asked to design an experience for the user.

User Experience results from the interplay of a wide range of concrete (form, colour, material, texture) and abstract (affective and sensorial quality, semantic quality, aesthetic quality) product dimensions, together with the perception of the target user and the context in which he encounters the product. The literature review showed us that User Experience has become an important subject for design researchers and product manufacturers. The main players here are the communities of Human-Computer Interaction HCI and Kansei Engineering KE. HCI has developed a wide range of User Experience evaluation methods around usability. Kansei Engineering on the other hand has contributed methods that treat the Kansei dimensions of User Experience, such as sensorial and affective quality, semantic quality and aesthetic quality. Kansei Engineering methods allow designers to evaluate form factors and colour choices on their impact on the user. They also propose systems for the automatic generation of designs that carry a certain Kansei. Yet, as shown earlier in the limitations, the methods have only been applied to static product properties. Most of the current research outcomes analyse and describe User Experience. However, very few propose tools or methods for User Experience conception. The research objective of this thesis is to propose methods and tools to designers that help them to improve their design concepts with regard to User Experience.

Therefore the question that is posed in this thesis is:

HOW TO BRING USER EXPERIENCE TO EARLY PRODUCT DESIGN?

3.2 THE RESEARCH HYPOTHESIS AND SUB-HYPOTHESES

In product development it is the designer’s role to create the experience that users will have with final products. The success in terms of User Experience is influenced by his choices during the conception process. As shown in section 1.2.1, the conception process is the crucial phase of product development because it is the stage when the final product is defined. Adaptations at a later stage are very costly. The design conception process is constituted of 4 activities: information / exploration, concept generation, followed by concept evaluation and choice (decision), and finally the communication of the chosen concepts. During the conceptual design, information, generation, evaluation and communication activities, undertake multiple iterations before a concept enters into product development.

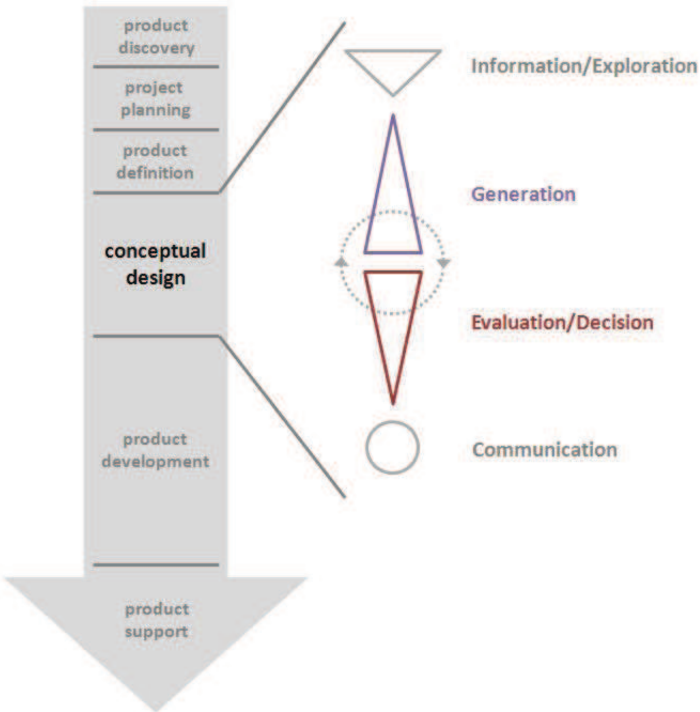


IMAGE 54: THE PRODUCT CONCEPTION PROCESS ADAPTED FROM BOUCHARD AND AOUSSAT (1999) AND CROSS (2008) AS PART OF THE PRODUCT DEVELOPMENT PROCESS ADAPTED FROM ULLMANN (2010).

The literature review showed us a wide range of tools to gather User Experience relevant information. However we saw very few tools or methods for the concept generation activity. Evaluation tools are today very advanced but not yet applied to early concepts. In order to bring User Experience in the conception process, this thesis therefore suggests investigating the applicability of Kansei tools for concept **GENERATION** and an extended application of Kansei methods for concept **EVALUATION**.

Classical product design has long focused on form-giving of products, including forms, colours, semantics and eventually material choices. As can be seen in the models of 2.1.2, these are only a few of many User Experience dimensions. This thesis postulates the following hypothesis:

HYPOTHESIS: TO DESIGN FOR USER EXPERIENCE, DESIGNERS NEED TO ADDRESS A WIDE RANGE OF DIMENSIONS DURING EARLY CONCEPT GENERATION AND EVALUATION.

During concept generation, the designer develops various ideas to respond to the design problem. The ideas are externalised as sketches and keywords, depending on the designer's skills in manual or digital form. The classical tools and representations (paper, pen – sketch; CAD – 3D model) have been developed for form and colour explorations. But these are not necessarily the best adapted tools to explore dynamic product properties and to anticipate the future User Experience. As stated in limitation 2, there is still a lack of concept generation tools that support designers to anticipate the User Experience. The first sub-hypothesis assumes that…

SUB-HYPOTHESIS A: DESIGN TOOLS THAT EXPLICITLY ADDRESS THE KANSEI DIMENSIONS CAN HELP DESIGNERS TO GENERATE CONCEPTS WITH A STRONGER USER EXPERIENCE POTENTIAL.

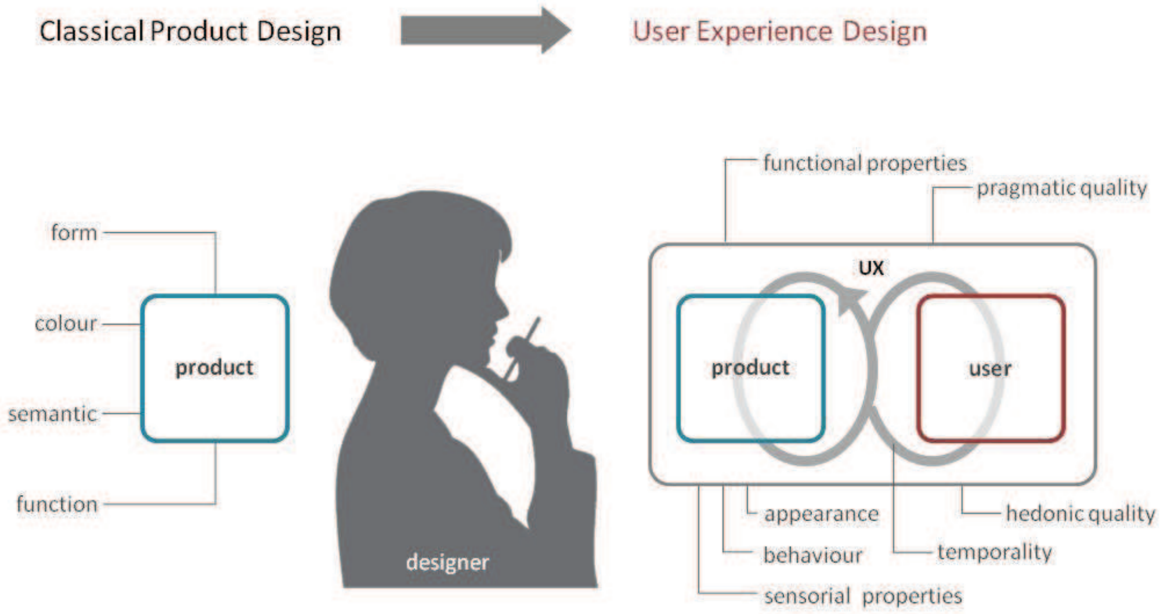


IMAGE 55: DIMENSIONS OF CONCEPT GENERATION IN CLASSICAL PRODUCT DESIGN (LEFT) AND AS A VISION FOR USER EXPERIENCE DESIGN (RIGHT).

During concept generation, the designer makes assumptions about the future User Experience. In order to choose one concept over another, designers need tools for the evaluation of their ideas. User Experience evaluation tools have started to find their way into product design. In the current research activities we have seen many applications of Semantic Differentials or Likert Scales, as well as the Self-Assessment Manikin (for valence and arousal). A few cases also applied physiological (electrodermal) and behavioural (eye tracking) measurements. However, as stated in limitation 1, in the design context Kansei evaluations have so far mainly be done on final products. In the conception process it would be an advantage if one could already evaluate design concepts on their User Experience potential. As a second sub-hypothesis it is hence assumed that…

SUB-HYPOTHESIS B: USER EXPERIENCE EVALUATIONS CAN BE DONE ON EARLY DESIGN CONCEPTS.

Moreover, it can be assumed that it is possible to extend concept evaluations in the field of Product Design beyond commonly investigated dimensions form, colour, and materials. The third sub-hypothesis therefore is that…

SUB-HYPOTHESIS C: USER EXPERIENCE EVALUATIONS CAN BE APPLIED TO DYNAMICALLY CHANGING DIMENSIONS LIKE INTERACTION GESTURES.

3.3 Summary

The research question of this thesis is centred on the topic of User Experience conception. Image 56 gives an overview on the hypothesis with its three sub-hypotheses and their positioning in the conception process. While the hypothesis spans over the concept generation and evaluation activities, sub-hypothesis A addresses the generation and sub-hypotheses B and C the concept evaluation.

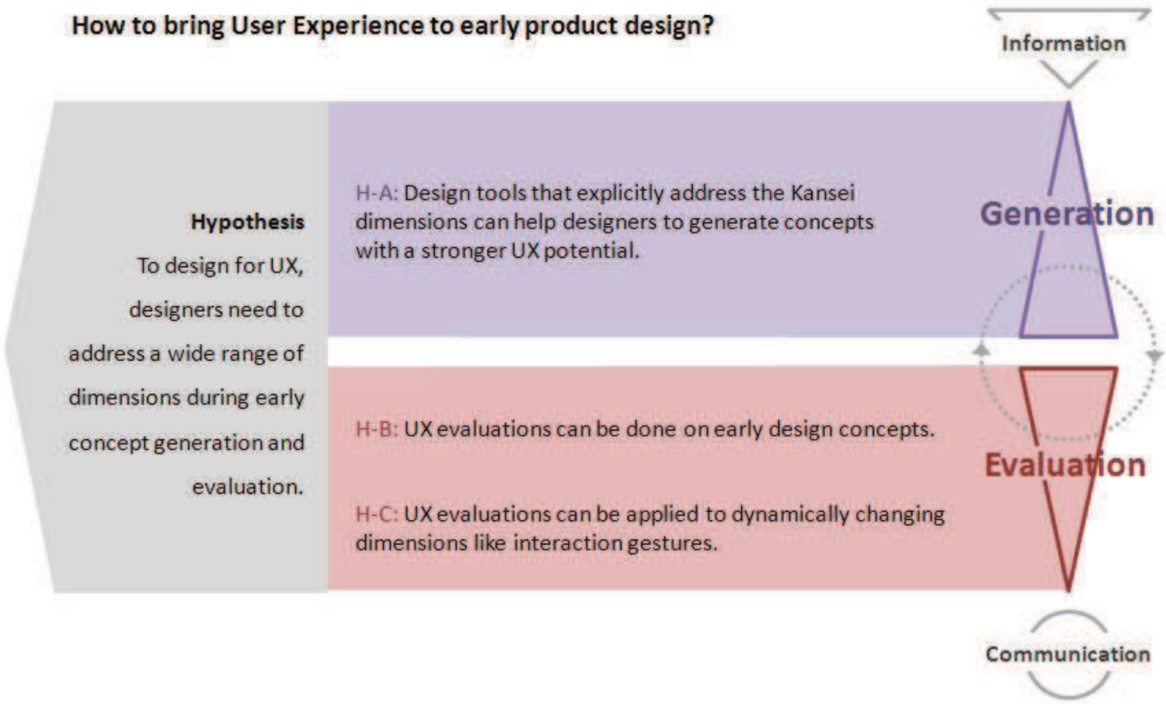


IMAGE 56: OVERVIEW ON THE RESEARCH HYPOTHESIS AND SUB-HYPOTHESES IN RELATION TO THE PRODUCT CONCEPTION PROCESS.

In the following experimental part, the hypothesis and sub-hypotheses will be investigated. Through the studies design dimensions from the designer's and from the user's point of view will be explored. Furthermore, tools for the generation and evaluation of User Experience concepts will be tested.

4 THE EMPIRICAL STUDIES

Three studies on the subject **'HOW TO BRING USER EXPERIENCE INTO EARLY PRODUCT DESIGN?'** are presented in this chapter. The field of the studies was the project SKIPPI in which a design software was developed. The participants of the study were designers who conceived new products with the SKIPPI software and who at the same time evaluated the software interaction as users.

Of the conducted studies, the first one investigated dimensions of User Experience in design research (study 1-A), in designer's concepts (study 1-B) and as perceived by users (study 1-C). In the second and third study generative tools were tested on their efficiency for the generation of User Experience rich concepts (study 2 and study 3-A). Furthermore methods for the evaluation of the proposed concepts were explored (study 2 and study 3-B).

Study 1: **THE RANGE OF UX DIMENSIONS**

Study 1-A: UX dimensions in design research

Study 1-B: UX dimensions in designers' concepts

Study 1-C: UX properties in final products as perceived by users

Study 2: **SKIPPI – A WORD-BASED TOOL FOR CONCEPT GENERATION**

Concept generation with and without Skippi / Expert evaluation of the generated concepts on their UX potential

Study 3: **GESTURAL INTERACTION – GESTURE GENERATION AND EVALUATION**

Study 3-A: Gesture generation through body storming

Study 3-B: UX evaluation of the generated interfaces

To begin with, the project Skippi, which is the research terrain, will be introduced. Then each study is described with its respective objective, participants, applied methods, results and discussion with regard to the hypothesis and sub-hypotheses.

4.1 Overview on the studies

The research question is **HOW TO BRING USER EXPERIENCE TO EARLY PRODUCT DESIGN.** This thesis therefore seeks to propose tools and methods for the generation and evaluation of design concepts on User Experience.

We have seen that the conception process consists of four phases: information/exploration, generation, evaluation/decision, and communication (Bouchard & Aoussat, 1999; Cross, 2008). In the generation phase designers envision the future User Experience with the help of various design tools (manual, numeric, visual, verbal, etc.). In the evaluation phase user tests are undertaken to confirm design choices. The experimental studies address the generation and the evaluation phase.

The studies sought to validate the pertinence of the main hypothesis: **TO DESIGN FOR USER EXPERIENCE, DESIGNERS NEED TO ADDRESS A WIDE RANGE OF DIMENSIONS DURING EARLY CONCEPT GENERATION AND EVALUATION (H).** To begin with a set of three studies was put into place to identify the wide range of User Experience dimensions. First of all a list of dimensions was extracted from pertinent papers of the literature review (study 1-A). Then designers' concepts were analysed on the present UX dimensions (study 1-B). Finally dimensions and their properties were identified from verbalisations of users on their experience with products (study 1-C). Together these three studies show which dimensions are recognised and appreciated by the future users, and if these are consciously treated by the designers during concept generation.

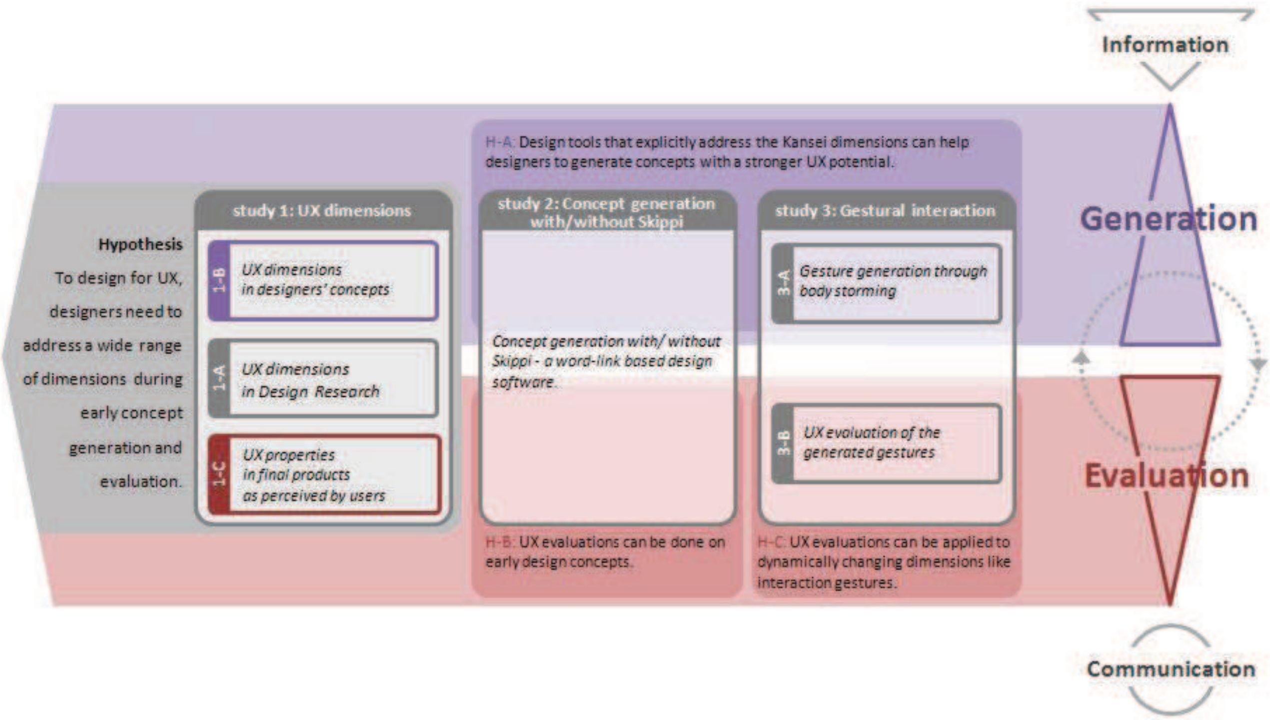


IMAGE 57: OVERVIEW ON THE STUDIES IN RELATION TO THE HYPOTHESES.

In the studies 2 and 3 specific tools for concept generation and evaluation were tested. Both had a concept generation part that sought to respond to the sub-hypothesis that **DESIGN TOOLS THAT EXPLICITLY ADDRESS THE KANSEI DIMENSIONS CAN HELP DESIGNERS TO GENERATE CONCEPTS WITH A STRONGER USER EXPERIENCE POTENTIAL** (H-A). In a second part, tools for the UX evaluation of the generated concepts/designs were applied. The objectives were to see if **UX EVALUATIONS CAN BE DONE ON EARLY DESIGN CONCEPTS** (H-B) and if **UX EVALUATIONS CAN BE APPLIED TO DYNAMICALLY CHANGING DIMENSIONS LIKE INTERACTION GESTURES** (H-C). In study 2, two groups of stakeholders of conception generated concepts with or without the use of Skippi followed by an expert evaluation of the generated concepts on their UX potential. In study 3 body storming was applied as a generative tool to design the interaction gestures of Skippi (Study 3-A). In a second step the interaction was evaluated on its UX value by users (study 3-B).

Studies 1, 2 and 3 cover both concept generation and evaluation. The studies 1-B and 3-A treat the generation of concepts by designers. Study 3-B addresses the evaluation of concepts by users.

4.2 THE SKIPPI PROJECT – THE TERRAIN OF THE STUDIES

The research terrain of the studies was the development of a software for early product design – SKIPPI (Système Ingénierie Kansei Produit Process Image de Marque). It is a software tool for product conception that links semantic and emotional product dimensions with data on functions, materials, and production processes. It is intended for the stakeholders of product conception – designers, engineers and marketers (Bouchard, 2013). The data is represented in form of words that are linked through lines. Their relation can be visualised through circles, tree diagram or proximity in the space. The user can search words inside the word graph and visualise paths that connect the words of his choice. This might inspire original ideas or inform him about possible solutions.

IMAGE 58: IMAGES OF THE SKIPPI SYSTEM – THE TERRAIN OF THE STUDIES.

SKIPPI played different roles in the studies of this thesis. Study 1 was conducted at the beginning of project. Its outcomes helped the developers to define the requirements of the users and to constitute the database of the software. In study 2 an advanced prototype of Skippi was used according to its final purpose – a tool that supports concept generation. Product concepts generated with or without the use of Skippi were compared to estimate the potential impact of this conception tool. The results helped the developers to improve the system. In study 3 the interaction of Skippi itself was the product that had to be conceived. Three different interaction modes (mouse, tactile and virtual) were put into place. The interaction gestures were conceived with the creativity tool body storming (explanation in 4.5.3.2). Following the implementation in an advanced prototype, User Experience tests were conducted on the designed three interactions with Skippi.

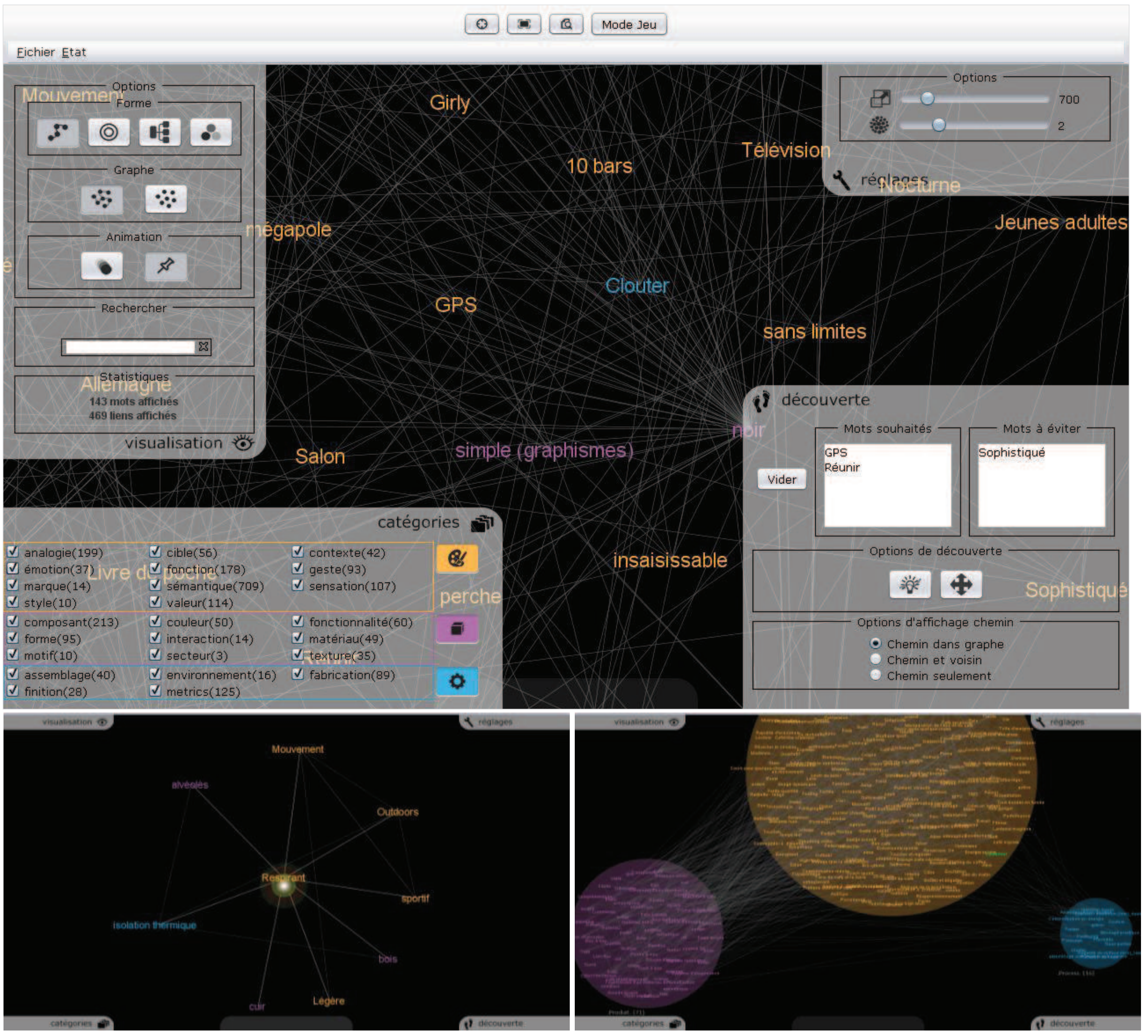


IMAGE 59: SCREENSHOTS OF THE SKIPPI INTERFACE.

4.3 Study 1: What constitutes the User Experience? – The range of User Experience Dimensions in Design Research, Design practice and as perceived by the user.

The first study session is constituted of three separate studies (Image 57). They were designed to validate the main hypothesis: **To design for User Experience, designers need to address a wide range of dimensions during early concept generation and evaluation (H).**

To investigate the hypothesis, three questions were asked:

Study 1-A: What User Experience dimensions have so far been identified by design researchers?

Study 1-B: Which of these dimensions appear in design practice in designers' concepts?

Study 1-C: Which properties of which dimension do users perceive and appreciate in final products?

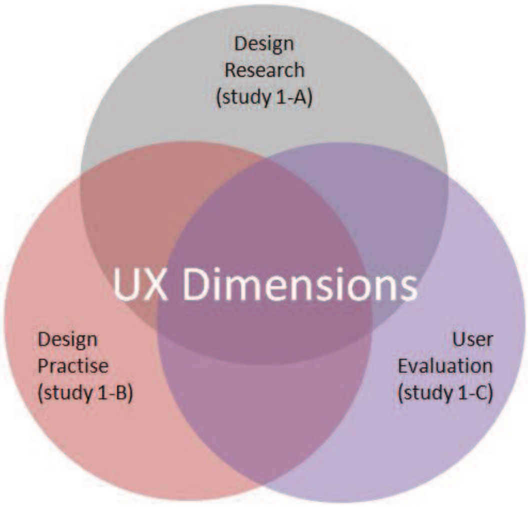


Image 60: The three directions to investigate UX dimensions in study 1.

4.3.1 Study 1-A: User Experience Dimensions in Design Research

4.3.1.1 Objective

The main hypothesis of this research is that designers need to address a wide range of dimensions during early concept generation and evaluation, to design for User Experience. In the literature review we came across a wide range of dimensions in the various models and studies of Kansei Engineering, Product Design, and Human-Computer Interaction. What was missing was a global overview of all dimensions that potentially influence the User Experience. Study 1 therefore sought to establish an exhaustive list of User Experience Dimensions from the various sources of Design Research.

4.3.1.2 Method

In order to establish a list of dimensions, models from the State of the Art were used: Forlizzi and Ford's 'initial framework of experience' (2000), Hassenzahl's 'model of User Experience' (2003), Crilly et al.'s 'Framework for consumer response to the visual domain in product design' (2004), Krippendorff's 'Interaction protocol of an interface' (2005), Schifferstein and Hekkert's 'Model of human-product interaction' (2008), Locher et al.'s 'Framework for aesthetic interaction' (2009), Kirkegaard Rasmussen's 'Typology of shape changes' (2012), Rooij et al.'s 'Abstract Expressions of Affect' (2013) and Bouchard, Kim, and Aoussat's 'Kansei Information' (2009).

4 groups appear in the selected models and frameworks (human, product, context, design condition). The design dimensions that appear in the models and frameworks of these papers were all written down in a table of 4 groups. The reference was annotated for each dimension. In a next step synonyms or terms that address the same design content were grouped together, for example 'dimension', 'size' and 'volume'. If possible they were merged or substituted by the most encompassing term. For example 'emotion' and 'affect' became 'affect', 'form' and 'shape' became 'form'. In the following step the hierarchy of the dimensions was chosen as a consolidation of the proposed levels from the different models and according to the mechanisms of human-product perception as seen in the State of the Art, mainly based on the theories of Russel (2003) and Cariani (2001) (see 2.1.3.2). In order to get a complete but synthetic list, a final reduction had to be applied. As a final step, dimensions in a lower level of the hierarchy that were only mentioned in one paper were removed from the list but the reference was kept in the naming of the next higher level of hierarchy. Furthermore the group 'design conditions' was omitted since it was only subject of one paper and it is outside the scope of this research.

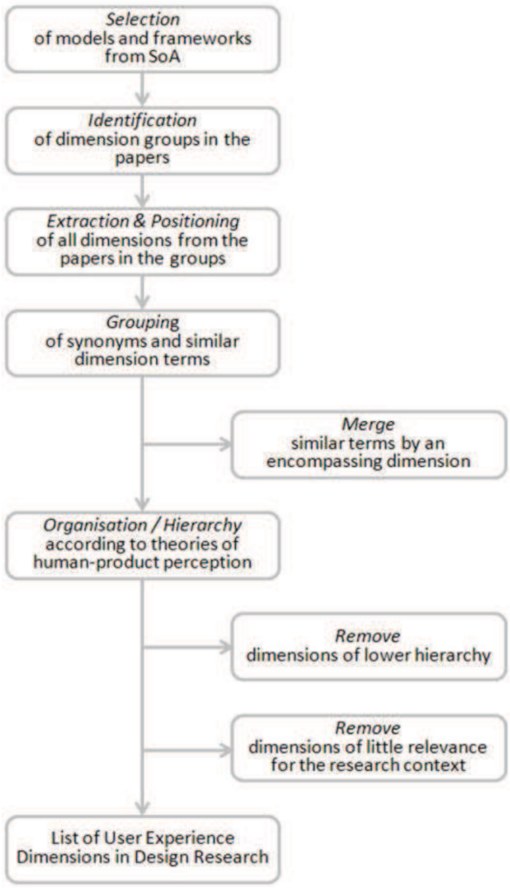


IMAGE 61: PROCEDURE OF STUDY 1-1.

4.3.1.3 RESULT

All found models separate the human and the product capabilities. The interaction is embedded in a situational context that represents a third pole of User Experience. In Table 11 all gathered dimensions are presented with the reference of their theory of origin.

A wide range of product dimension that potentially influence the User Experience was found. Among them are the classical product design dimensions form, colour, material, and texture, but also dimensions that have gained importance in the interaction context like the product behaviour, a product sensory capacities, or sensorial properties. Among the dimensions related to the human we find the profile of the target user, his knowledge and memories, his values, concerns and motivations, his emotions, and his responsive behaviour. The externalities that influence the User Experience with a product are formed by situational factors, cultural factors, and social factors. The dimensions addressed in the models belong to different macro or micro levels of design contents. In Table 11, an arrangement of these dimensions is proposed, limited to three levels of hierarchy.

TABLE 11: USER EXPERIENCE DIMENSIONS IN THEORY.
COMPILED FROM [1](KRIPPENDORFF, 2005), [2](CRILLY ET AL., 2004), [3](FORLIZZI & FORD, 2000), [4](LOCHER ET AL., 2009), [5](SCHIFFERSTEIN & HEKKERT, 2008), [6](ROOIJ, BROEKENS, & LAMERS, 2013), [7](HASSENZAHL, 2003), [8](RUSSELL, 2003), [9](Y. LIM ET AL., 2009), [10](MUTLU ET AL., 2006), [11](KIRKEGAARD RASMUSSEN ET AL., 2012), [12](BOUCHARD, KIM, ET AL., 2009).

HUMAN	target user	age[2]
		gender[2]
		cultural background/living environment[4]
		personal taste / aesthetic sophistication[4]
	sensory system / state[1/2/4/5]	
	stable cognition & affect[2/3/4/5]	cognitive contents (knowlege[4],experience/memories[3/4])
		personality[2/4] / disposition
		motivations[2/4]/values[3/12]/concerns[5]/needs
	event dependent cognition & affect[5]	core affect[8]
		perceived character[7] (affective[8/12], aesthetic[3], semantic[1/12])
	motor system / state[4/5]	actions/behaviours[1/2]
PRODUCT	product sector[12]	
	function/practical purpose[3]	
	feature[3]	functionality[5/7]
		content[4/7]
		sensory capacities[1]
		composition/component[5]
		technology[5]
	intended character[1/7]	affective[8/12]
		aesthetic[3]
		semantic[1/12]
		analogy/symbolic[2/12]
		brand style/objective[2]
		style[2/12]
	sensorial property[5]	
	static appearance / structural property[5]	material[2/5]
		texture[2/11/12]
		viscosity[11] / elasticity
		colour[2/12]
		graphic[2/12]/ detail[2]/ label[5]
		form[3/6/11/12] / geometry[2]
		dimensions/size/volume[2/6/11]
	behaviour/action[1/2/5]	visual response [6/9/10/11]
		response speed[10]
	production quality	tolerances, finishing, ageing[2]
EXTERNALITIES /CONTEXT[1/2/3]	cultural factors[3]/references[2]	similar products[2]/brands/activities
		clichés/stereotypes[2]
		trends/fashions/tastes[2]/conventions
	situational factors[2/4]	viewing time[2]
	social factors[2/3]	

4.3.1.4 DISCUSSION

Despite the objective to establish a complete list of dimensions from design research papers, some of the dimensions from theory had to be omitted in order to keep the list in a handy format. The list provided the base for the following two studies 1-B and 1-C. Depending on the situation in which one wishes to consult this list, amendments might still be necessary. Especially the notion of the design conditions might be of interest for stakeholders of design management.

4.3.1.5 Conclusion of study 1-A

The established list already shows a wide range of dimensions that are subject of current design research. If design researchers investigate these dimensions, it means that each of them is somehow relevant for the User Experience with products and it therefore needs to be addressed by designers during concept generation and evaluation (H). This list was a first proposal on which the following study 1-B builds. Here the list will be confronted with dimensions in design practice.

4.3.2 Study 1-B: User Experience dimensions in designers' concepts

4.3.2.1 Objective

In the literature review we saw that any dimension of a product that is perceivable through human sensing means (visual, audible, tactile, gustatory, and olfactory) potentially influences how users experience a product. The hypothesis of this thesis supposes that the conscious consideration of a wide scope of these dimensions by designers can enrich the User Experience value of design concepts.

Study 1-A brought us a collection of dimensions that design researchers have identified as influencing User Experience (see Table 11). Since this collection is a compilation of theoretical models, study 1-B sought to answer two questions: 1. Is Table 11 giving a complete picture of User Experience dimensions? and 2. which of these dimensions do product designers really treat in their conception work? The study attempted to answer these questions, through an investigation of dimensions in product designers' concepts compared to those gathered from the theoretical models.

4.3.2.2 Participants

Two companies participated in the study. One of them is an industrial design agency, the other the product development division of a telecommunication device manufacturer. The design agency has experience in a wide range of sectors including sport, health care, automobile, packaging and communication. The designed products range from air pumps and pill dispenser, to portable gas bottles and garage doors. The telecommunication manufacturer develops products like mobile phones, e-readers, and tablet PCs.

The study was divided into two parts. Ten professionals participated in part 1 and 2 of study 1-B, among them 8 designers and 2 engineers. The research focus lay on designers. Nevertheless, two engineers of the development team from the telecommunication device manufacturer were included. The participants were the same in both parts; except for one designer and one engineer who were substituted by a colleague. Part 2 was conducted one month after part 1. Both parts took place at the participants' work place.

4.3.2.3 METHOD

In order to analyse the designers' concepts on their represented dimensions, common research methods for design data collection were reviewed. Since most parts of conception activities are of intrinsic nature, researchers need means to see what is going on in the minds of designers. Sketches, renderings and CAD models are their main working tools. One can analyse these representations to draw conclusions on work contents. But it is in their nature to contain mainly information on forms and colours. Not all aspects of a design idea can be visually represented. However, they may be expressed through words (Goldschmidt and Sever 2011). The design process integrates different stages of exploration, generation, evaluation and communication (Bouchard & Aoussat, 1999; Cross, 2008). These activities may be the source of keywords describing design concepts. Segers, Vries and Achten believe that words deserve a more important role in design research as verbal expressions, as well as in written format (Segers, Vries, and Achten 2005). It is assumed that concepts can be described through words matching a limited set of dimensions. Verbal descriptions therefore seem an appropriate means to access the contents treated by designers during concept generation and communication. Two verbal techniques were chosen for the study: **VERBAL REPORTS** and **WORD MAPS**.

VERBAL REPORTS of professionals allow researchers to access information related to the contents of their work. Someren et al. introduce three different types of verbal reports: **RETROSPECTIVE VERBALISATION** (the participant recalls processes and contents after the activity is finished from the long-term memory), **INTROSPECTION** (the participant interrupts the activity and recalls the processes and contents from the working and long-term memory) and **CONCURRENT VERBALISATION**/Think Aloud (the participant verbalises his thoughts in real-time during the execution of the activity. It reveals processes and contents directly from the working memory without interruptions or suggestive prompts). Retrospection holds the risk of information loss since only relevant aspects are recalled. Introspection allows for a nearly real-time account but the participants need to interrupt their actual activity. Concurrent verbalisation give access to what happens exactly at the moment it happens but might modify the activity of the participants (Someren, Barnard, and Sandberg 1994). Think Aloud protocols have already been employed by various design researchers to analyse design processes (Gero and McNeill 1998), cognitive activities of the designer (Kim et al. 2010), or design contents (Suwa and Tversky 1997).

Word maps are a way to gather concept contents through written accounts. The professionals note keywords of their thoughts on the problem the moment they occur. If written on separate sheets the words can be positioned in relation to each other and create a word map. Kokotovich showed that such word based maps allow visualising the complexity of design dimensions to be handled and structured by the designer. Furthermore, they reveal relations between the dimensions (Kokotovich 2008). Goldschmidt and Sever stated that designers easily relate lexical data to forms (Goldschmidt and Sever 2011).

In order to outbalance the respective disadvantages of retrospective and concurrent techniques, the study was divided in **two parts.**

Part 1: Retrospective concept descriptions

The technique of retrospective verbal reports was employed. Each professional individually described one of his/her conceived products and the processes that had lead to the outcome in about 30 minutes. Table 12 lists the projects that were subject of part 1; all of which were projects that had recently been completed industrial demands. The participants brought visual supports (sketches, prototypes, etc.) to illustrate their narration. No suggestive questions were asked by the two present researchers. During the verbal reports, the researchers noted each keyword evoked by the participant on a separate post-it notes. A keyword was each word or word-group that described the product, the target user, the use context or the interaction (e.g. adjectives: dynamic, red, warm; nouns: wood, moulding, display; verbs: rotate, scroll, creak).

Table 12: Projects analysed in part one of study 1-B.

Sector	Product
Sport	A light-weight bicycle air pump
Automobile	Graphics for a motorbike chassis
Cleaning	A detergent bottle
Distribution	A portable gas bottle
	A logo for a gas distributing company
	An animation for gas distributor display
Handcraft	A home workshop tool
Communication	A portable home telephone
	A mobile phone (luxury brand)
	A mobile phone (sports brand)
	An e-reader

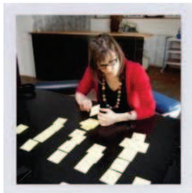
As a second task, we handed each participant the post-it notes with his keywords. They were asked to cluster them. The study was audio-recorded. The sorted post-its were photographed and reprocessed into Excel sheets. Based on the initial sorting of the participants, the two interviewing researchers classified the words into 51 dimensions. The dimension was chosen with regard to the participants' discourse.

PART 2: CONCEPTS IN WORD MAPS

In contrast to part 1 that was based on completed projects from different sectors, part 2 was done on a real-time conception activity. All participants received the same fictitious task to "conceive a communicating coffee machine for Adidas". This unusual brief was chosen because it contained familiar elements for all participants coming from quite different sectors of experience. After facing the brief, the participants had one hour for their ideation. They were instructed to create their concept through a word map. They could write their ideas as keywords on post-it notes and place them on an A1 paper surface. They could also draw lines with markers to connect words. The duplication or relocation of words was allowed. They were encouraged to share their thoughts (Think Aloud), so that the two observing researchers could follow their activity. The activity was videotaped. All produced word maps were photographed, reproduced as Adobe Illustrator images, and all key-words listed in Excel sheets. In line with part 1 the two interviewing researchers classified the words from the post-it notes into 53 dimensions. The dimension was chosen with regard to the participants' discourse.

Table 13 gives an overview of the two parts, including their respective objectives, the adopted methods, the projects and the participants.

TABLE 13: OVERVIEW ON THE METHODOLOGY OF THE TWO STUDY PARTS.

	Objective	Method	Projects	Participants	
Part 1	Extraction of concept words for the categorization of User Experience dimensions	Retrospective verbal reports, Post-it note sorting	Completed design projects from diverse sectors (see Table 12)	8 designers 2 engineers	
Part 2		Word mapping	A fictive design brief: "Communicating coffee machine for Adidas"		

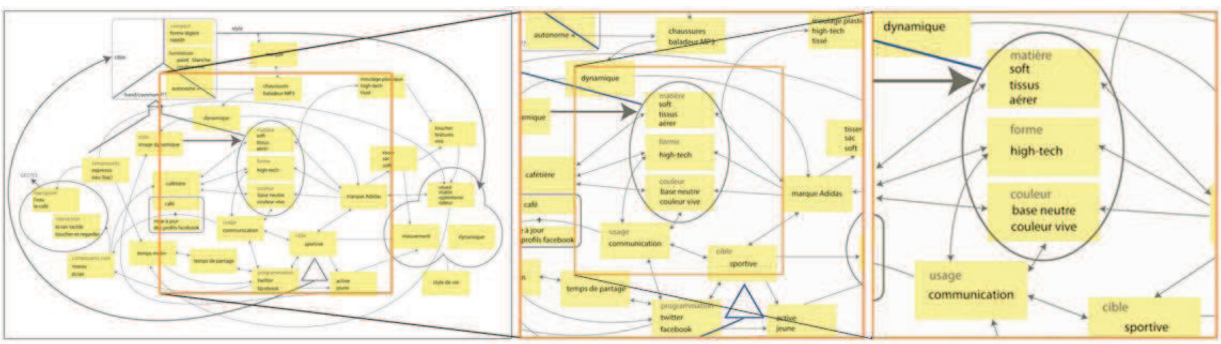


IMAGE 62: EXAMPLE OF AN INDIVIDUAL WORD MAP AND ZOOM-IN, STUDY 1-B PART 2.

4.3.2.4 Results

621 concept words were expressed in part 1 of the study. 489 words were written in part 2. 68 words from part 1 reappeared in part 2 (among them e.g. plastics, metal, black, touch screen, ecologic, dynamic, compact). The words were classified into the dimensions of design research from study 1-A. Table 14 shows the absolute word occurrence per dimensions for part 1 and 2 with example words from the study (translated from French into English).

17 design dimensions were added to the list from design research. They are marked *italic* in Table 14. Among them are mainly dimensions that define the situational factors and different types of product behaviour. Furthermore, we added production methods, the product weight, component positions, product type and name. On the human side we added interaction gestures and body postures, as well as two aspects of the target user: his occupation (his job or hobby) and the quantity of users (from individual to groups).

Five dimensions were not represented through the designers' concept words (sensory system/state, perceived character, production quality, viewing time, and social factors). They are marked grey Table 14. The product features, intended character and static appearance were the most represented dimension groups.

In part 1 (retrospective verbalisation) the mainly found expressions were on properties that had found their way into the final product. The participants gave many details on form and colour choices of the product. Words describing the affective character appeared 3x more often in part 1 (retrospective verbalisation) than in part 2 (real-time conception), the colour choice 3x, graphics and details 2.5x, the form 4x, the dimensions/size/volume 3x, and production methods 2x more often in part 1. In contrast, in part 2 (real-time conception) the participants sought to define the product purpose before working on visual or behavioural properties. Here the dimension 'function/practical purpose' was mentioned 3.5x more often than in part 1. In part 2, the participants also reflected 3x more often on products that might be related to their concept.

4.3.2.5 Discussion

The objective of this study was to compare User Experience dimensions in design research and design practice. The goal was to see 1) if the list of identified design dimensions from research in Table 11 was complete and 2) which of these dimensions product designers really treat in their conception work.

As mentioned in the results, 17 dimension types were added. The greatest imprecision in the theoretical models was on the definition of externalities. The designers in the study defined the use context quite precisely through related objects, time, place and activities.

Table 14: Design dimensions in practice, with examples and word occurrence in the design concepts.

dimension			part 1 (621 words)	part 2 (489 words)	example properties (from the study)
human			85	81	
	target user		17	23	
		single / group	3	8	couple, family, individual
		occupation	4	7	worker, senior executive CEO, golfer
		age	5	6	45+, child, young adult
		gender	1	0	woman
		cultural background/living environment	3	1	cosmopolitan, Londoner
		personal taste / aesthetic sophistication	1	2	fashion victim, MTV fan
	sensory system / state		0	0	
	stable cognition & affect		35	29	
		cognitive contents (knowledge, experience/memories)	0	1	memories
		personality / disposition	4	3	rebel, optimist, opinion leader
		motivations/values/concerns/needs	29	25	trust, authenticity, sustainability
	event dependent cognition & affect		2	0	
		core affect	2	0	fun, sad
		perceived character	0	0	
	motor system / state		33	29	
		actions/behaviours	10	17	erase, go to page…, leave, look at, taste
		interaction gesture	19	10	push, wink, lift-off, scratch, shake, strike
		posture / body	4	2	sitting, head, spine,
product			423	327	
	product sector		2	1	cosmetics, bricolage, sport
	product type		2	2	smart phone, shower gel, coffee maker
	product name		1	1	Binder, Café' in
	function/practical purpose		14	53	classification, decoration, communication
	functional property		23	15	stable, breathable, unbreakable, hermetic
	feature		98	90	
		functionality	29	19	video call, illumination, thermal isolation
		content	9	14	information, sport news, city map, horoscope
		sensory capacities	6	7	acceleration, voice recognition, heart rhythm
		composition/component	41	34	battery, arm, body housing, screen, handle
		technology	11	14	3G, Bluetooth, GPS, Wi-Fi
		position	2	2	inside, external
	intended character		109	76	
		affective	15	4	surprising, reassuring, pleasant, funny
		aesthetic	6	0	phantasy, pretty, aesthetic, elegant
		semantic	50	35	urban, sporty, masculine, industrial
		analogy/symbolic	24	31	monolith, pocketbook, water drop, cosmetic flask
		brand style/objective	9	2	internationality, innovation, rupture
		style	5	4	retro-cool, murdered-out
	sensorial property		5	11	warm, soft, hard, odoriferous
	static appearance / structural property		142	57	
		material	21	14	stainless steel, carbon, wood, cotton
		texture	5	2	grained, smooth, plaited
		viscosity/elasticity	1	1	flexible, stiff, ductile
		colour	31	11	white, red, dark blue, golden, elastomer
		graphic/detail/label	27	10	arabesque, little squares, floral
		form/geometry	45	12	asymmetric, curved, circular, straight
		dimensions/size/volume	11	4	compact, huge, long
		weight	1	3	ultra-light, light, weight-reduced
	behaviour/action		11	14	
		visual response	8	5	diagonal movement, reflection, rotation, light
		sonorous response	2	3	clack, creak
		tactile response	1	0	inertia, vibration
		olfactory/gustatory response	0	5	perfume, odour, taste
		response speed	0	1	quick
	production method	*fabrication, assembly, finishing*	16	7	injection moulding, weaving, engraving
	production quality	tolerances, finishing, ageing	0	0	
context			52	70	
	cultural factors/references		25	23	
		similar products/brands/activities	16	11	stationeries, Apple, athletics, architecture
		clichés/stereotypes	6	9	made in China, Tuareg, science fiction
		trends/fashions/tastes/conventions	3	3	tradition, fashion wear, fashionable
	situational factors		27	47	
		viewing time	0	0	
		related products/features/things	7	27	Facebook, soap, MP3 player, back pack
		place	9	8	bar, workshop, library, outdoors, street
		time	6	6	Sunday, summer
		event/activity	5	6	promenade, soccer,
	social factors		0	0	

We also see a lack of detail in the definition of product behaviour in the theoretical models. The models focus on visual properties. However, as stated in the introduction and seen in the designers' concept words, sonorous, tactile and olfactory/gustatory responses play an important role when designing for User Experience too.

Of the 5 dimensions that were not represented in practice, the sensory state, the perceived product character and the viewing time are outside of the designer's conception scope. He can work on the intended character and equip the product with certain sensory properties but he cannot know which sensory properties the user will experience and what character the user will really attribute to the product. Therefore these two can only be part of User Experience evaluations but not of concept generation.

Another dimension that was not found in the concepts was production quality. Instead of it production methods that are a similar dimension were added. It looks like instead of defining the production quality, designers are rather able to choose production methods to reach a certain product character. Social factors were another dimension missing in the concepts. They might be the most complex element of the use context and therefore difficult to anticipate by the designers.

The study enabled us to add precision to the list of dimensions. Table 14 shows the list that combines the dimensions from theory (study 1-A) and the findings from practice (study 1-B). All in all the totality of theoretical models was already close to an extensive view. This compilation can provide a useful base for design education.

From the result of study 1-B can be stated that design practice already addresses a large range of User Experience dimensions. But the two-part study (retrospective, part 1 and real-time, part 2) also showed that even though nearly all these dimensions find their way to the final product concepts (part 1), not all of them appear in the early design phase (part 2). As stated in the introduction, the earlier design amendments occur in product development, the less fatal their impact on development costs (Folkestad and Johnson 2001). That means what is needed now are design tools that help designers to handle these manifold dimensions from the early phases of design onwards. Observations made with the word map method in part 2, hint at one possible direction for such a design tool. In 4.3.2.7 the potential of word-based conception tools will be discussed.

4.3.2.6 LIMITATIONS

A wide range of words from retrospective verbal reports on real design concepts and from word maps on a fictitious concept could be extracted in this study. The words were classed into 53 design dimensions. In the studied projects' product features, intended character and static appearance were the most represented dimension groups. These results are complementary with those of our colleagues from a previous study (Kim et al. 2010). The obtained data shows tendencies in the occurrence of the design dimensions. The found proportions are likely to reoccur but the number of words is only representative for the regarded projects. If repeated on other projects the distribution will probably vary depending on the sector and type of the product.

The quantity of words expressed per dimension does not represent its importance to the designer because the level of granularity between the identified dimensions (Table 14) differs. While colours, values, or emotions represent a limited number of possible conditions (Kay et al. 1997; Rokeach 1973; Scherer 2005), the number of semantic descriptors is infinite. Process words could be further categorised into fabrication, assembly, and finishing but their occurrence in this study was too low to create relevant subcategories. There were very few words on style, but each of them forms an umbrella term that characterises several other dimensions. For example "murdered out" describes the colour black as well as a matte surface texture which represent coolness.

It is important to add that not all of the listed dimensions are relevant in every design project. Priorities have to be set according to the product type, the sector or the brand image.

4.3.2.7 Annotation: The potential of word-based design tools

During part 2 of the study the participants employed word mapping for their conception activity. All attendees responded to the brief: "A communicating coffee machine for Adidas". Here are two examples for the created concepts. Concept A) is a portable coffee machine module to be attached to a joggers arm. It communicates the exercise progress and uses the emitted body heat to make a fresh coffee at the end of the morning run. Concept B) is a community coffee machine for a sports club around which club members gather and get latest sport news over a coffee.

During the one hour of word mapping, six designers advanced with ease and arrived at one or two concepts. Two senior designers gave spontaneous feedback about this word-based method after the study was completed.

> Participant A: *"The words are a good start base. This helps to not overcharge the concept while defining the project parameters. When one limits himself to […] just a few words, one can focus on the concept. When you draw, you have to combine a lot of things immediately."*

> Participant B: *"This [the word-mapping method] seems very coherent to me and helps to define a maximum. […] this helps to find a more in depth answer than I would get, if I started directly with sketches for searching a solution. Generally, when one searches, one makes sketches of the product to see the consequence directly. For a task that seemed a bit absurd*

at the beginning, with looking for links one sees that one can actually propose something. It helps to deepen his reflection. "

Three (novice) designers reached a few different product ideas but did not reach one coherent idea in the course of the available hour. The two engineers on the other hand had difficulty with the word mapping method; they were able to define various product constraints but were not able to reach a final concept.

This observation leads us to assume that word maps can be a useful design tool, especially for experienced designers. They can stimulate the divergence of ideas and help them to generate a holistic product concept. However, it has limitations for professionals like engineers whose ideas tend to converge quickly. These findings are complementary with those of Kokotovich who had found that word based maps are a useful tool for students since they prevent a premature embodiment of ideas and leave more space for creative connections (Kokotovich 2008). Segers, Vries and Achten (2005) experimented with word-relations during architectural conception and saw their stimulating effect in the explorative design thinking part. Words can contribute to the conception process because they serve to quickly externalise memory contents. Associations are often triggers for new ideas (Segers, Vries, and Achten 2005). Lawson and Loke argue "that creative design may be as dependent on words as it is on pictures". Verbal descriptions leave room for interpretation which they consider suitable for the early conception (Lawson, Loke, and Tower 1997).

4.3.2.8 Conclusion of study 1-B

Studies 1-A and 1-B enabled us to establish an overview on dimensions that designers need to take into account when designing for User Experience. As stated in the main Hypothesis: **To design for User Experience, designers need to address a wide range of dimensions during early concept generation and evaluation.** The dimensions from design research in study 1-A cover both the concept generation and the evaluation of User Experience. The dimensions that were added from study 1-B come from the concept generation. Therefore a third investigation complements the two studies on User Experience dimensions. The goal of designing for User Experience is a positive experience of the target user with the final product. The following study 1-C therefore looks at properties of those various dimensions that users perceive and appreciate in final products.

4.3.3 Study 1-C: User Experience properties in final products as perceived by users

4.3.3.1 Objective

A great part of the compilation of dimensions from the literature review (study 1-A) has been found in designers' concepts (study 1-B) and further dimensions were added to the list. The objective of this third study (1-C) was to look at real user experiences with products in order to see which of the many dimensions users consciously perceive and appreciate through specific properties.

4.3.3.2 Method

This study was undertaken with two focus groups. In preparation of the study, the participants were asked to choose one or two products or objects which they associate with a positive User Experience. They had to bring the product or photos/videos of it to the focus group session. Each participant presented the object of his choice and explained his User Experience with it. The other participants (if possible) tried the object in action and then exchanged their impressions on it. About 10 min were spent on each object. The focus group sessions were video-taped. The accounts of the participants were transcribed. The answers to the following two points were extracted from the discourses: Which properties of the product or object were mentioned by the participants and which of them did they appreciate or dislike.

4.3.3.3 Participants

The focus group session was repeated two times, with one group of 5 persons (average age 28; 2 female, 3 male) and another group of 6 persons (average age 28; 1 female, 5 male). They were young university graduates.

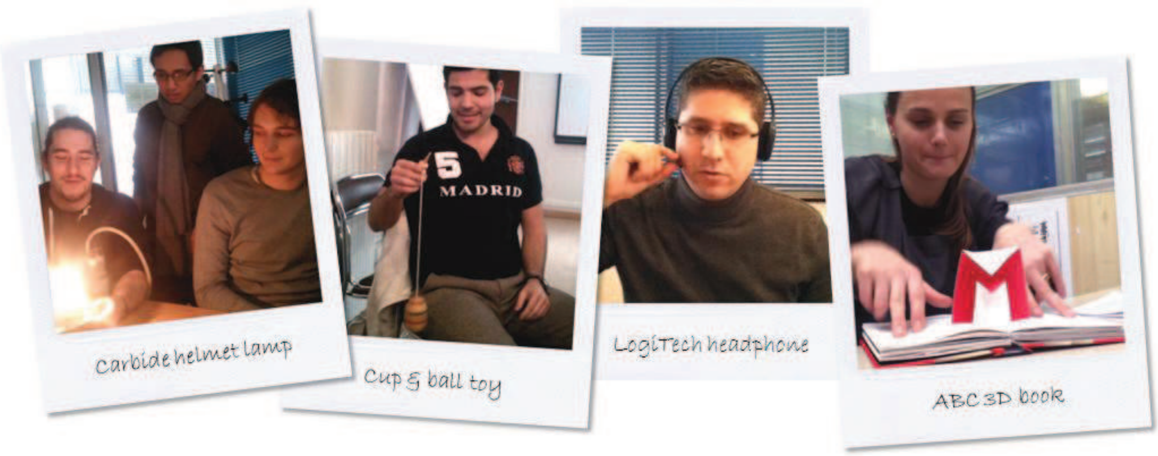


Image 63: Impressions from the focus groups.

4.3.3.4 Result

The users described the object(s) of their choice and their experience with it. There was for example the cup and ball toy. It consists of a stick and a ball with a hole, both connected through a string. The player holds the stick and makes the ball swing. The challenge is to place the ball on top of the stick. The participant described the object as easy to use but difficult to master. The player adjusts his body movement to the flying speed and direction of the ball. He remembered feeling strong frustration when it did not work, but high satisfaction and a sense of achievement when the ball was caught. An object from numeric art chosen by another participant is Bill Gaver's key table (Gavers et al. 2003: A table connected with to a picture frame. When your key hits the entrance table, a picture frame above it rotates by some degrees. The degree of rotation depends on the intensity of the impact (the key is gently placed versus thrown on the table). This way, the object captures and reacts on different moods of the user. The participant described it as a lifeless object that becomes animated. It reacts like a person. She liked that the object acts by itself without any pushing of buttons. And that it never moves the same way. She pointed at reports of users who adapted their behaviour to provoke a specific reaction of the picture frame.

In the participants' accounts appeared various properties that characterise user experiences with products. Table 15 assembles the evoked dimensions and properties (translated from French into English). The words marked bold reappeared for several of the 14 objects.

Table 15: Overview on dimensions and their properties evoked by users on their experiences with products. (nb) = number of products concerned out of 14.

dimension			properties identified in study 1-3
human			
	sensory system / state		**visual** (10), **tactile** (9), **auditory** (2)
	stable cognition & affect	motivations/values/ concerns/needs	**comfort** (3), preciousness (1), vintage (1), reliability (1), security (1), challenge (1), achievement (1)
	event dependent cognition & affect	core affect	**surprise** (4), **fun** (2), **amusement** (2), frustration that turns into satisfaction (1), **reassurance** (3), flow (1), addiction (1)
		perceived character	**diverting** (2), performing (1), **like an animate being** (3)
	motor system / state	actions/behaviours	sit down (1)
		interaction gesture	**push** (4), **throw** (3), **rotation** (2), **carry** (2), lift (1), pull (1), release (1), slide (1), zip/unzip (1), snap open/close (1), stroke (1)
		posture / body	attached to the body (1)
product			
	function/practical purpose		**illuminate** (3), **communicate** (3), **save** (2), navigate (1), divertissement (3), transport (1)
	functional property		**transportable** (2), **foldable** (2), **robust / unbreakable** (2)
	feature	functionality	compatibility with different systems (1)
		content	**different levels of difficulty** (2), spatial separation of contents (1)
		sensory capacities	different moods (1), intensity of impact (1), control with body movement (1)
		composition/component	multiple interaction modalities (1)
	sensorial property		**soft touch** (2), tactile comfortable (1), tactile marks (to find the buttons blindly) (1)
	static appearance / structural property	material	rubber (2), paper (1), textile (1), wood (1)
		viscosity/elasticity	pleating (1)
		colour	orange (1)
	behaviour/action		**random patterns / slightly varying responses** (5), movement fits characteristic of the material (1)
		visual response	**seamless transition** (2), interaction becomes invisible (1), luminous feedback (1), translation (1), rotation (1), slide out (1), fold/stand up (1), complexity of the movement (1)
		sonorous response	sound feedback on interaction (1)
		tactile response	change of surface quality on touch (1)
		response speed	position evolves steadily (1)

Compared to the dimensions in designers' concepts, we see that fewer dimensions were consciously perceived by the users. They did not mention many properties of appearance, but many that describe the product behaviour. Since users evaluated products in this study, one could see properties in the human sensory system and the perceived character of the product which naturally were not present in designers' concepts.

The participants liked when an inanimate object gave them the impression of becoming animate. Objects that reacted in a way that was not totally predictable were perceived as having "a soul". The users enjoyed being surprised by varying object responses and expressed a feeling of amusement. Despite the desire for some unexpectedness, the participants perceived combinations of multisensory responses (see/hear/feel) as reassuring. The behaviour of the object was compared to that of a human. Humans can predict certain aspects of each other's behaviour but never totally. To discover the interactive principle was considered as part of "the magic". Understanding the interaction principle was seen as a challenge. First trials often caused frustration but once mastered satisfaction. Complex movements from the object were also mentioned to be more interesting than simple ones. All of the chosen objects were manipulated through body gestures, many with the hands, some with the arms and a few with the whole body.

4.3.3.5 Discussion

The participants focused on describing product behaviours instead of product appearance. This result suggests that User Experience is more strongly caused by behavioural qualities than static appearances. However, the products that the participants chose to bring to the study were all rather well designed. An aesthetic appearance was therefore not evoked as particularly important for the User Experience but if it had been bad, the product would probably not have been chosen by the participants. Presumably, the quality of the appearance is unconsciously taken into account when users experience products. The behaviour is the more front-face experience, especially when technologies are employed that manage to surprise the users.

Users compared product behaviour to human (or animal) behaviour. To draw analogies with the known animate world seems a human instinct. The human tries to interpret new situations based on patterns that he already knows (Axelrod, 1973). Interactions cannot always be designed based on typical human behaviour. Yet analogies from the familiar physical world give orientation, as showed the success of the desktop metaphor for Xerox (Moggridge, 2007a). We saw that predictable behaviour is not necessarily what users enjoy. The notion of surprise appeared in many accounts of the participants. The results also confirm that amusing object behaviour or object responses that raise curiosity effectively engage users (Moggridge, 2007b). It is furthermore interesting for designers to know that humans like challenges (Shalom H Schwartz, 2009) and that even an experienced frustration will be appreciated once the person succeeds (Moggridge, 2007a). The human learns to understand an unfamiliar object by interacting with it (Russell, 2003).

Study 1-C showed that users today are familiar with various hand gestures to manipulate objects. History has shown that users are able to quickly adopt gestures from new media, like it was the case with the computer mouse (Moggridge, 2007a), the smart phone touch screen or the Wii gesture control. For the moment the used range of gestures is still limited. And motor controls, as characteristic for nearly all of the chosen products are not the only means to interact with objects. Physiological body responses can also be interaction triggers. As seen in the literature review (2.1.4.1), products can be equipped with a wide range of sensors that capture user actions and the surrounding ambiance. This is a great field of exploration for designers and design researchers.

4.3.3.6 Conclusion study 1-C

In this study users reported about their experience with products. Their accounts served to extract properties of User Experience dimensions that are consciously perceived and appreciated by users. Users mainly relate product behaviours, sensorial properties, use gestures, their own values and felt emotions with positive User Experience. The objective was to complete the overview on User Experience dimensions with the view point of the users.

4.3.4 Conclusion of study 1

This first set of studies had for goal to provide us with an overview on dimensions that play part in User Experience. In order to extract such information three populations concerned with the question were addressed: Design researchers, designers and users.

If one had simply asked users to describe User Experience, one would have only been able to extract consciously perceived properties. Design researchers accumulated a wider knowledge of dimensions that influence User Experience. Users only recognise many of those if they are not well designed. Study 1-A and 1-C showed that the range of dimensions that together create the User Experience is large. As shown in study 1-B, designers have knowledge of these dimensions. They even treat more dimensions than design researchers have so far mentioned in their models.

This validates the first part of the main hypothesis: **To design for User Experience, designers need to address a wide range of dimensions.** The second part of the main hypothesis is related to User Experience design **during early concept generation and evaluation.** We have seen in study 1-B that even though many of the dimensions are present in the final products, they are not all taken into account during early concept generation. The classical design tools have been conceived for form-giving. Now tools that allow generating User Experience concepts are needed. The method applied in study 1-B suggests that word-based tools that link design dimensions might be appropriate.

Moreover, study 1-C showed us that users particularly associate experiences with product behaviour and interaction gestures. As seen in the literature review, this is a so far little regarded field of User Experience evaluations.

The following two study sessions will therefore serve to explore specific tools for the generation and evaluation of User Experience in concepts and interaction gestures.

4.4 Study 2: Concept generation with/without Skippi - a word-link based Design Software.

4.4.1 Objective

The first set of studies investigated the range of User Experience Dimensions. This second study looks further into conception methods (Image 57). Sub-Hypothesis A states that **DESIGN TOOLS THAT EXPLICITLY ADDRESS THE KANSEI DIMENSIONS CAN HELP DESIGNERS TO GENERATE CONCEPTS WITH A STRONGER USER EXPERIENCE POTENTIAL.** The project Skippi (see 4.2) of which this thesis is part served to develop a software for early concept generation. Study 2 therefore takes the opportunity to test if a tool like Skippi has an impact on the User Experience value of designers' concepts. In order to evaluate the UX value of the generated ideas it was necessary to put an evaluation method for early concepts into place. Such a method would confirm the second sub-hypothesis 1-B that **UX EVALUATIONS CAN BE DONE ON EARLY DESIGN CONCEPTS.**

4.4.2 Method

4.4.2.1 The brief

The research question addresses the early stages of product conception. The study subject was therefore a fictive design brief: **TO DESIGN AN INTERACTIVE BAG FOR THE BRAND DIESEL** (see the precise instructions translated from French into English in the following box).

Design brief:

You are designer in a small design agency in Paris. Your boss seeks to broaden the scope of his clients to big brands. He recently learned that **DIESEL** wants to bring **WEARABLE TECHNOLOGY** into their products. He would like to exploit this opportunity to initiate a collaboration. Tomorrow he has the possibility to meet the artistic director of DIESEL during a fashion fair. To be prepared for this meeting he asks you to come up with some ideas for **AN INTERACTIVE BAG FOR DIESEL.**

4.4.2.2 The equipment

In order to evaluate the impact of the design tool Skippi, the study was undertaken with two conditions. Half of the participating designers worked with Skippi, the other half without.

The workspace was a desk equipped with a pile of white A3 paper sheets, colour pens, markers, pencil, rubber, sharpener, post-it notes. The participants of the work condition 'with Skippi' additionally had a laptop with the Skippi software running on their work desk (Image 64). The functionalities and interface of the software were explained to them beforehand.

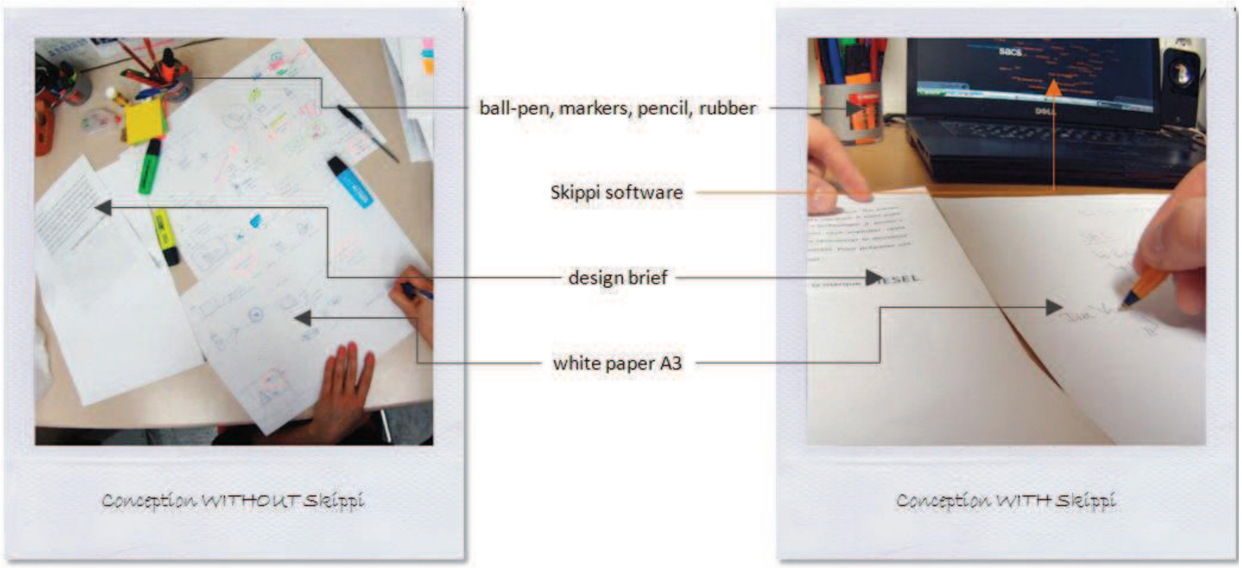


IMAGE 64: STUDY SETTING – LEFT CONDITION WITHOUT AND RIGHT WITH SKIPPI.

4.4.2.3 THE COURSE OF ACTION

4.4.2.3.1 DATA GENERATION

At the beginning the participants received a sheet with the brief (see the previous box). They were asked if they understood the brief and if they were familiar with the brand DIESEL. Each participant had up to 60 minutes to individually work on the brief. They could finish the activity at any earlier moment. Like Lim & Kim (2011) the choice of form of the output was left to the participant, in order to capture a realistic concept generation for each participant's individual work style.

After finishing the idea generation, the participants were asked to present their ideas and their approach. Their explanations were video recorded in order to capture the retrospective verbalisations and the sketches to which the explanations were related.

The participants who had worked under the condition 'with Skippi' were furthermore invited to fill in a questionnaire with the following questions:

- The frequency with which Skippi was used during the conception task (not at all / rarely / a few times / often / very often)
- Their general estimation of the impact of Skippi on their generated ideas, and more specifically on the criteria: originality, thoroughness, feasibility, practicality, and brand image (of DIESEL) (impact: not at all / very little / medium / strong / very strong)
- An estimation of the impact of Skippi on their approach / work style.

4.4.2.3.2 Data Treatment

The results were analysed on three levels:

i. the presence of UX Dimensions in the keywords from verbalisations and idea sheets
ii. the User Experience potential of the generated concepts through expert evaluation
iii. the subjective experience of the participants who had worked with Skippi

i. For a quantitative analysis of the word data, all debriefing interviews were transcribed analogous to study 1-B. All concept keywords from the verbalisations and those that were written on the participants' idea sheets were listed in an excel table. The words per participant were then classed into the dimensions from study 1-B (Table 14). The occurrence of the User Experience dimensions in the generated concepts was compared between the participants of the two groups (with/without Skippi).

ii. For a qualitative analysis of the generated concepts, two methods of idea evaluation were employed. In order to have comparable data all participants' representations were homogenised into idea sheets. The sheets were created using Adobe Illustrator while respecting the following constraints (see Image 65):

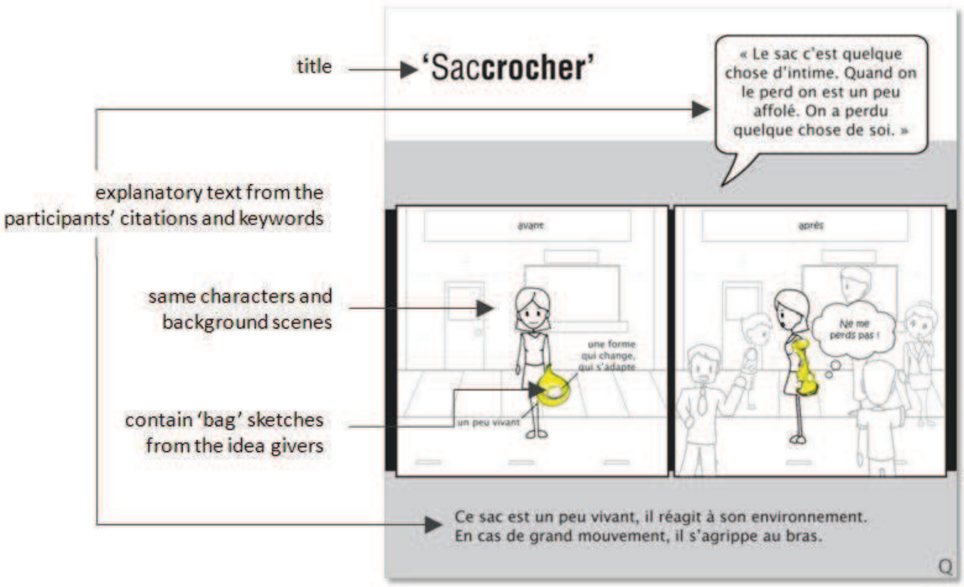


Image 65: 4 examples of the 29 idea sheets, study 2.

- Each scenario is constituted of an image (or image sequence) that illustrates the use situation.
- The same characters and background images were used for all participants' ideas.
- The scenarios contain sketches of the bag from those participants who had provided the idea. If no design was visualised a stereotype of a bag was used.

- Additionally to the image an explanatory text was added. It was composed from the participants' verbalisations and keywords on the work sheets.
- If several participants had had the same idea, it was represented with one single idea sheet.

The idea sheets were sent to the participants to validate the researcher's interpretation of their concepts. The validation happened via a web questionnaire in which they could see the sheet(s) with their idea(s) and answer if it corresponded to their intention on a 5-point Likert-Scale (from 'not at all' to 'totally'). They could communicate necessary amendments in a textbox.

The ideas were analysed on the more criteria: **UNIQUENESS** and **THOROUGHNESS** (Dean & Hender, 2006). As **UNIQUE** were considered ideas that appeared **ONLY ONCE** during the exercise (ideas that were not repeated by several participants). In the evaluation the number of participants per condition that created one or more unique ideas was counted. **THOROUGHNESS** of the proposal defines the degree of profoundness with which the idea had been treated by the idea giver. It was scored on the following scale:

0 = keywords only

1 = quick situation sketch

2 = product in situation sketch

3 = product in situation sketch with some information on technology, materials or another dimension

4 = product in situation sketch with definition of the essential dimensions

Furthermore an expert jury of 6 professionals from the design domain was constituted. The idea sheets were integrated in a web questionnaire. They evaluated each idea on a set of criteria. In order to define the evaluation criteria two sources were consulted: first of all the product properties that were evoked by multiple final users in study 1-C, secondly two members of the expert jury were asked to give their evaluation criteria with regard to the brief (before having seen the outcome of the participants). Table 16 shows how all gathered criteria were combined into seven evaluation criteria: **CORRESPONDENCE WITH BRIEF AND BRAND, USEFULNESS, PRACTICALITY, PLEASURE, DYNAMIC, ORIGINALITY,** and **FEASIBILITY.**

COMFORT, SENSORIAL QUALITY and **AESTHETICS** were not taken for two reasons: 1. Some of the idea sheets group very similar ideas of different participants. For these design specific information was lost through the homogenization. 2. Even in the original productions, the dimensions comfort, aesthetics or sensorial aspects were little represented at this early conception stage.

TABLE 16: EVALUATION CRITERIA FOR STUDY 2. (✓ = CRITERIA CHOSEN FOR THE QUESTIONNAIRE)

	totality of criteria	study 1-C	expert 1	expert 2	relevance for questionnaire	criteria in questionnaire *"The proposal…*
brand & brief	correspondence with the target user		x	x	✓	*…corresponds to the project brief and the brand image of DIESEL."*
	correspondence with the brand image		x	x	✓	
	correspondence with the brief		x	x	✓	
UX	utility		x	x	✓	*…is useful."*
	practicality/usability		x	x	✓	*…is practical."*
	User Interface/ assuring feedback	x		x		
	surprise / amusement / pleasure	x	x		✓	*…is pleasant for the user."*
	aesthetic / attractiveness		x			
	ergonomic / comfort	x	x			
	ecology		x			
	economy		x			
	sensorial quality	x				
	animated character (varying responses)	x			✓	*…is dynamic."* *(responds to user or environment)*
Implementation	Novelty / originality /idea impact		x	x	✓	*…is original."*
	Realism – feasible with appropriate means		x	x	✓	*…is feasible."*
	compatibility with other systems	x				
	Parisian touch (cosmopolitan, Latin)			x		

The members of the jury of experts received the questionnaire with the seven criteria. They were asked to evaluate the ideas on a 5-point Likert Scale (from 'not at all' to 'very much').

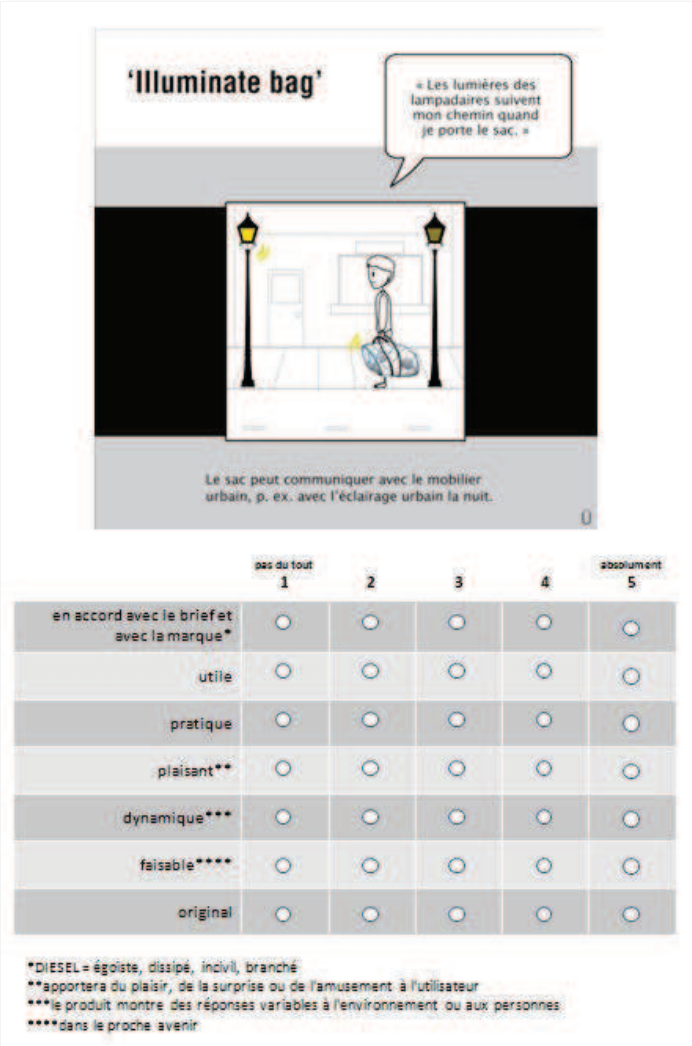


IMAGE 66: EXAMPLE OF THE EXPERT QUESTIONNAIRE, STUDY 2.

Each participant had produced a certain number of ideas. Since the jury rated each idea, the idea with the overall highest rating was chosen as reference value for this participant. This follows the assumption that the client (DIESEL) too would choose his preference from the presented ideas. From the example in Table 17 one can see that participant P1 produced idea 'C', 'D' and 'K'. Participant W03 too proposed idea 'C' and besides this 'A', 'N', 'U' and 'V'. The highest rated idea for participant P1 is 'C' with 25.4

points, the highest rated for W3 is 'N' with 25.7 points. These values went into the T-test and the average and error-type of the T-test are noted per criteria per group with/without Skippi.

TABLE 17: EXAMPLE OF THE EXPERT RATINGS, CHOICE OF HIGHEST RATED CONCEPT PER PARTICIPANT.

participant	idea code	C1 brief/brand	C2 useful	C3 practical	C4 pleasant	C5 dynamic	C6 feasible	C7 impact	sum 'UX value'
P1	C	4.1	2.3	3.3	4.9	4.5	2.2	4.1	25.4
	D	3.0	3.9	3.7	3.0	2.3	3.3	2.6	21.8
	K	2.5	1.3	2.3	2.0	2.7	1.3	3.0	15.1
W3	A	2	3	3	3	3	3.1	3.5	20.6
	C	4.1	2.3	3.3	4.9	4.5	2.2	4.1	25.4
	N	2.7	3.5	3.5	3.8	3.5	4	4.7	25.7
	U	1 .0	2.7	1.5	1.8	2.0	1.0	2.3	11.3
	V	3.1	2.5	2.8	2.3	3.5	3.7	3.0	20.9

iii. An additional set of qualitative data was directly extracted from the responses of the questionnaire that the participants, who had worked with Skippi, had filled in subsequently to the conception exercise.

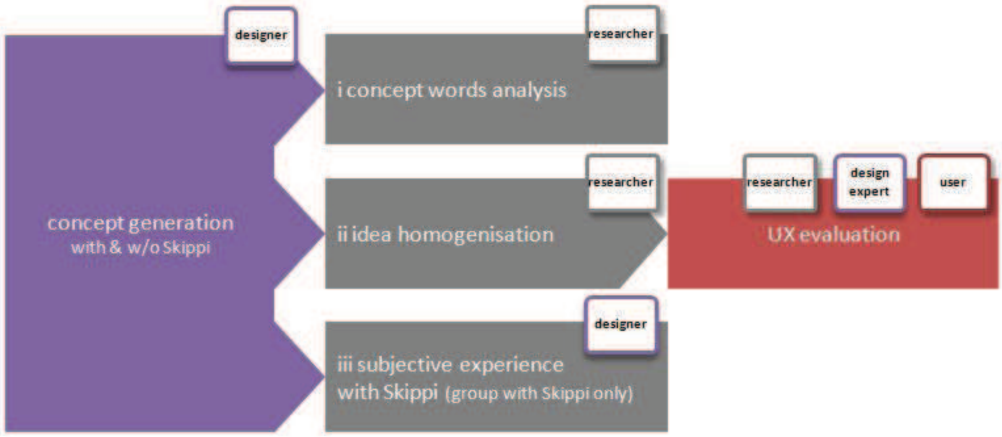


IMAGE 67: COURSE OF ACTION STUDY 2.

4.4.3 PARTICIPANTS

4.4.3.1 THE DESIGNERS

14 designers participated in study 2. They were divided into 2 groups of which one worked with Skippi and the other group without. The characteristic of each group was the following:

TABLE 18: PARTICIPANTS OF THE CONCEPT GENERATION EXERCISE IN STUDY 2.

	condition with Skippi	condition without Skippi
gender	2 female, 5 male	2 female, 5 male
average age	28 years	29 years
years of work experience	4 x 0-3 years (novice)	3 x 0-3 years (novice)
	1 x 3-5 years (junior)	2 x 3-5 years (junior)
	1 x 5-10 years (senior)	1 x 5-10 years (senior)
	1 x 10 years + (expert)	1 x 10 years + (expert)

4.4.3.2 THE JURY MEMBERS

6 experts in product design and 7 potential users were available to evaluate the participants' ideas through an online questionnaire.

TABLE 19: PARTICIPANTS OF THE IDEA EVALUATION IN STUDY 2.

	expert jury	user jury
gender	3 female, 3 male	4 female, 3 male
average age	36 years	31 years
years of work experience	4 x 5-10 years (senior) 2 x 10 years + (expert)	all university degree

4.4.4 RESULTS

4.4.4.1 GENERAL RESULTS

The participants chose to work between 30 and 58 minutes, on average 42 minutes.

The designers created their concepts through three types of intermediate representations (Image 68):

- idea sketches: one concept was represented through various detailed sketches and keywords (8/14 participants, 4 with and 4 without Skippi),
- use scenarios: various scenarios of different concepts were represented in quick sketches and keywords (4/14, 1 with, 3 without Skippi),
- word-maps: key words of ideas were listed in relation to each other, scenarios were evoked in the verbal discourse only (2/14, 2 novices with Skippi).

Some sheets figured all three types of representations, others only one.

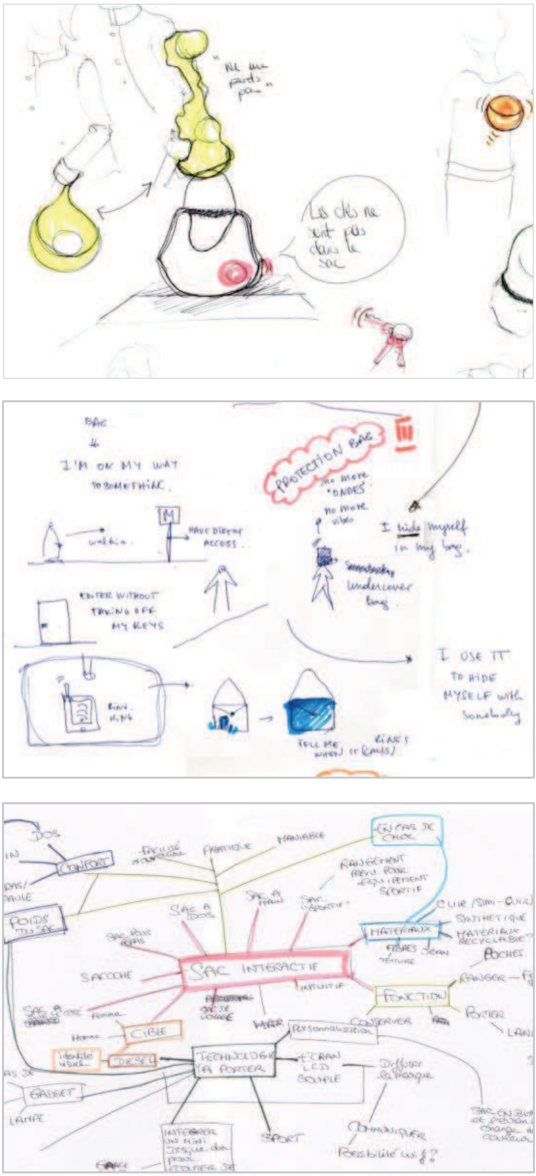


IMAGE 68: EXAMPLES OF THE THREE TYPES OF INTERMEDIATE CONCEPT REPRESENTATIONS CHOSEN BY THE PARTICIPANTS: SKETCH (FIRST), USE SCENARIOS (SECOND) AND WORD-MAP (THIRD).

4.4.4.2 QUANTITATIVE RESULTS: THE PRESENCE OF UX DIMENSIONS IN THE CONCEPTS

Skippi had no impact of the quantity of mentioned concept words. In average the participants with Skippi employed 48 words, without Skippi 53 words. The variation between the participants was higher than between the two groups. It ranges from 35 to 73 with Skippi and from 38 to 88 words without Skippi.

With Skippi word repetitions were lower than without. There are 50 words used more than once without Skippi and only 32 words with Skippi. The Skippi system therefore led designers to a higher variability in concept words.

Skippi had a slight impact on the design dimensions treated in the concepts (see Table 20). We see a shift from dimensions of 'static appearance' to dimensions of 'intended character/meaning' through the use of Skippi. Especially the 'semantic quality' increases. There is a slight decrease in the abstract dimension 'motivations/values/concerns/needs'.

The average word appearance of the participants who worked with Skippi resembles that of the word-mapping (communicative coffee machine for Adidas) from part 2 of study 1-B.

The brand ('DIESEL') is mentioned as a term on the sheets or in the verbalisations of all 7 participants who worked with Skippi and only of 2 participants without Skippi. 4 participants without Skippi talk about 'not forgetting something' (versus 0 with Skippi), 4 participants with Skippi mention 'RFID' (versus 1 without Skippi). Here Skippi helped to concretise an abstract idea into a solution because it includes information on technology, material, the brand, etc.

4.4.4.3 Qualitative results 1: Analysis of the Uniqueness and Thoroughness of the produced ideas

At this early stage of conception one rather sees ideas and not yet concepts. An idea addresses only few dimensions; a concept is more complex and already addresses several dimensions. 58 ideas were identified as the sum of all participants. The participants without Skippi produced on average 4.7 concepts per person, those with Skippi 3.6 concepts per person (Image 69). The standard deviation in the group without Skippi is more than 3 times higher than of the group with Skippi.

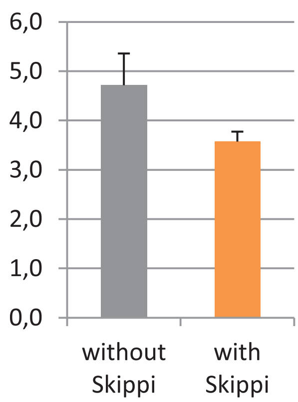


Image 69: Average number of ideas per group without (left) and with Skippi (right).

The 58 ideas could be grouped into 29 discrete ideas. That means a concept like 'a bag that adapts its pattern to the wearer's mood' that appeared in the concept sheets of 7 participants (4 without/ 3 with Skippi) was considered as one single discrete idea.

TABLE 20: DESIGN DIMENSIONS IN THE CONCEPTS OF STUDY 2 CONDITIONS WITH AND WITHOUT SKIPPI, AND COMPARED TO STUDY 1-B, PART 2.

dimension		study 2 WITHOUT Skippi words per person	study 2 WITH Skippi words per person	study 1-B part 2 words per person
human		10.5	7.8	8.1
target user		2.7	2.2	2.3
	single / group	0.2	0.2	0.8
	occupation	0.7	0.3	0.7
	age	0.5	0.8	0.6
	gender	0.7	0.3	0
	cultural background/living environment	0.7	0.5	0.1
	personal taste / aesthetic sophistication	0	0	0.2
sensory system / state		0	0	0
stable cognition & affect		5.2	2.5	2.9
	cognitive contents (knowledge, experience/memories)	0	0	0.1
	personality / disposition	1.2	0.5	0.3
	motivations/values/concerns/needs	4	2	2.5
event dependent cognition & affect		0	0	0
	core affect	0	0	0
	perceived character	0	0	0
motor system / state		2.7	3.2	2.9
	actions/behaviours	1.3	0.8	1.7
	interaction gesture	0.8	0.7	1.0
	posture / body	0.5	1.7	0.2
product		29.2	28.3	32.7
product sector		0.3	0	0.1
product type		1	1.7	0.2
product/brand name		0.5	1	0.1
function/practical purpose		1.3	1.7	5.3
functional property		1.3	1.7	1.5
feature		10.3	11.2	9.0
	functionality	3.3	2.7	1.9
	content	1.2	1.7	1.4
	sensory capacities	1.7	3.5	0.7
	composition/component	2.5	2.3	3.4
	technology	1.2	0.3	1.4
	position	0.5	0.7	0.2
intended character		4.5	6.7	7.6
	affective	0.7	0.8	0.4
	aesthetic	1.2	0.8	0
	semantic	1.3	3.5	3.5
	analogy/symbolic	0.7	0.8	3.1
	brand style/objective	0.5	0.3	0.2
	style	0	0	0.4
sensorial property		0.2	0.3	1.1
static appearance / structural property		7	4.2	5.7
	material	0.7	2	1.4
	texture	0.3	0	0.2
	viscosity/elasticity	0.7	0.5	0.1
	colour	1.7	0.7	1.1
	graphic/detail/label	0.8	0.5	1.0
	form/geometry	0.8	0.2	1.2
	dimensions/size/volume	1.8	0.2	0.4
	weight	0.2	0	0.3
behaviour/action		2.7	1.5	1.4
	visual response	2.2	0.8	0.5
	sonorous response	0.2	0.5	0.3
	tactile response	0.2	0	0.0
	olfactory/gustatory response	0	0.3	0.5
	response speed	0	0	0.1
production method	*fabrication, assembly, finishing*	0.2	0	0.7
production quality	tolerances, finishing, ageing	0	0	0
context		14	13.3	7.0
cultural factors/references		1	1.7	2.3
	similar products/brands/activities	1	0.5	1.1
	clichés/stereotypes	0	0.2	0.9
	trends/fashions/tastes/conventions	0	1	0.3
situational factors		12.3	10.8	4.7
	viewing time	0	0	0
	related products/features/things	7.3	5.8	2.7
	place	2.7	1.2	0.8
	time	0.3	0.3	0.6
	event/activity	2	3.5	0.6
social factors		0.7	0.8	0

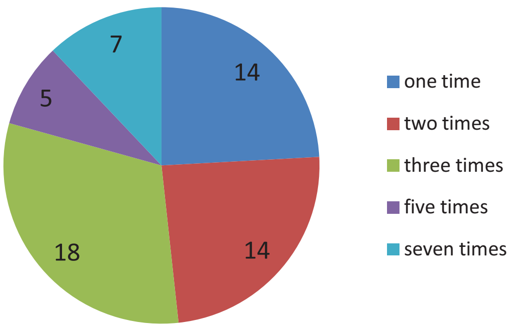


IMAGE 70: OCCURRENCE OF UNIQUE AND REPEATED CONCEPTS IN TOTAL (58 CONCEPTS / 14 PARTICIPANTS).

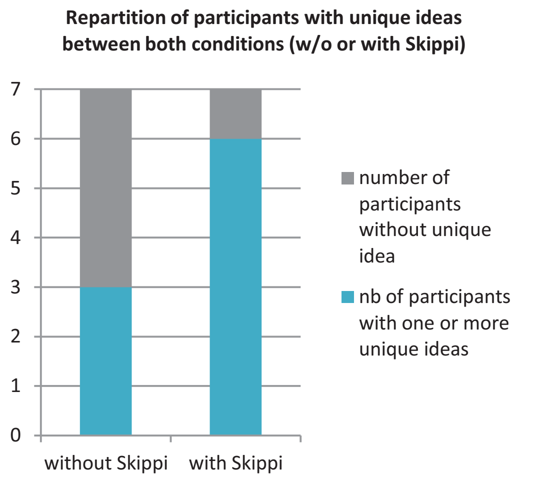


IMAGE 71: DISTRIBUTION OF PARTICIPANTS WITH UNIQUE IDEAS VERSUS PARTICIPANTS WITHOUT UNIQUE IDEAS BETWEEN THE TWO CONDITIONS W/O SKIPPI AND WITH SKIPPI.

Among the 58 ideas, one idea occurred in the production of 7 participants, another idea was given by 5 participants, six ideas were mentioned by 3 participants, seven ideas by 2 participants and fourteen ideas that were unique (=29 ideas) (Image 70). An analysis of ideas per participant showed an advantage for the group who worked with Skippi. In this group 6 out of 7 participants came up with one or more unique ideas. Without Skippi only 3 out of 7 designers had one or more unique ideas (Image 71).

In order to compare the thoroughness of the productions, each idea was evaluated on the level of detail with which the idea giver had illustrated this idea (based on the scale in 4.4.2.3.2). The idea with the highest thoroughness score per person was taken as reference value. Overall one can conclude that there is a higher level of thoroughness in the productions with Skippi. 5 participants without Skippi handed in propositions on a level of 1 (quick situation sketch) and 2 participants on level 2 (product in situation sketch).

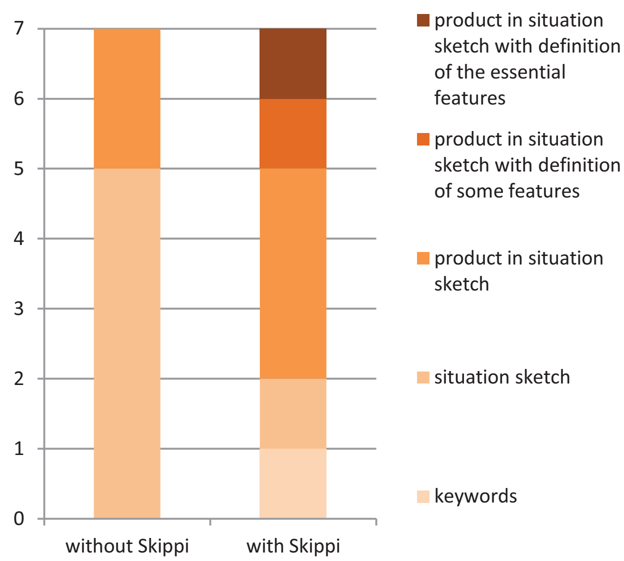


IMAGE 72: DISTRIBUTION OF THE LEVELS OF THOROUGHNESS BETWEEN THE TWO CONDITIONS W/O SKIPPI AND WITH SKIPPI.

Under the condition with Skippi there are 1 participant with level 0 (keywords only), 1 with level 1 (quick situation sketch), 3 with level 2 (product in situation sketch), 1 with level 3 (product in situation sketch with some feature information) and 1 with level 4 (product in situation sketch with definition of the essential dimensions).

4.4.4.4 Qualitative results 2: Expert and user evaluations of the UX potential of the ideas

In order to evaluate the quality of each participant's production their data was harmonized into idea sheets as explained under 4.4.2.3.2 and evaluated by a jury of experts and a jury of users. The jury of experts reached an agreement in their evaluations of the 29 idea sheets (alpha Cronbach = 0.713, all correlation values are different from 0 with a significance of alpha=0.05p). The UX ratings do not show any significant difference between the two conditions without and with Skippi on the criteria 'fit with brief and brand' ($t(12)=-0.554$, $p=0.590$), 'pleasant' ($t(12)= 0.274$, $p=0.789$), 'dynamic' ($t(12)=-0.576$, $p=0.575$), 'feasible' ($t(12)=1.212$, $p=0.249$) and 'original' ($t(12)=1.034$, $p=0.322$). The difference is significant for 'useful' ($t(12)=3.525$, $p=0.004$) and 'practical' ($t(12)=3.673$, $p=0.003$) where the participants of the group without Skippi performed better than those of the group with Skippi.

The jury of potential users arrived at very similar evaluation scores. The accordance between the users is alpha Cronbach = 0.697. The user's UX ratings too do not show any significant difference for the criteria 'pleasant' ($t(12)=1.067$, $p=0.307$), 'dynamic' ($t(12)=0.798$, $p= 0.440$), 'feasible' ($t(12)=-0.243$, $p=0.812$) and 'original' ($t(12)=0.466$, $p=0.650$). A slight difference can be found for 'fit with brief and brand' ($t(12)=-2.850$, $p=0.015$) where the group with Skippi performed better than the group without. A significant difference appears for 'useful' ($t(12)=4.778$, $p=0.000$) and 'practical' ($t(12)=5.219$, $p=0.000$) where the participants of the group without Skippi performed better than those of the group with Skippi.

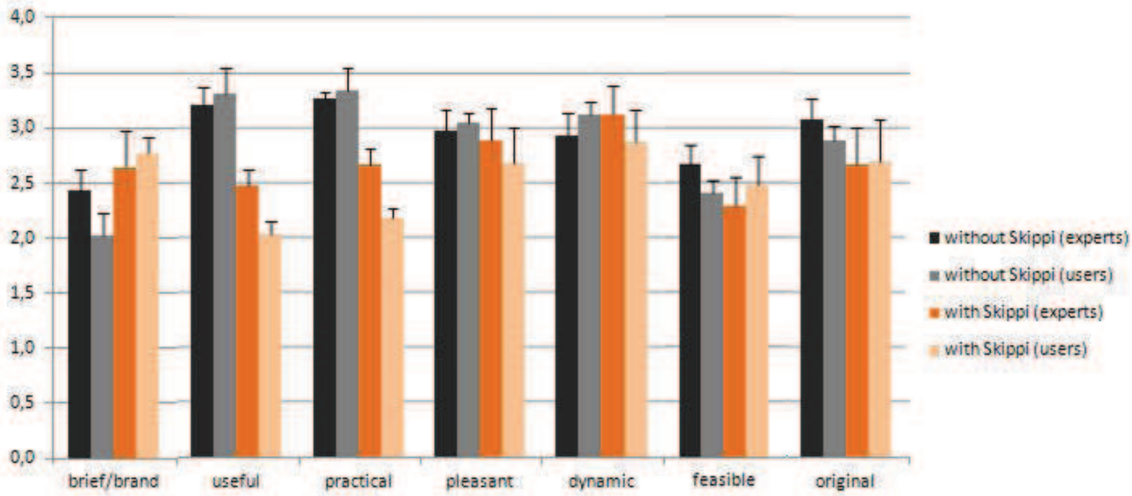


Image 73: Results of the expert and the user jury evaluation on the seven UX criteria.

If we compare the ratings of the experts with those of the users we see that on nearly all criteria the expert rating scores are higher than the user ratings. The agreement between the users and the experts is high (alpha Cronbach = 0.821). The user and the expert ratings don't show any significant difference on 6 out of the 7 criteria: 'fit with brief and brand' ($t(11)=-0.113$, $p=0.912$), 'practical' ($t(11)=1.319$, $p=0.214$), 'pleasant' ($t(11)=0.973$, $p=0.369$), 'dynamic' ($t(11)=0.349$, $p=0.733$), 'feasible' ($t(11)=0.794$, $p=0.444$) and 'original' ($t(11)=-0.447$, $p=0.664$). Only the agreement on 'useful' is not sufficient between the experts and the potential users ($t(11)=1.563$, $p=0.146$).

For the inter-accordance of the two groups (experts and users) per idea we see that the experts agreed on 16 of 29 ideas (12x alpha Cronbach>0.7, 4x alpha Cronbach>0.6) and that they were totally discordant on 2 ideas (alpha Cronbach<0). The user jury agreed on 20 ideas (16x alpha Cronbach>0.7, 4x alpha Cronbach>0.6). They too totally disagreed on 2 ideas (alpha Cronbach<0). However, the 2 ideas of disagreement were not the same between the 2 groups. And of those with accordance only 7 are identical between the experts and the users. Despite the gap between the ideas on which experts and on which users agree, their overall judgements reach the same best rated idea for 11 out of the 13 designers. In the case of the 3 designers for whom the best idea rated by experts and by users was not the same, it was always the idea that had reached the highest for one and the second highest score for the other group.

4.4.4.5 Self-reports of the Skippi Users

All 7 participants who had worked with Skippi filled in a questionnaire after completing the study brief. They indicated that they had used Skippi often (5/7) or at least a few times (2/7). They mentioned two use objectives. They first used Skippi to find inspiration words. To do so, they searched words that were related to their own brainstorming and to words from the brief (7/7). In a second time, they used Skippi to fine-tune the concepts with forms and materials (2/7).

Six out of the seven participants said that Skippi had an influence on their generated concepts. They mentioned that the words proposed by Skippi made them think in a direction that they would not have thought of by themselves (6/7). They appreciated furthermore that it linked new ideas with their own (2/7). More precisely they felt that Skippi had a medium impact on the originality (3 on a scale of 5), practicality of their concepts (3 on a scale of 5), as well as on their consideration of the brand image (3.3 on a scale of 5). On average they also stated a slight impact on thoroughness and feasibility (both 2.6 on a scale of 5). A comparison of the self-evaluations with the data analysis and the highest scores per criteria from the expert evaluations we see that participants P2 and P7 (both junior level designers) identified an impact of Skippi that is also reflected in the external evaluations. For the other participants the concurrency varies. The impressions of P1 and P6 (novice designers) fit on most criteria, except 'thoroughness'. P3 (novice), P4 and P5 (both design experts) are rather distant from the judgements that the jury gave their ideas.

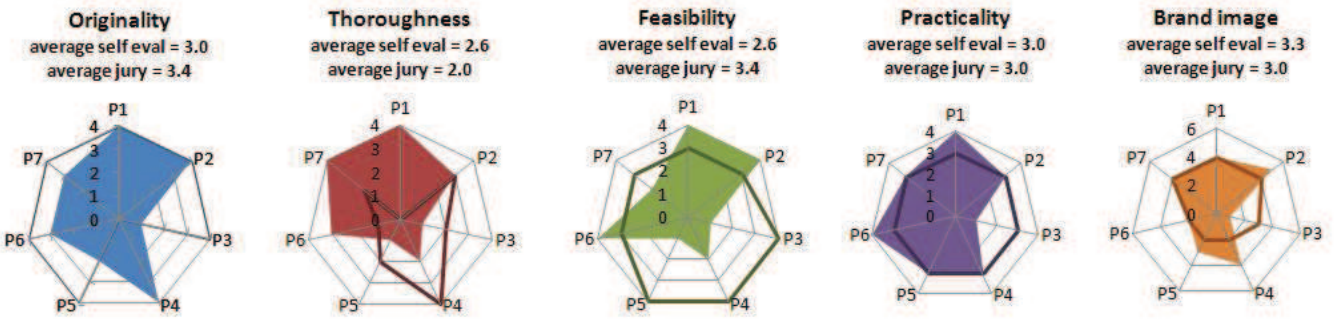


IMAGE 74: SELF-REPORTED IMPACT OF SKIPPI ON THE GENERATED IDEAS (FILLED) COMPARED WITH MAXIMUM SCORES FROM THE EXPERT EVALUATION (LINE) PER PARTICIPANTS P1 TO P7 OF CONDITION WITH SKIPPI.

A slight impact on their work approach was recognised by five of the seven participants. One of seven said it had a great impact, one other said it had no impact on his work style. Rather than changing the work approach it "*opens the horizon for unexploited potentials and accelerates the ideation by stimulating the imagination through the proposed words*" (P1). Skippi "*facilitates brainstorming*" (P3) and brings an "*impersonal viewing point, that means a certain detachment*" of the designer from the subject (P6).

4.4.5 DISCUSSION

The results of study 2 will be discussed with regard to Sub-Hypothesis A and B. First of all the impact of the tool Skippi on the concept generation (H-A) is discussed. In a second time the evaluation of User Experience applied on early concepts (H-B) is analysed.

4.4.5.1 THE IMPACT OF SKIPPI ON CONCEPT GENERATION

Like in Lim and Kim (2011), the same types of concept representations appeared: 1) idea sketches, 2) concept words / descriptions, and/or 3) scenarios of the use situation (Y. Lim & Kim, 2011)

The ideas generated with the help of Skippi did not show a higher User Experience potential. Sub-hypothesis A can therefore not be validated. Nevertheless, an impact of Skippi on the proposed concepts could be observed. Skippi lead the designers to more thoroughly worked concepts and more unique ideas. Furthermore a wider range of User Experience dimensions appeared in the productions of the participants who had worked with Skippi. However, 2 design novices who worked with Skippi created pure word-maps. This might have been directly caused by the use of the tool and it points at a risk of the tool. Skippi does not replace the classical design skills. It should only be used as an additional tool to enhance the creative production.

An interesting observation is related to the originality/uniqueness of the proposed ideas. On the one hand an objective idea count was undertaken to identify the number of unique ideas per participant.

On the other hand, the juries too were asked to evaluate the originality of the ideas. Here a great discrepancy could be seen. Some of the ideas that both juries rated as very original actually appeared in the productions of several participants. They were therefore not as original as they seem. The best example here is the idea of the 'chameleon bag' that scored 3.6 for the users and 3.5 for the experts on the criterion originality. The idea for such a bag was given by 7 out of the 14 participants. It was the least unique idea of all. An assumption to explain this phenomenon is that this idea has already appeared in movies, art, or other non-everyday life worlds. It is already imaginable in all our minds. But it is something that does not exist yet, and therefore seems original. We expect to see it soon. So the idea itself is not unique but to propose it as a well-fitting answer to a real world brief might be considered as original by the people.

4.4.5.2 UX evaluation of early concepts

The second objective of study 2 was to apply UX evaluations on early design concepts (Sub-Hypothesis B). A jury of design experts and a jury of potential users evaluated the 29 ideas sheets on 7 UX criteria. Both juries arrived at a high level of agreement for 6 out of the 7 UX criteria; only 'usefulness' was rated differently by both juries. For most criteria the user jury was more exigent than the expert jury. 6 experts were needed to achieve a good agreement level. For users slightly more people seem necessary to arrive on the same level of coherent score repartition (alpha Cronbach > 0.7).

The coherence between the evaluations of the experts and the potential users was rather unexpected. Professionals were expected to be able to judge such early design proposals. But even users with very different backgrounds were able to imagine the future product and to reach the same conclusions as the experts and the other potential users. This confirms the findings of an older study where researchers could show that design students and users judge designs along similar dimensions (Smets & Overbeeke, 1995).

The results strengthen the Sub-hypothesis B that it is indeed possible to evaluate the User Experience potential of a product at a very early concept stage. It furthermore indicates that such an evaluation can be done by both, experts or a bigger group of potential user. The potential users might be even more discerning than the experts concerning the quality of the proposed ideas on the UX criteria.

The applied concept evaluation method has two limitations. Firstly, the produced ideas had different levels of thoroughness. In order to compare the propositions, the distinct ideas have to be put on the same informational level. This requires a certain amount of design work from the researcher or the designers. This extra design work might serve the designers to formalise their ideas and to simultaneously create communicable material. But the question that only design practice can answer is: to which extent is this extra effort justified and reasonable?

The second limitation is related to the scale of 10 UX criteria: **CORRESPONDENCE WITH BRIEF AND BRAND, USEFULNESS, PRACTICALITY, PLEASANTNESS, DYNAMIC, ORIGINALITY, FEASIBILITY,** as well as **COMFORT, SENSORIAL QUALITY** and **AESTHETIC.** This set of 10 UX evaluation criteria for early concepts seems a good starting point. However, it is not always possible to evaluate all these 10 criteria. With regard to the intrinsic information of the idea representations, the criteria that are applicable need to be chosen out of the 10. In the case of this study **COMFORT, SENSORIAL QUALITY** and **AESTHETICS** were difficult to evaluate from the ideas sheets. And even though the juries did an evaluation on **PRACTICALITY**, it is not sure that the informational value of the presented ideas on this dimension was sufficiently high. When the experts and users evaluate early concepts on these criteria, they evaluate the potential of the idea and complete the presented idea with their own imagination. Nevertheless, one can assume that a concept with a high UX potential is well positioned to become a product with a good UX. But the following cycles of concept refinement can strengthen or weaken the UX value of the final product. In this thesis only the possibility for the evaluation of early concepts was assessed. Further research is needed to ensure that this UX potential stays along the conception process. Concepts should therefore be re-evaluated on the chosen criteria after each generation cycle.

4.4.5.3 LIMITS OF WORD-BASED DESIGN RESEARCH METHODS

Study 1-B, 1-C and study 2 apply word analysis (from verbalisations, word maps and keywords) as a means to access information in design concepts. These studies show that the method serves to extract information on design concepts that cannot be communicated through sketches. However, we also see that this method is only practicable for qualitative research but not for quantitative comparisons between different projects. The fact that some dimensions appear often in one project and little in another might be caused by the nature of the project or the stage of development during which the analysis was done. However, the method of word analysis can be used to compare the production of participants who worked on the same brief.

4.4.6 CONCLUSION OF STUDY 2

The first objective of study 2 was to test if the word-link-based Design tool 'Skippi', that explicitly addresses the Kansei dimensions, leads designers to generate concepts with a stronger User Experience potential (Sub-Hypothesis A). The tools Skippi shows an impact on early product concepts in form of enhanced uniqueness and deeper thoroughness of the early production. However, the study did not confirm an impact of Skippi on the User Experience potential of the concepts generated with the help of this tool. Sub-hypothesis A is therefore not validated.

Study 2 allowed showing that **IT IS POSSIBLE TO APPLY UX EVALUATIONS ON EARLY DESIGN CONCEPTS**. This validates the Sub-Hypothesis B. To do so a set of 10 UX criteria was proposed: **CORRESPONDENCE WITH BRIEF AND BRAND, USEFULNESS, USABILITY, PLEASURE, DYNAMIC, ORIGINALITY, FEASIBILITY,** as well as **COMFORT, SENSORIAL QUALITY** and **AESTHETICS.** However, it is not always possible to evaluate early concepts on all these 10 criteria since the representations do not always contain information on all of them. The applicable criteria need to be chosen before conducting the evaluation.

According to the results, evaluations can be undertaken by design professionals as well as by a panel of potential users. However the evaluation material (the representations of the concepts) needs to be homogenised, if a comparison between various concepts is the objective of the UX evaluation.

4.5 Study 3: Gesture generation through body storming and UX evaluation of the generated gestures

4.5.1 Objective of study 3

In the preceding two studies, we came across user experiences that were strongly driven by dynamic product properties like the modes of interaction. One limitation of current research on User Experience is the focus on properties of product appearance. This third study therefore had for objective to test a design tool adapted for the gesture dimension that helps designers to generate interactions with a strong UX (Sub-Hypothesis A) and that it is possible to apply UX evaluations to dynamically changing dimensions like interaction gestures (Sub-Hypothesis B) (Image 57).

4.5.2 Global Method

The proceeding of the study is here presented divided into two parts. First study 3-A describes the method employed for the generation of interaction gestures. A set of the generated gestures was then implemented in the Skippi prototype and in study 3-B a procedure was put into place to evaluate the users' experience with the generated interaction gestures, and thereby their generation method.

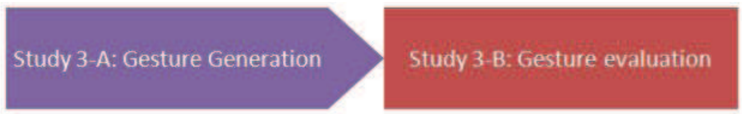


Image 75: The two parts of study 3.

4.5.3 Study 3-A: Gestures generation through body storming

4.5.3.1 Objective

This study has for objective to test the tool 'body storming' for the generation of interaction gestures. Sub-hypothesis A assumes that tools that explicitly address a specific Kansei dimensions, like gestures, can help designers to generate products, here interactions, with a stronger User Experience.

4.5.3.2 Method

If innovative ideas are sought, conception teams today often initiate brainstorming session. The technique has become commonly known and is widely employed. However, it has a weak point when it comes to define dynamic behaviour. An idea noted on a sheet can hardly express a sequence of activities. Movements of dancers and mimic actors have already been the source of inspiration for gesture design (C. Hummels & Stappers, 1998; Caroline Hummels, Overbeeke, & Klooster, 2006). In this study, we therefore propose a brainstorming that captures movements – the body storming. The technique of body storming has been employed previously by researchers and practitioner. However their purpose so far has been to act out roles in order to understand use contexts or people's behaviours (IDEO, 2013; You, Chen, & Deng, 2013). In this case the body storming served the generation of gesture sequences.

The interaction gesture generation in this study had four stages: 1. A creativity session in which the gestures were generated, 2. a UX rating session in which the ideas where sorted on their pertinence and 3. a feasibility session. The chosen gestures were then 4. implemented in the Skippi prototype.

IMAGE 76: COURSE OF ACTION STUDY 3-A.

1. **THE CREATIVITY SESSION** took half of a day. It started with a presentation of the latest version of the Skippi prototype. This was followed by the body storming. About 70 labels with the functionalities of Skippi were lined vertically on both sides of a white board. The participants were invited to mimic gestures for one functionality after another. The movement sequences were photographed with the cascade function. After mimicking, the idea contributor sketched the movement with an explanatory legend on a post-it note that was stuck next to the functionality label. The body storming took about 60 minutes. In a third step half of the participants refined the ideas from the post-it notes on A3 sheets with sequence sketches, arrows and legends. This took about 2 hours. After the creativity session, the refined sheets were properly redrawn as Adobe Illustrator images.
2. **THE UX RATING SESSION** was based on the Adobe Illustrator images. Here again members of the Skippi development team gathered to rank the generated gestures per functionality on their User Experience potential. Thereby the following criteria were applied: **PLEASANTNESS, DYNAMIC/FLUIDITY** of the movement, and **AFFORDANCE** of the gesture. The ranking happened whether on accordance of all members or on votes if no accordance could be found. Feasibility concerns were deliberately excluded during this rating session. It took 2 hours.
3. **THE FEASIBILITY SESSION** was conducted as a third step during 2 hours. The team met again and, on advice of a programmer, assessed the necessary means and time effort for the implementation (-2 very difficult, -1, 0, 1, 2 easy) of each gesture. In order to reach a quick implementation, a compromise between the highest rated gestures and the implementation complexity led to the selection of six gestures for the first gestural prototype of Skippi.
4. **THE IMPLEMENTATION** of the gestures was undertaken by one programmer. As medium, were chosen a vertical wall-mounted screen and the Kinect (Microsoft, 2013) as motion capturing device.

Image 77: Photo sequences of 3 gestures from the body storming during the creativity session.

4.5.3.3 Participants

Research suggests that a large group of average users is helpful to define simple interaction gestures; but that a small group of experts may come up with more diverse gestures; even though they might be less intuitive (Kühnel et al., 2011). The participants of the four stages of interaction gesture generation were all professionals and members of the Skippi development team. They had good knowledge of the software and its development stage at the time of the sessions. The group was constituted of experts in design, engineering and informatics. The following table gives details of the constitutions of the groups per session.

Table 21: Participants of the 4 stages of study 3-A.

	creativity session	UX rating session	Feasibility session	Implementation
gender	3 female, 5 male	3 female, 3 male	3 female, 2 male	1 male
years of work experience	2 x 3-5 years (junior)	1 x 0-3 years (novice)	1 x 0-3 years (novice)	1 x 5-10 years (senior)
	3 x 5-10 years (senior)	3 x 5-10 years (senior)	3 x 5-10 years (senior)	
	3 x 10 years + (expert)	2 x 10 years + (expert)	1 x 10 years + (expert)	
expertise	4 x Design	3 x Design	2 x Design	1 x Informatics
	3 x Informatics	2 x Informatics	2 x Informatics	
	1 x Engineering	1 x Engineering	1 x Engineering	

4.5.3.4 Results

In this study the technique of body storming was experimented for the generation of interaction gestures for 70 functionalities. The body storming generated 122 gestures (Image 78), with 1 to 8 ideas per functionality. The gestures were expressed in 3D with total freedom for hand, arm and body movements.

The generated gestures could be classed in different ways. A first distinguishing point is the body parts required for the gesture. Since the gestures were envisioned for a Virtual Reality environment, they range from **ONE FINGER** (9 gestures), **TWO FINGERS** (3 gestures), **ONE HAND** (28) or **BOTH HANDS** (30), to gestures of the **HANDS IN CONNECTION TO THE HEAD** (20), movements of the **HEAD** (2), movements of the **UPPER BODY** (24), and gestures that involve the configuration of **ALL BODY** parts to each other (6 gestures).

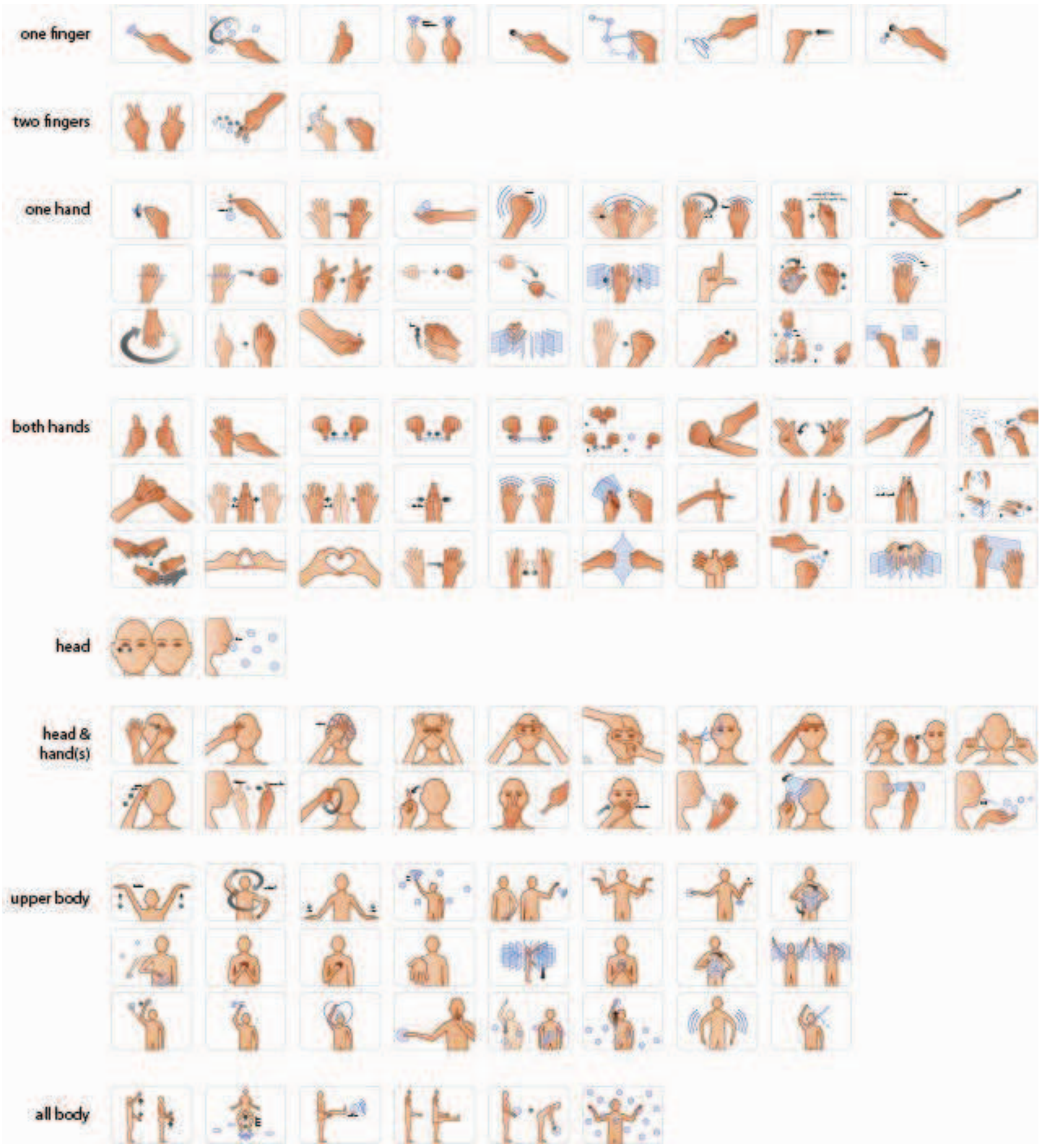
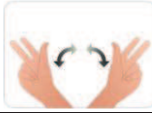


IMAGE 78: ALL 122 GESTURES GENERATED THROUGH BODY STORMING DURING THE CREATIVITY SESSION.

Another way to class the ideas was inspired by the work of Wobbrock and colleagues. They propose a taxonomy of **FORM** (static versus dynamic; static is a pose, dynamic is a pose with a trajectory (Bordegoni & Hemmje, 1993)), **NATURE** (symbolic, metaphoric, physical, abstract), **FLOW** (continuous or discrete) and **BINDING** (reference of the gesture to environment) (Wobbrock, Morris, & Wilson, 2009). The gesture base was analysed on the first three. The creativity session generated 29 **STATIC** gestures and 93 **DYNAMIC** gestures. Of the dynamic gestures 28 are of **DISCRETE** and 65 of **CONTINUOUS** flow. Looking at the nature of gestures we find 34 **SYMBOLIC** gestures like 'thumbs up' to indicate 'preferences', 40 **METAPHORIC** gestures like a spiral finger movement that resembles a hurricane for the functionality 'randomise the visualisation', 43 **PHYSICAL** gestures like 'kick a word' to delete it from the screen and 5 **ABSTRACT** gestures. Table 22 shows the types of classifications with their occurrence and examples. The gestures of the class **NATURE – PHYSICAL** are mostly gestures adapted from already known physical or virtual interfaces, like tap with a finger to activate an element.

TABLE 22: CLASSIFICATION OF THE GENERATED GESTURES.

		example	occurrence
Form	*static*		29
	dynamic		93
Flow	*continuous*		65
	discrete		28
Nature	symbolic		34
	metaphoric		40
	physical		43
	abstract		5

A Factor Analysis of the gesture classification shows a significant positive correlation between **PHYSICAL** and **ONE FINGER, PHYSICAL** and **ALL BODY** and **METAPHORICAL** gesture done with the **HEAD.** There is a significant negative correlation between **PHYSICAL** and **HEAD & HAND**. We also see that **HEAD & HAND** are usually employed for **STATIC** and not for **DYNAMIC** gestures. **SYMBOLIC** gestures are rather **STATIC,** while **METAPHORICAL** gestures are more of **DYNAMIC** form. **PHYSICAL** gestures are mostly **DYNAMIC** with a

TABLE 23: CORRELATION MATRIX (PEARSON (N)) OF THE GESTURE CLASSIFICATIONS.

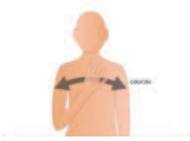
Variables	one finger	two fingers	one hand	two hands	head	head & hand	upper body	all body	static	dyna-mic	conti-nuous	dis-crete
static	0,063	-0,089	-0,167	0,084	-0,072	**0,221**	-0,083	-0,038	**1**			
dynamic	-0,063	0,089	0,167	-0,084	0,072	**-0,221**	0,083	0,038	**-1,000**	**1**		
continuous	0,013	-0,063	0,003	-0,114	0,121	-0,073	0,133	0,061	**-0,596**	**0,596**	**1**	
discrete	-0,079	0,165	0,166	0,050	-0,070	-0,136	-0,074	-0,034	**-0,305**	**0,305**	**-0,583**	**1**
symbolic	-0,105	0,019	-0,165	0,070	-0,080	0,120	0,106	-0,057	**0,555**	**-0,555**	**-0,407**	-0,078
metaphoric	-0,064	-0,111	0,159	-0,074	**0,185**	0,115	-0,082	-0,159	**-0,308**	**0,308**	0,164	0,117
physical	**0,186**	0,104	0,046	-0,063	-0,095	**-0,280**	0,023	**0,229**	**-0,291**	**0,291**	**0,313**	-0,076
abstract	-0,058	-0,033	-0,113	0,170	-0,027	0,132	-0,102	-0,047	0,176	-0,176	**-0,221**	0,084

The **bold values** are different from 0 at a significant level of alpha=0,05.

CONTINUOUS flow. **ABSTRACT** gestures are negatively correlated with a **CONTINUOUS** flow.

In order to choose one gesture per functionality, a rating session was initiated. Differences in rating behaviour could be seen between the pragmatic approach of the programmer who put affordance in the centre of his rating and a design researcher who focused on the playfulness of the gesture. The rating session therefore proceeded through votes. The result was an excel table with an order of gestures per functionality. The following feasibility session added annotations about the implementation effort to the table. Finally, six gestures were chosen for implementation in the first gestural prototype of Skippi.

TABLE 24: THE SIX GESTURES CHOSEN FOR IMPLEMENTATION IN THE SKIPPI PROTOTYPE

functionality	gesture	functionality	gesture
change the visualisation form of the word graph		reanimate word graph	
centre the word graph		start game mode	
stop word graph animation		save state	

4.5.3.5 DISCUSSION

The body storming proved to be an excellent tool to generate interaction gestures. All participants contributed to the ideation and easily found ideas. The high number of dynamic gestures is most likely a result of the possible bodily engagement and the sequential format of the body storming. A classical brainstorming would have probably created more static gestures of symbolic nature.

We clearly see that the participants adopt typical gestures from tactile interfaces for functions like pointing, moving, or panning. The first propositions therefore were often based on finger movements. On a second thought they came up with 3-dimensional gestures that make use of more body parts.

This discrepancy in the choice of gestures between affordance and playfulness, as encountered in the rating session, is most likely to reappear among end users too. In order to outbalance these two requirements, we found it helpful to consider well known stereotypes from other application fields that can be transferred and adapted to the software context. This makes interaction gestures original and provides ease of use at the same time.

To rate the gestures per functionality and check their feasibility was one way to choose from the large bank of generated gestures. However, to design a coherent gesture interface, this approach is not sufficient. It is also necessary to find an appropriate balance between gestures of high bodily engagement and small gestures, as well as between dynamic movements and static forms. To create a comfortable gesture flow is like composing music or a dance. The succession of functionalities has to be anticipated so that the user will be stimulated and engaged but not exhausted when interacting with the software. It is also important to keep the adequateness of the gesture dynamic with the meaning of the addressed functionality in mind. For example, we chose a 'jump' as a gesture for the functionality 'game mode' since this movement is playful in itself.

4.5.3.6 Conclusion of study 3-A

In study 3-A the creativity technique **BODY STORMING** was tested as a tool for the generation of interaction gestures. It proved to be an effective tool which enabled the participants to produce a wide gesture data bank. In order to validate their effectiveness in terms of User Experience (Sub-Hypothesis A), six gestures were chosen from this data bank for the implementation in a first gesture prototype. The implemented gestures were tested and evaluated by Skippi users. This is described under the following study 3-B.

4.5.4 Study 3-B: User Experience evaluation of the generated gestures

4.5.4.1 Objective

Study 3-B had two objectives. First of all, it served to evaluate the User Experience value of the interaction gestures that were generated through body storming in study 3-A. The assumption is that design tools, like body storming that explicitly address a specific Kansei dimension, here gestures, can help designers to generate interactions with a strong UX (Sub-Hypothesis A). The evaluation of the User Experience with the interaction gestures opens a second experimental ground. As shown in the literature review, User Experience evaluations in product design have so far focused on static dimensions like form and colour. Study 3-B therefore also sought to test if it is possible to apply UX evaluations to dynamically changing dimensions like interaction gestures (Sub-Hypothesis C).

4.5.4.2 Participants

21 young product conception professionals participated in study 3-B. Since the study object was gestures/bodily engagement, a simple assessment of the personality type was added. To find out if the participants are extrovert or introvert, they were asked to position themselves on a 5 point scale between the poles 'reserved – expressive', 'reflective – spontaneous', 'individualist – team spirit'.

TABLE 25: PARTICIPANTS OF THE INTERACTION EVALUATION IN STUDY 3-B.

gender	8 female, 13 male
average age	28 years
field of expertise	8 x design 7 x engineering 3 x ergonomic 2 x marketing 1 x project leader
years of work experience	13 x 0-3 years (novice) 4 x 3-5 years (junior) 2 x 5-10 years (senior) 2 x 10 years + (expert)
personality	7 x tendency introvert 8 x balanced 6 x tendency extrovert

4.5.4.3 METHOD

An interaction experience only becomes tangible in an interaction context. The evaluation of User Experience with interaction gestures was therefore embedded in a study set up with three experimental conditions that actively engaged the participants in simple tasks with the Skippi software.

4.5.4.3.1 THE THREE EXPERIMENTAL CONDITIONS

At the beginning the participants viewed a short introduction video of the Skippi software that explained its purpose as an inspirational tool for early product design. Following this they first observed a demonstration of the key functionalities of Skippi (3 minutes). In a second time the participants were guided through a tutorial with a set of interactions in order to learn interacting with Skippi (about 7 minutes). As a third step they could freely explore Skippi while responding to a simple design brief (5 minutes). These three steps were repeated through 3 different interaction conditions (see Image 82). Condition 1 was a classical work set up in which the interaction with Skippi was facilitated by the mouse. In condition 2 the mouse was replaced by a touch sensitive screen. The participants could directly interact with the displayed elements. In condition 3 certain commands of

IMAGE 79: THE 3 CONDITIONS OF STUDY 3: 1. MOUSE DRIVEN, 2. TACTILE AND 3. GESTURAL INTERACTION.

Skippi could be conducted through gestures. For this purpose a wall-mounted screen was connected to the Microsoft Kinect. The connection between Kinect and Skippi was handled by Virtools.

IMAGE 80: THE ORDER OF THE THREE INTERACTION CONDITIONS.

4.5.4.3.2 THE MEASUREMENT POINTS

The temporal component of experience was one important finding of the literature review. The evaluations in this study were therefore placed at three specific moments of each condition. For each

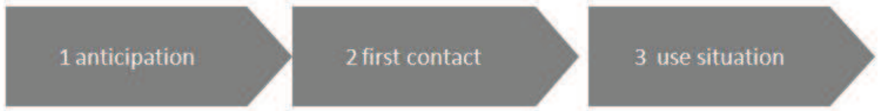


IMAGE 81: THE THREE UX MEASUREMENT POINTS ON THE TIME SCALE.

condition the state of User Experience was captured after the demonstration (1. anticipation), after the learning phase (2. first contact) and after the exploration phase (3. use situation).

4.5.4.3.3 THE MEASUREMENT METHODS

In order to capture the subjective impressions as well as physiological and behavioural information on the participants' User Experience a combination of self-reported, behavioural and physiological measurements were employed in parallel. 3 pilot tests narrowed down the scope of measurement methods.

The pilot tests showed that the number of 9 questionnaires was manageable by the participants. For the questionnaire the User Experience criteria from study 2 were adopted to the context of interaction. Since it was not the evaluation of a concept the two criteria 'correspondence with brief and brand' and 'feasibility' were omitted. Included in the questionnaire were **PLEASURE**, **DYNAMIC**, **ORIGINALITY**, **COMFORT**, **USEFULNESS**, aesthetics with the term **ELEGANT**, sensorial quality with the term **STIMULATING** and usability with the three terms **REASSURING** (feedback), **INTUITIVE** and **EASY**. The criteria had to be rated on a 5-point Likert scale (from 'not at all' to 'very much').

For the behavioural measurement a fixed eye tracking device iviewX RED and a helmet iviewX HED from SMI (SMI, 2013) was tested. Only the classical condition with mouse allowed capturing the eye gaze of the participants through the fixed device iviewX RED. This was not possible for condition 2 and 3. In condition 2 the participants' heads got too close to the screen while interacting with the touch screen. In condition 3 the person was too distant from the tracking system. The helmet iviewX HED did neither work since the luminosity of the screens was too high to identify the precise elements (single words) looked at on the screen. Eye tracking therefore had to be excluded from the measurement methods in this study.

Since the particular interest of the study lay on the User Experience with gestures, video recordings were put into place to observe the participants' movements while gesticulating (condition 3). A webcam was placed on top of the screen to capture the movements of the upper body and the facial expressions of the participants while they executed the gestures.

As physiological measurements were tested electrodermal activity (GSR) and FaceReader (Noldus Information Technology, 2013). In the pilot tests, the electrodermal activity was not influenced by the bodily movements during the gesture interaction and therefore a reliable means to measure the arousal caused by the gestures. Condition 1 and 2 also furnished more or less proper GSR curves. However interfering objects like metal element in table and chair brought noise to the curves. A trial data treatment showed that arousal during the first two conditions could not be assigned to the interaction modes (mouse and tactile) but was rather caused by the contents proposed by the system. The GSR data was therefore only employed for condition 3: Gesture interaction, where the impact of the contents was very small caused by the limitation on 6 executable functionalities.

The pilot tests also showed that the study setting did not allow obtaining reliable results with FaceReader. The participants moved too often out of the camera focus area. The tool seems adapted for frontal views with participants who passively observe something. In our case, the participants worked actively with the software and often changed their face angle and position. Face reader could therefore not used as a measurement tool in this study.

The three measurements presented in Table 26 were chosen for study 3-B. To summarise the proceeding of study 3-B, Image 82 illustrates the 3 conditions, with the 3 measurement points and applied measurement methods.

TABLE 26: MEASUREMENTS SELECTED FOR STUDY 3-B.

		Condition 1: MOUSE			Condition 2: TACTILE			Condition 3: GESTURE		
measure		**1-1 demo**	**1-2 learn**	**1-3 explore**	**2-1 demo**	**2-2 learn**	**2-3 explore**	**3-1 demo**	**3-2 learn**	**3-3 explore**
Self-report	Questionnaire									
Behavioural	Video recording									
Physiological	GSR									

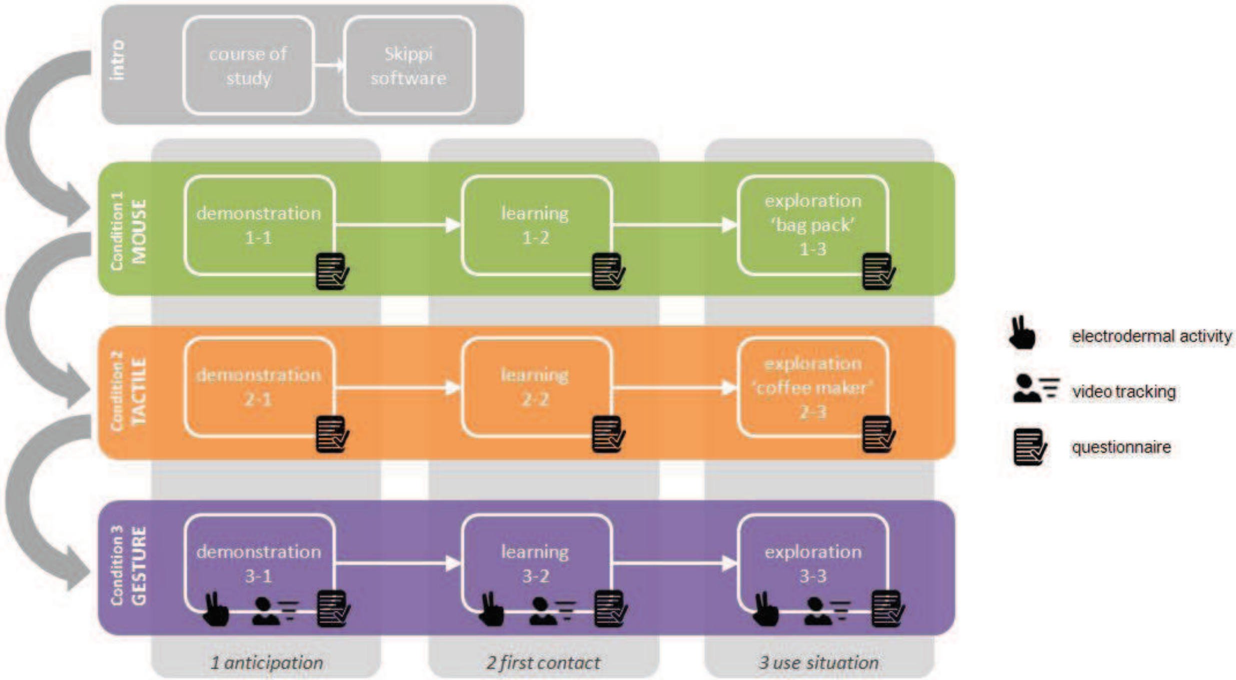


IMAGE 82: COURSE OF ACTION OF STUDY 3-B.

4.5.4.3.4 GENERAL SETTING

To ensure an equivalent course of actions between all participants and all conditions, the Skippi software was restarted after each phase of each condition, while the participant filled in the questionnaire. The study was scheduled to last about 60 minutes including all 3 activities (demonstration, learning, exploring) for the 3 conditions (mouse, tactile, gestural) and the questionnaires. The set up of the study lab with the three work posts can be seen in Image 83. Condition 1 (mouse) and 2 (tactile) were done in a sitting position, condition 3 (gestural) in the up-right position.

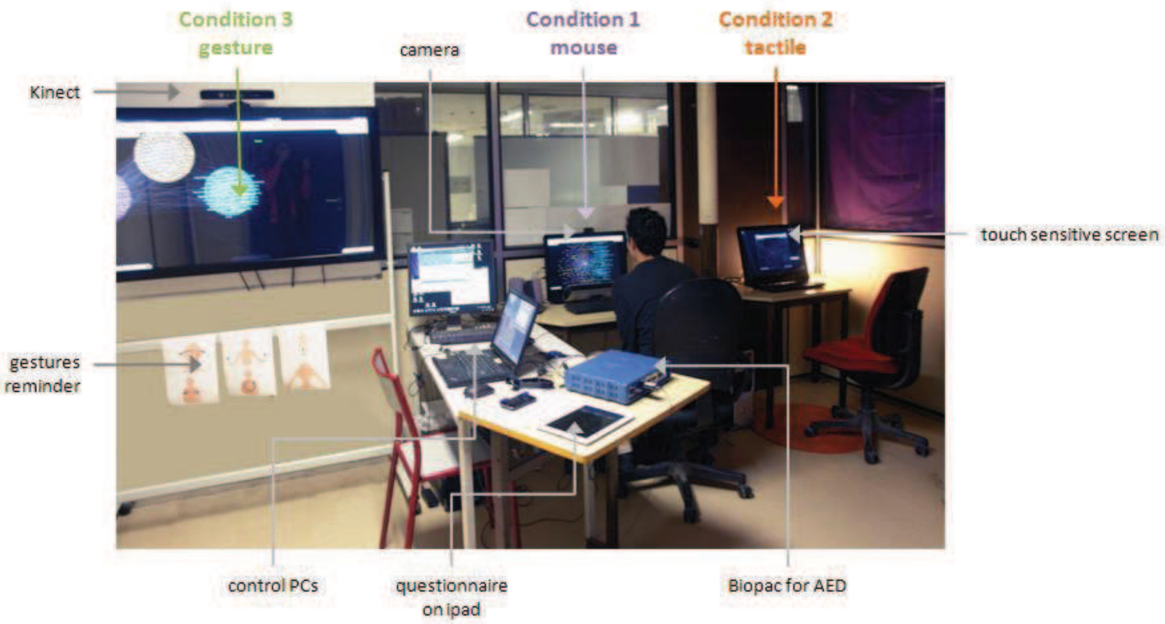


IMAGE 83: SET UP OF STUDY 3-B.

4.5.4.4 Results

The study furnished results on the User Experience of the three interaction modes – mouse, tactile and gestural and specifically on each of the implemented six gestures. Furthermore insights about the evolution of User Experience over three times points within 15 minutes could be extracted.

4.5.4.4.1 User Experience between the three conditions

The study compared the User Experience between three interaction conditions: mouse, tactile, and gestural. Of the three evaluation points in time per condition, the last one was taken to compare the users' experience between the three interactions because it accumulates the experiences from the demonstration, first trial and use situation.

The User Experience was evaluated on 10 criteria on a 5-point scale (=values from min 0 to max 4). All criteria scores were above or equal 2 which means in the upper part of the 5-point scale (0 to 4). We see that the gestural interaction received the highest score before tactile interaction for being stimulating, pleasant, dynamic, original and simple. The tactile interaction was considered the most elegant before gestural and mouse interaction and slightly more practical than mouse and then gestural interaction. The gestural interaction was rated slightly more reassuring than mouse and then tactile interaction.

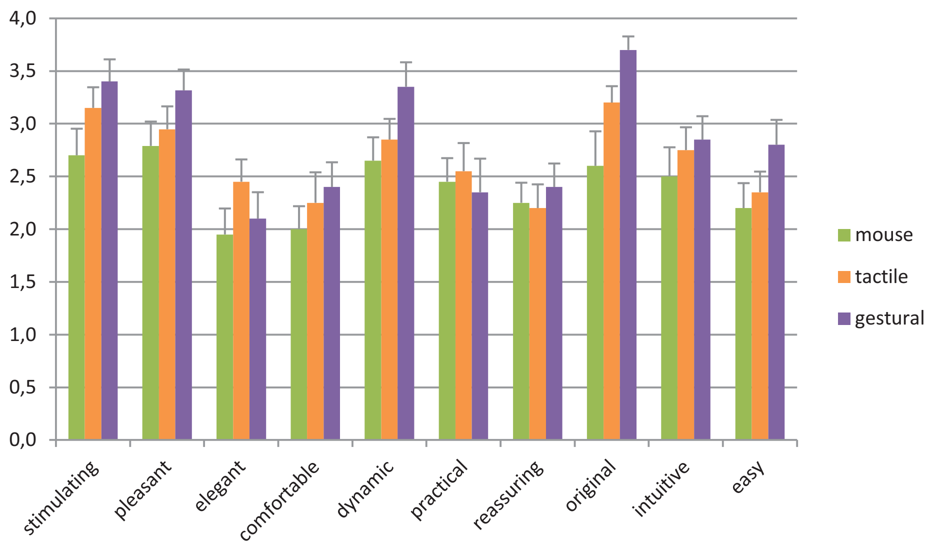


Image 84: Ratings of the 10 UX criteria for the three interaction modes.

The total average scores of the UX criteria show that the gestural interaction was rated the highest, followed by tactile and finally the classical mouse interaction. In comparison to this the direct ranking of the three interactions by the participants in the questionnaire at the end of the session put tactile on rank 1, followed by gestural and third mouse interaction.

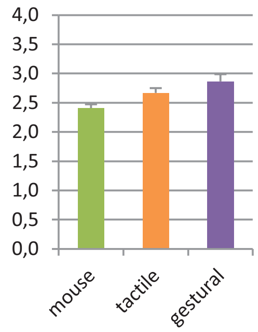


IMAGE 85: AVERAGE UX SCORES FOR THE THREE INTERACTION MODES.

TABLE 27: DIRECT RANKING OF THE THREE INTERACTION MODES.

rank	ranking points	interaction mode
1.	42	tactile
2.	40	gesture
3.	38	mouse

In their free comments lots of enthusiasm for the gestural interaction can be observed: *"The mouse is the most precise and traditional but also the least playful mode […] the gesture mode is the most playful."* (P09); *"I find gestures and tactile interaction nicer than the mouse"* (P08). They describe their experience with the gestures as *"fun"* (P05, P14) or *"funny"* (P11), *"playful"* (P10, P09, P17), *"enjoyable"* (P06, P07, P10, P21), *"interesting"* (P12, P16), and *"fluid"* (P21).

The participants also argue that despite the fun factor the tactile interaction seems the best adapted for that kind of software: *"This interaction mode [gestural] is the most playful but it does not allow complex operations. It is therefore not necessarily the best adapted for Skippi even if it offers the best User Experience"* (P09). *"I really liked the tactile interaction with Skippi. I think it is the best adapted for such a mind map."* (P08); *"The tactile display makes the experience more fluid and more interesting"* (P10, P07); and *"Tactile is my preferred because one really gets the feeling to take the ideas in one's hands and to stir them."* (P13).

4.5.4.4.2 User Experience at the three time points

The participants were asked to rate the 10 criteria for the three conditions at three points in time. First after seeing the demonstration, then after a first hands-on exercise with the tutorial, and finally after 5 minutes of free exploration. The objective was to compare how the User Experience changes over this short time span from anticipation, first contact, to use situation.

Looking at the average value of all criteria, there is hardly any difference observable, between the three time points and the three conditions. The evaluation increases after the first contact and slightly decreases again after the real use situation but not as low as the level at the first

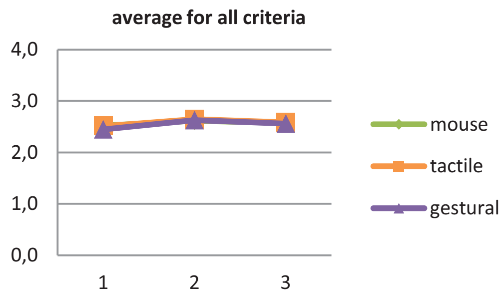


IMAGE 86: AVERAGE EVALUATION OVER THREE TIME POINTS.

point. However the differences are more distinct if we analyse each criterion separately.

During the anticipation there is a strong correlation between stimulating, pleasant and original. Here the conventional tool mouse has the lowest score and gestural interaction the highest. Another correlation in anticipation can be found between practical and comfortable. Here the tactile is rated highest and the mouse lowest. For most criteria the distance between the scores is the highest at the evaluation point 1 (anticipation). Over the following two points the scores for the three interaction modes approach each other. But the order mostly stays the same. Except for the gestural interaction that manages to overtake tactile and mouse despite a less favourable score at the anticipation point 1 for the criteria comfortable, reassuring, intuitive and easy.

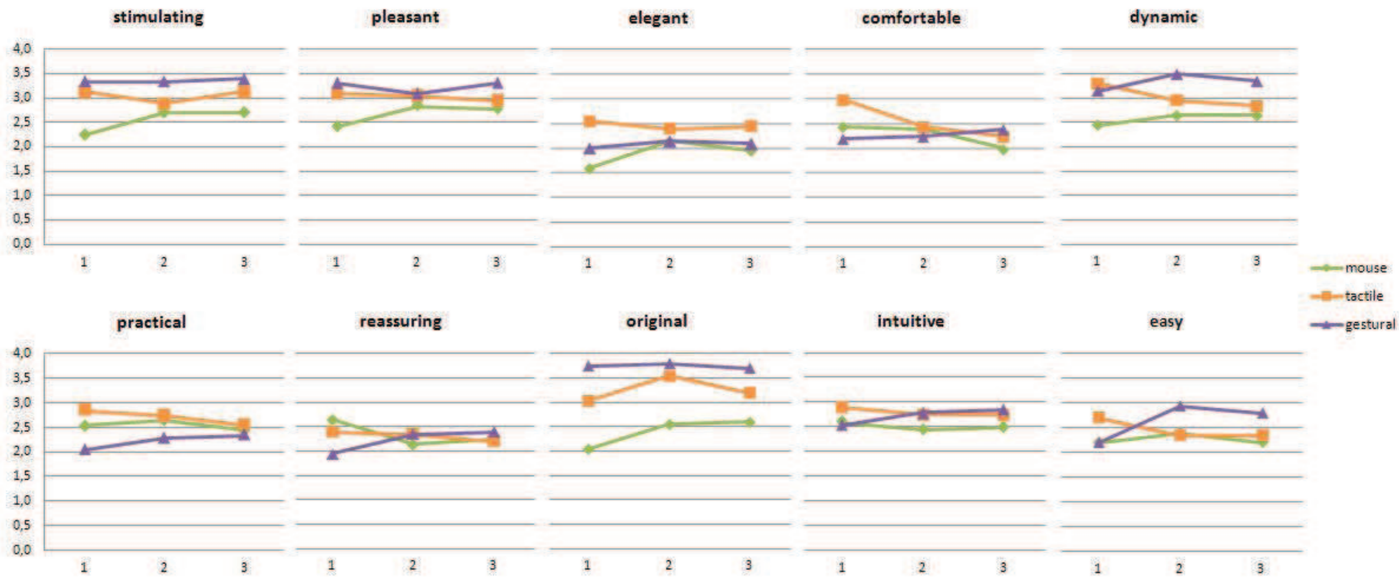


IMAGE 87: UX EVALUATION DATA FOR 10 CRITERIA ON 3 TIME POINTS: 1=ANTICIPATION, 2 = FIRST CONTACT, 3 = USE SITUATION.

The GSR data has been analysed for the three points in time during the gestural interaction. While there appears no significant arousal during the observation of the gesture demonstration (anticipation), the execution of certain gestures provokes an electrodermal response. During the tutorial and the free exploration condition, arousal was evoked by some of the gestures (see details in the next sub-section). However, GSR data is purely qualitative. One cannot compare the amplitudes between the arousals for the same gesture during these two conditions.

4.5.4.4.3 The evaluation of the gestures

At the end of the experimental session, the participants filled in a questionnaire about their appreciation for each gesture. The UX scores show that the gesture for 'save state' gained the highest rating for all criteria (from 0 to 4 for each criterion). The second highest rating received the 'change visualisation' gesture, followed by 'stop animation', then 'game mode', then 'reanimate' and finally ‘centre graph’. This is equivalent with the rating the participants gave when directly ranking the gestures by their preference, only the last two gestures are inversed.

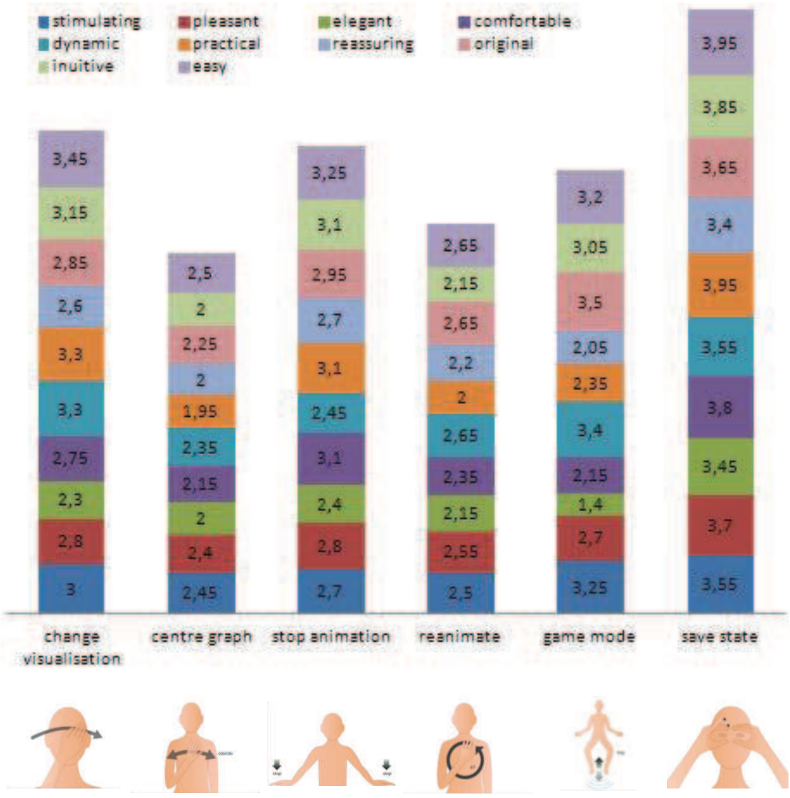


IMAGE 88: UX EVALUATION SCORES FOR THE SIX IMPLEMENTED GESTURES.

TABLE 28: DIRECT RANKING OF THE GESTURES.

rank	ranking points	gesture
1.	114	save
2.	83	change visualisation
3.	72	stop word animation
4.	67	enter game mode
5.	46	centre image
6.	38	reanimate words

The participants gave the following free feedback about their experience with the gestures: *“The gestures are comfortable to use, easy to do and easy to memorize.”* (P18) and *“I really enjoyed this new way of interacting with a software. The gestures are easy. […] They are quite intuitive but still need a minimum of exercise”* (P08). They also pointed at limitations in the current set up *“I would like to do other gestures that are not yet integrated in the interface.”* (P08) and *“This manipulation mode is not natural for me. This complicates the manipulation. However, certain gestures are quite easy and nearly intuitive.”* (P20)

The GSR curves objectively confirm the subjective impression that the participants gave in the questionnaires. The GSR data of 8 participants could be exploited. The GSR responses were not equally pronounced for all participants but the data allowed the following conclusions: For all participants, there are peaks in the electrodermal response after they performed the gestures for 'save state', 'change visualisation' and 'game mode'. Nearly all participants (6/8) showed a change in electrodermal response following the gesture for 'stop animation'. Half of the participants (4/8) showed a GSR reaction on the gesture for ‘reanimate’. Half of the participants (4/8) also reacted on the 'centre' gesture. However, here in 50% of the cases the arousal appeared when the gesture failed to trigger the functionality. Other peaks in the GSR curves occur when the participants switch between the activities questionnaire and interaction. The gestures that cause a GSR response for all participants (‘change visualisation’, ‘game mode’ and ‘save state’) are also those that were ranked highest by the participants and that reached the highest UX scores in the questionnaire.

4.5.4.4.4 The generated gestures and the participants’ motions

The video recordings allow recapitulating the success rate for each gesture. ‘Game mode’ and ‘save

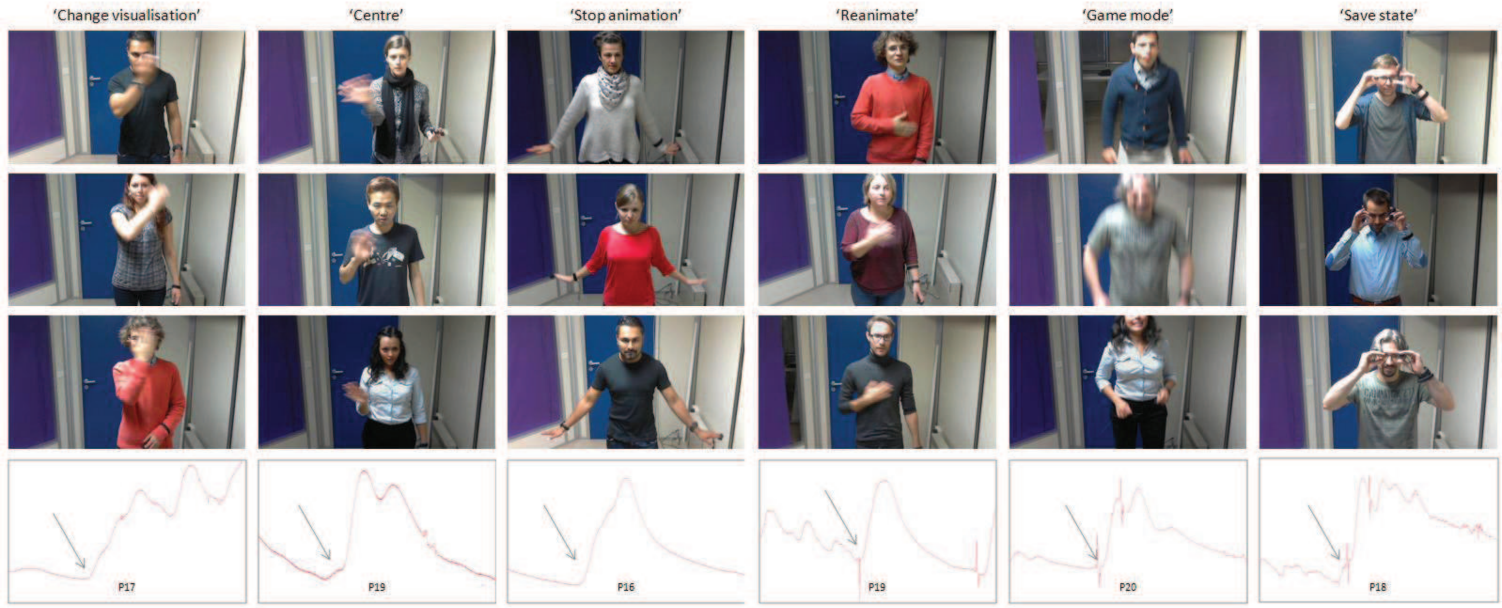


Image 89: Example images of participants executing the six gestures, and an example of the GSR response per gesture.

state’ cause no problem at all. Everybody managed to activate these functionalities each time they intended to. If we limit the analysis to a maximum of three first tries we see a success rate of 90% for the gesture ‘reanimate’, and 76% for ‘stop animation’ and ‘change visualisation’. The lowest score was attained by ‘centre’ with only 57% of the participants executing this gesture successfully. After 3 tries all gestures attained a success rate close to 100%.

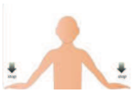
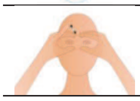
Table 29: Success rate of the 6 gestures at the first three tries.

		change visualisation	centre	stop animation	reanimate	game mode	save state
success rate on first three attempts	*participants*	16/21	12/21	16/21	19/21	21/21	21/21
	percentage	76%	57%	76%	90%	100%	100%

The behaviours that caused gesture failure or that had not been anticipated by the conception team are listed in Table 30. While all participants show the expected behaviour and no execution problems for the ‘save state’ and ‘game mode’ gestures, most unexpected behaviour that caused failure occurred for the gestures ‘centre’ and ‘stop animation’. The problems for ‘centre’ were the too low execution speed, the too low number of repetitions and a too high arm position that caused confusion with the gesture for ‘change visualisation’. The problem with the gesture ‘stop animation’ was mainly caused by the fact, that the participants interpreted it as a dynamic gesture instead of a static pose.

Other observed behaviours did not necessarily lead to failure but still inspired necessary refinements. For example for the ‘change visualisation’ gesture 6 out of 21 participants expected the selection to move forward and backward depending on the direction in which the gesture was executed. So far only one direction had been implemented. The gesture ‘reanimate’ was quickly adopted by all participants but some reinterpreted it as a ‘belly stroking’ movement which worked fine for the system and which seemed more meaningful than just a circle in the air. It was furthermore interesting that 6 out of 21 participants interacted with the system as if it was a human by smiling to it to encourage a positive reaction or by looking very seriously to the screen and talking to it when it did not react on their gesture.

Table 30: Listing of tagged behaviour during gesture interaction that caused gesture failure or was not anticipated during the gesture generation.

		unexpected behaviour that causes failure	**nb of participants concerned**	**unexpected behaviour that does not cause failure**	**nb of participants concerned**	**other observation**
	**change visualisation**	too low under eye level very quick	5/21 3/21	movement from hand joint movement from elbow movement from shoulder one angle for each viz type forward/backward movement same gesture to indicate that someone is crazy	3/21 5/21 2/21 1/21 6/21 2/21	The trajectory for ‘change visualisation’ and ‘centre’ too similar. Only difference in position. Both gestures often done on neck level which triggers one or the other functionality.
	**centre**	too slow movement too few repetitions too high too tight amplitude	5/21 6/21 3/21 1/21			The gesture seems uncomfortable. The hand waving in front of the body does not look natural.
	**stop animation**	push hands down wrong angle claps arms to body bird wings movement	6/21 4/21 3/21 3/21	all body stiff	1/21	Participants expect gesture to be defined through dynamic movement instead of static arm position.
	**reanimate**	too high not full circle	7/21 1/21	hands stroke belly	5/21	
	**game mode**					
	**save state**					
	concerns several gestures	one hand gestures don't work for left hand	6/21	people smile / look serious to kinect or screen while executing gesture; especially when it did not work during previous attempt.	6/21	

An analysis of the video data reveals different behaviour patterns among the participants concerning the precision of the gestures (high, medium, low), the amplitude of the gesture execution (big, medium, small) and the speed of execution (high, medium, slow). Those three behaviours were noted for each participant and the data was correlated with the participants’ personality type (introvert, normal, extrovert), as well as the success rate in the gesture execution (noted 1 for those who managed all gestures on the first three attempts, 0 for those who failed to execute at least one gesture at the first three attempts). The correlation matrix shows that 'high precision' in gesture execution leads to a 'high success rate' (0,523). 'High precision' is positively correlated with a 'medium speed' (0,633) and 'medium amplitude' (0,552). 'High precision' is negatively correlated with 'high speed' (-0,533) and 'big amplitude' (-0,533). One can also see that 'low precision' is negatively correlated with a 'medium amplitude' (-0,520), 'medium speed' (-0,471) and often the result of a 'high speed' gesture execution (0,730). 'Big amplitudes' appear often as a result of 'high speed' (0,738) and can mainly be found for 'extrovert' participants (0,738). 'Medium amplitudes' are negatively correlated with 'high speed' (-0,713) and positively with 'medium speed' (0,510). They can hardly be observed for 'extrovert' participants (-0,713). 'High speed' is correlated with 'extrovert' participants (0,475). And it has a negative correlation with the 'success rate' (-0,484). 'Medium speed' has a positive correlation with 'success rate' (0,556).

'Small amplitudes' and 'low speed' are not coupled with specific other behaviours or the 'success rate'. There is no specific correlations for 'introvert' or 'normal' participants. An 'extrovert' personality however has an impact on the way people execute the gestures. Yet, none of the three personality types had an impact on the 'success rate' of the gesture execution.

Table 31: Correlation matrix (Pearson(n)) for gesture interaction behaviour (precision, amplitude, speed), participants' personality and gesture execution success. The bold values are different from 0 at a significant level (p=0,05).

Variables	high precision	medium precision	low precision	big amplitude	medium amplitude	small amplitude	high speed	medium speed	low speed	normal	extrovert	introvert	success rate
high precision	1												
medium precision	-0,748	1											
low precision	-0,389	-0,320	1										
big amplitude	**-0,533**	0,252	0,411	1									
medium amplitude	**0,552**	-0,192	**-0,520**	-0,713	1								
small amplitude	-0,117	-0,040	0,222	-0,228	-0,520	1							
high speed	**-0,533**	0,022	**0,730**	**0,738**	**-0,713**	0,091	1						
medium speed	**0,633**	-0,311	**-0,471**	-0,420	**0,510**	-0,196	-0,645	1					
low speed	-0,085	0,252	-0,228	-0,313	0,208	0,091	-0,313	-0,420	1				
normal	0,055	-0,113	0,079	-0,420	0,311	0,079	-0,194	0,028	0,032	1			
extrovert	-0,309	0,252	0,091	**0,738**	**-0,713**	0,091	**0,475**	-0,194	-0,313	-0,645	1		
introvert	0,266	-0,131	-0,198	-0,271	0,381	-0,198	-0,271	0,175	0,298	-0,560	-0,271	1	
success rate	**0,523**	-0,283	-0,354	-0,258	0,283	-0,079	**-0,484**	**0,556**	-0,032	-0,222	-0,032	0,315	1

4.5.4.5 Discussion

4.5.4.5.1 The User Experience of the three interaction modes

The participants enjoyed the gestural interaction the most and attributed it the best User Experience. Yet at the same time they found the tactile interaction the most adapted for the Skippi software because of the distance to the words and links that need to be manipulated. The subjective feedback of the participants was well reflected in the UX scores of the 10 criteria. And it explains why the score for gestural is the highest, despite the fact that the participants ranked tactile interaction as their first choice. Two of the participants therefore proposed an interaction mix of tactile and gesture (P19, P21). This would also correspond to the different use situations – individual work or team work. The preference for tactile over mouse interaction confirms the findings of other researchers (Cohé & Hachet, 2012).

The rating over time shows that participants have stereotyped expectations relative to mouse, tactile or gestural interaction that are formed by their former experiences. While the gestural interaction got immediately high scores for being stimulating, original, pleasant and dynamic, it was expected to be less comfortable, reassuring, intuitive and easy to use. The proposed gestures convinced the participants. After first trial and further free exploration, the scores rose and even went ahead of the tactile and mouse interaction. It is not surprising that the participants enjoyed working with gestures but it is a positive result for the gesture generation method that the designed and implemented gestures also work on the usability related UX criteria.

The observed time span was quite short (about 15 minutes), nevertheless the data already shows that the participants' evaluations change from first excitement to habituation. At the first evaluation point (anticipation) the distance between the scores of gesture, mouse and tactile is much high than in the two evaluation following points. At the third evaluation point criteria with extreme anticipation scores reach a medium score. This finding indicates that it is possible to test User Experience after quite short time spans of use without getting extreme results caused by novelty and surprise.

4.5.4.5.2 The User Experience of the implemented gestures

The UX scores for each gesture brought nearly the same result as the direct preference ranking by the participants. On the one hand, one could therefore argue that the evaluation on the UX criteria was not necessary because the users are able chose their preferences. On the other hand, this is an excellent confirmation of the validity of the UX criteria. Because it hints that in their totality they reflect the criteria on which the users base their choice of preference. For a professional in charge of conception, the evaluations on the UX criteria are much more informative than pure preference indications. They point at strong and weak points of each concept (here gesture) and at dimensions that need amelioration.

The electrodermal activity was congruent with the results from the UX scores and ranking. This indicates that GSR is a good means to evaluate the User Experience with interaction gestures. Interestingly the gesture 'game mode' caused less arousal than 'save state' or 'change visualisation' despite its high corporal engagement. A possible explanation lies in the feedback of the functionality that follows the gesture. The gesture 'save state' was the most appreciated by the participants. It was also the only gesture that was coupled with a sound (shutter sound), since otherwise no feedback would have been perceivable. Participants apparently enjoyed the tangibility through this reference to the physical world in this interaction. The videos show all big smiling faces. This hints that gestures gain on UX value if they are accompanied by a sound, as already suggested in previous studies on the effectiveness of gestures coupled with sounds (Kajastila & Lokki, 2012). The other high rated gesture was 'change visualisation'. It was not coupled with a sound but it leads to a fluid movement of the words on the screen. The word constellation distorts from one arrangement (e.g. circle) to another (e.g. tree diagram). The two gestures ('change visualisation' and 'save state') were repeated several times by most participants which was not the case for the other gestures. This confirms that a positive User Experience arises from the interplay of various dimensions (main Hypothesis) - here an affording gesture executed by the user coupled with an aesthetic visual or auditory response from the product (the software). The other gestures also caused arousal for some of the participants but not all of them. And it often occurred in cases of failure. So the arousal was probably rather caused by frustration or the challenge to master the gesture than by a positive User Experience.

In this study the first user testing was done on already implemented gestures. Time constraints did not allow a preliminary testing of the gestures independent of the Skippi interface. The evaluation method proposed by Nielsen and his colleagues seem a useful step to add into the gesture generation phase. They propose to undertake user tests for the matching of the functionality and gesture and for the memorably of the gestures (Nielsen, Störring, Moeslund, & Granum, 2003). This procedure could have added an important criterion for the choice of gestures before implementation and improved the here measured User Experience.

4.5.4.6 Conclusion of study 3-B

Study 3-B had for objective to show that design evaluations can also be done on dynamically changing properties (Sub-hypothesis C). Therefore a comparative evaluation of three interaction modes was initiated. The results confirm the validity of the Sub-hypothesis C. It was possible to evaluate the different User Experience of the users with mouse, tactile and gestural interaction. Furthermore precise interaction gestures too, could be analysed based on the criteria of User Experience. The achieved high UX scores of the gestures confirmed the pertinence of the tool body storming as a mean to generate UX rich interactions, as stated in Sub-hypothesis A. The evaluation furthermore led to specifications for the gesture improvement.

4.5.5 Conclusion of study 3

Study 3 was undertaken to respond to two Sub-hypotheses. In a part 3-A the creativity technique of body storming was tested on its potential for gesture generation. The second part 3-B could validate the User Experience quality of the outcome of this generative tool and therefore validate Sub-hypothesis A. At the same time, this study did show that User Experience evaluations in the design domain can as well be applied to dynamically changing properties (in this case 3 types of interaction modes and 6 specific interaction gestures) and not only static appearances. This validates Sub-hypothesis C.

4.6 Conclusion of the empirical studies

Three studies were undertaken in this thesis. The first explored User Experience dimensions in design research, design practice and as seen from the users. It confirmed the main Hypothesis that **to design for UX, designers need to address a wide range of dimensions during early concept generation and evaluation.**

The second study explored design concepts on their User Experience potential. The first objective was to evaluate the effectiveness of the design generation tool Skippi and to show that **Design tools that explicitly address the Kansei dimensions can help designers to generate concepts with a stronger UX potential (sub-hypothesis A).** Skippi did indeed have an impact on the range of dimensions in the concepts, on the uniqueness of the ideas and on the thoroughness of the presented concepts. However the study did not show an impact on the User Experience potential. Sub-hypothesis A could therefore not be validated. The second objective of study 2 was to show that **UX evaluations can be done on early design concepts (Sub-hypothesis B).** The results hint that it is possible to do UX evaluation at a very early conception stage which confirms Sub-hypothesis B.

Gestural interaction was the focus point of the third study. It too had two objectives. This time the tool 'body storming' was tested as a means to generate interaction gestures. In a second part the gestures were evaluated on their User Experience value and compared to classical mouse and tactile interaction. The results show that the gestures evoke a strong User Experience. They confirm the effectiveness of the tool 'body storming' which is in accordance with **Sub-hypothesis A**. They furthermore confirm **Sub-hypothesis C** that **UX evaluations can be applied to dynamically changing dimensions like interaction gestures**.

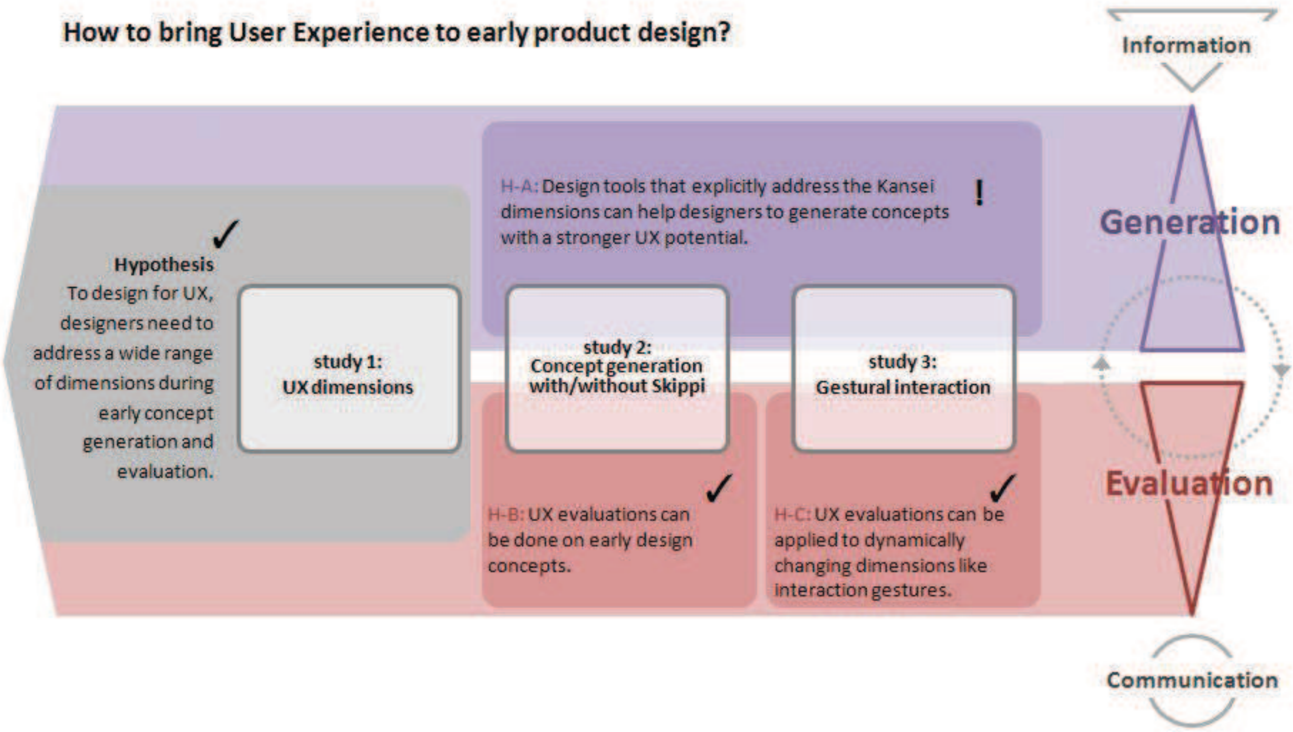


IMAGE 90: SYNTHESIS OF THE STUDIES WITH THE VALIDATED ✓ /PARTLY VALIDATED ! HYPOTHESIS AND SUB-HYPOTHESES.

5 CONTRIBUTIONS

This chapter brings together the findings of this thesis and shows how they contribute to design research and design practice. First of all a model of the product conception process that integrates the totality of the contributions is presented. Following this the 5 key contributions (Image 91) are each discussed in detail. They come in form of design generation and evaluation tools, insights for design theory and a model on User Experience.

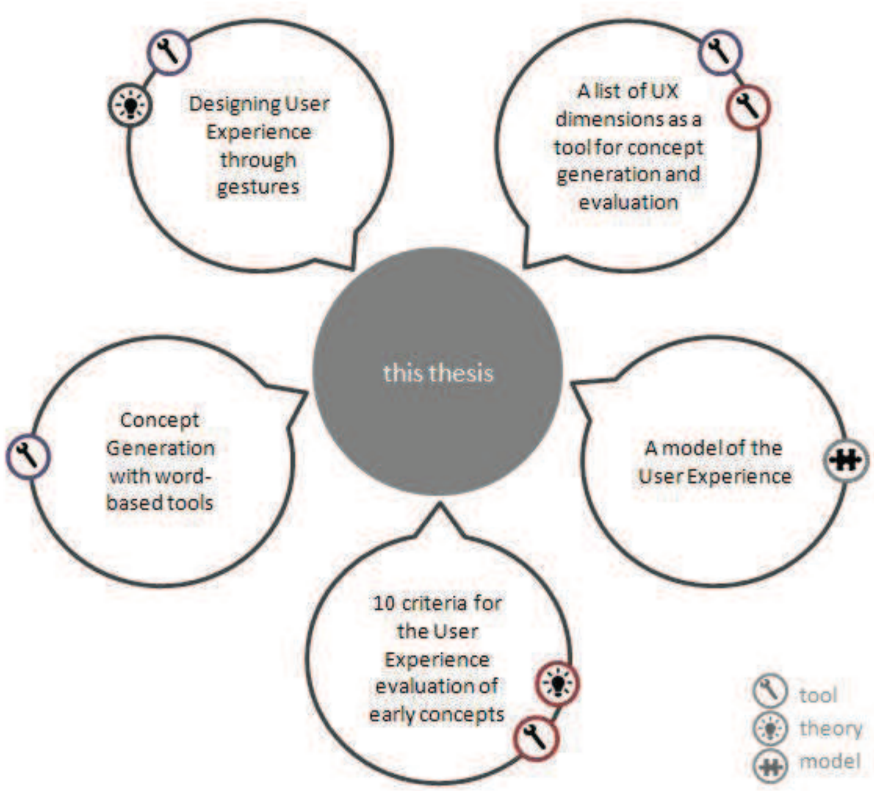


IMAGE 91: OVERVIEW OF THE CONTRIBUTIONS OF THIS THESIS.

5.1 A MODEL ON PRODUCT CONCEPTION FOR USER EXPERIENCE

This thesis investigated how the User Experience of future products can be brought into the early conception process. The conception process is constituted of 4 activity types: information gathering, concept generation, concept evaluation and communication (Bouchard & Aoussat, 1999; Cross, 2008). The literature review showed that there already exist various tools to gather information related to User Experience. However, few tools could be identified that assists the generation of design concepts with special regard to User Experience. Furthermore, a wide range of evaluation tools is already available in the User Experience domain. Yet their application is still quite limited to final products or advanced prototypes. This thesis' focus therefore lay on the generation and evaluation of early concepts. Various generation tools have been tested and created along the way.

As a first approach to bring the User Experience to early product design the following proceeding is suggested. The designer faces a new brief. He starts by gathering User Experience related information on this new project. To do so he can use for example ethnographic tools like observation or participatory tools like Design Probes or Focus Groups (see 2.2.1). Charged with this information he enters the activity of concept generation. His classical tool so far is sketching. The findings of this thesis recommend the designer to **TAKE A WIDE RANGE OF UX DIMENSIONS AS SOON AS POSSIBLE INTO ACCOUNT**. In order to facilitate a consideration of many UX dimensions right away, this thesis proposes him a **LIST OF UX DIMENSIONS**. The list reminds him of otherwise unconsidered UX dimensions. Another tool developed in the course of this thesis (Skippi) is based on **CONCEPTION THROUGH WORDS** in addition to sketches. The Skippi software proposes designers words related to their first ideas. The words belong to many different dimensions and therefore enrich the concepts with various UX dimensions. A third tool proposed to the designer for the generation of UX rich concepts is the creativity technique **BODY STORMING**. Through body movements interaction gestures of the user with the product can be envisioned in a tangible way. Tools like these three can enhance the outcome of the conception generation activity. Of course, they are just propositions and other tools should be developed that support the UX generation.

The mentioned tools help designers to arrive at first concept ideas. This thesis has shown that it is possible to **EVALUATE VERY EARLY CONCEPTS** on their UX potential under the condition that they are presented in a unified format that allows comparison. In order to avoid wrong decisions at this stage of development that will be costly later on, it is recommended to undertake such evaluations from as early as possible and onward. On the one hand, the designer can evaluate his concept proposals by himself, for example by using the **LIST OF UX DIMENSIONS** like a checklist. On the other hand, a panel of users or design experts can evaluate the UX potential of the concepts based on **10 UX CRITERIA** that are another contribution of this thesis. The scores for each criterion point at weak and strong points of the concepts.

Once the designer receives the feedback from the evaluations a new generation cycle starts. Step by step the concept is getting more precise and more detailed. The representation of the concepts evolves too. Prototypes appear and at the end the final product. This thesis has shown that the user-product interaction has a particular impact on the User Experience. It is therefore recommended to also conduct **EVALUATIONS ON THE INTERACTION DESIGN**. These can be done starting from early concepts, then on prototypes, and finally on the product. The more the product development process advances the better users can actually experience the product. The experience on a concept level is rather imagined. Prototypes can be used to try out certain selected experiences. Even though only the final prototype allows evaluating the effective User Experience, it is useful to start the evaluation process during the conception phase. The earlier User Experience problems are detected the easier they can be corrected and the less cost-intensive the product development process becomes.

In the following, the developed tools, theories and model are presented in more detail.

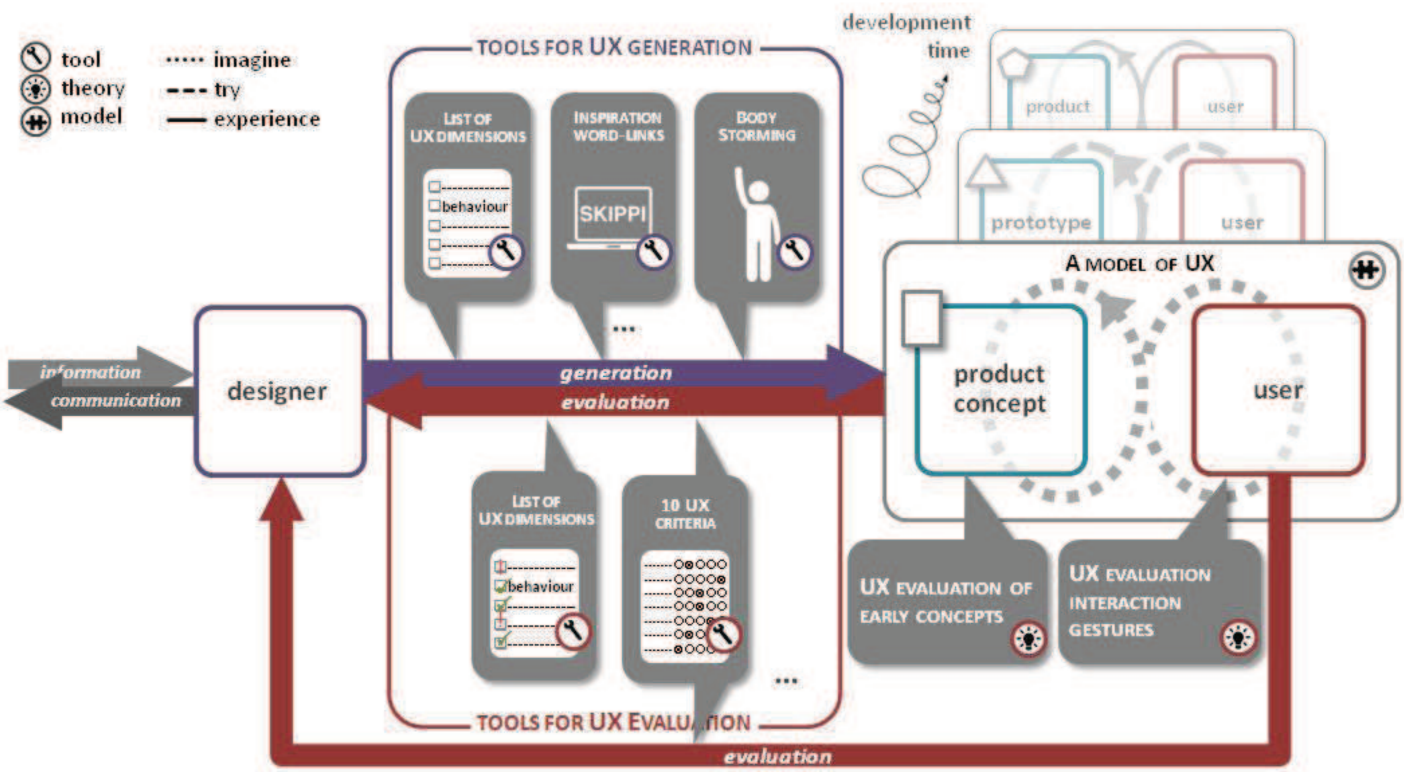


IMAGE 92: A MODEL OF PRODUCT CONCEPTION FOR USER EXPERIENCE GENERATION AND EVALUATION.

5.2 A List of UX dimensions as a tool for concept generation and evaluation

The first study served to establish a comprehensive list of design dimensions that together form the User Experience. The dimensions belong to three key poles 'human', 'product' and 'context'. This list is designated for design practice and design education to raise awareness of otherwise easily neglected design dimensions. It can serve designers in the early phase of concept generation in order to define the future product from all its angles. With regard to the complexity of the list, it is recommended that the designer or conception team chooses its priority dimensions from the list to

Table 32: The final list of User Experience Dimensions.

human		
	target user	single / group
		occupation
		age
		gender
		cultural background/living environment
		personal taste / aesthetic sophistication
	sensory system / state	
	stable cognition & affect	cognitive contents (knowledge, experience/memories)
		personality / disposition
		motivations/values/concerns/needs
	event dependent cognition & affect	core affect
		perceived character
	motor system / state	actions/behaviours
		interaction gesture
		posture / body
product		
	product sector	
	product type	
	product name	
	function/practical purpose	
	functional property	
	feature	functionality
		content
		sensory capacities
		composition/component
		technology
		position
	intended character	affective
		aesthetic
		semantic
		analogy/symbolic
		brand style/objective
		style
	sensorial property	
	static appearance / structural property	material
		texture
		viscosity/elasticity
		colour
		graphic/detail/label
		form/geometry
		dimensions/size/volume
		weight
	behaviour/action	visual response
		sonorous response
		tactile response
		olfactory/gustatory response
		response speed
	production method	fabrication, assembly, finishing
	production quality	tolerances, finishing, ageing
context		
	cultural factors/references	similar products/brands/activities
		clichés/stereotypes
		trends/fashions/tastes/conventions
	situational factors	viewing time
		related products/features/things
		place
		time
		event/activity
	social factors	

define the design priorities of each project. The hypothesis is that the relevance of the dimensions differs between product sectors and product types. While User Experience with fashion might be mainly induced by colours, patterns and forms, the User Experience with sport products is highly related to values like reliability and quality through materials and functionality.

In a second step the totality of the dimensions list can be used as a check list for the evaluation of the concept ideas. Does the concept give a response to each dimension? What dimensions are not addressed by the proposed concept and how can the concept be improved? The list gives designers a guideline during concept generation and evaluation towards a holistic User Experience design.

To use the proposed dimensions list as a tool for product conception one could proceed in the following way:

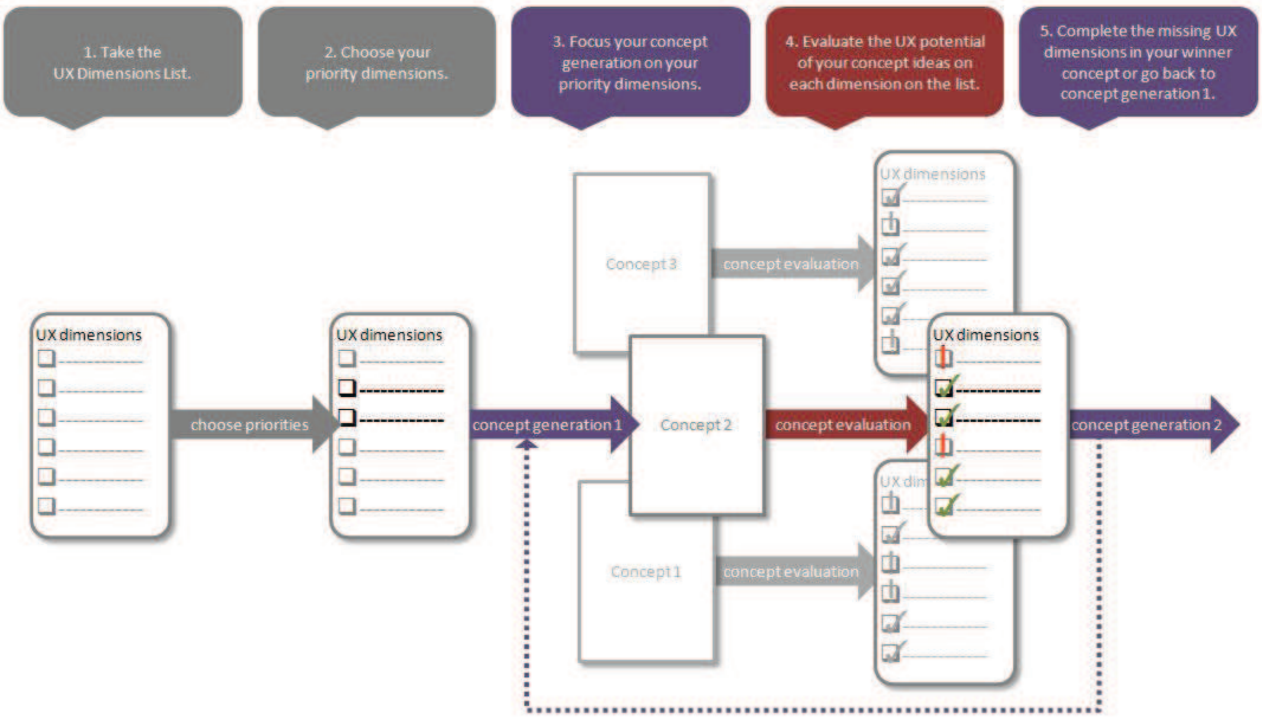


IMAGE 93: RECOMMENDED WORK SEQUENCE WITH THE UX DIMENSIONS LIST.

5.3 CONCEPT GENERATION WITH WORD-BASED TOOLS

The experimental terrain of this thesis was the development of the design software 'Skippi'. Skippi is a tool that inspires and informs designers, engineers and marketers in the early phases of product conception. It is built on a rich database of conception words that are linked with each other. The words belong to the dimensions design (emotion, sensation, semantic, etc.), product (form, colour, material, functionality, etc.) or process (fabrication, assembly, finishing, etc.). This thesis served to generate word-links for the database of the software and later to test the effectiveness of the tool in concept generation work.

As one brick of the database creation, designers and engineers were asked to undertake a fictive concept generation solely through the creation of a word map (study 1-B part 2). This task revealed that experienced designers benefit from a word-based work style as a way to better diverge their ideas and to quickly propose concepts that define a wide range of design dimensions. The comparative study 2 confirmed this subjective impression. While word based conception tools like Skippi do not necessarily enhance the User Experience potential of the proposed concepts, they bring designers to create more unique concepts than the comparison group who worked without the tool. Their concepts also show a higher degree of thoroughness in the design details. We saw that designers easily adopt such a word-based tool in addition to their regular design tools and therefore recommend the use of Skippi or other word-based tools for early product design in combination with the classical tools.

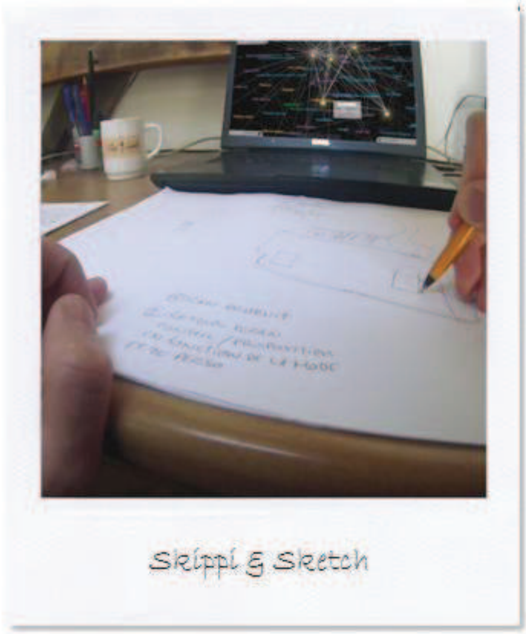


IMAGE 94: VISION OF A DESIGN ACTIVITY THAT COMBINES TRADITIONAL TOOLS LIKE SKETCH WITH NEW TOOLS LIKE SKIPPI TO ENHANCE THE UX VALUE OF EARLY CONCEPTS.

5.4 A MODEL OF THE USER EXPERIENCE

The first part of the literature review brought together information on the mechanisms of User Experience. The main elements were summarized in a descriptive model of User Experience. They are sensor, cognition & affect and response on the human side, and sensor, abstract & concrete dimensions and response on the product side. The ‘infinite’ lined arrow between them shows the path the information takes through the human and the product system. On this path, the information is processed and transformed with each interaction sequence. The superimposition of the model with itself indicates that even the same interaction sequence is never perceived the same way at a later point in use over time. That means the User Experience underlies permanent changes within an interaction sequence and over a long time of product ownership.

This model (see 2.1.6) contributes to design research as a first complete illustration of the main mechanisms of User Experience. As such it is also interesting for design education to explain to design students how User Experience works. All dimensions from the contributed dimensions list can be positioned in the model. The list and the model are therefore complementary.

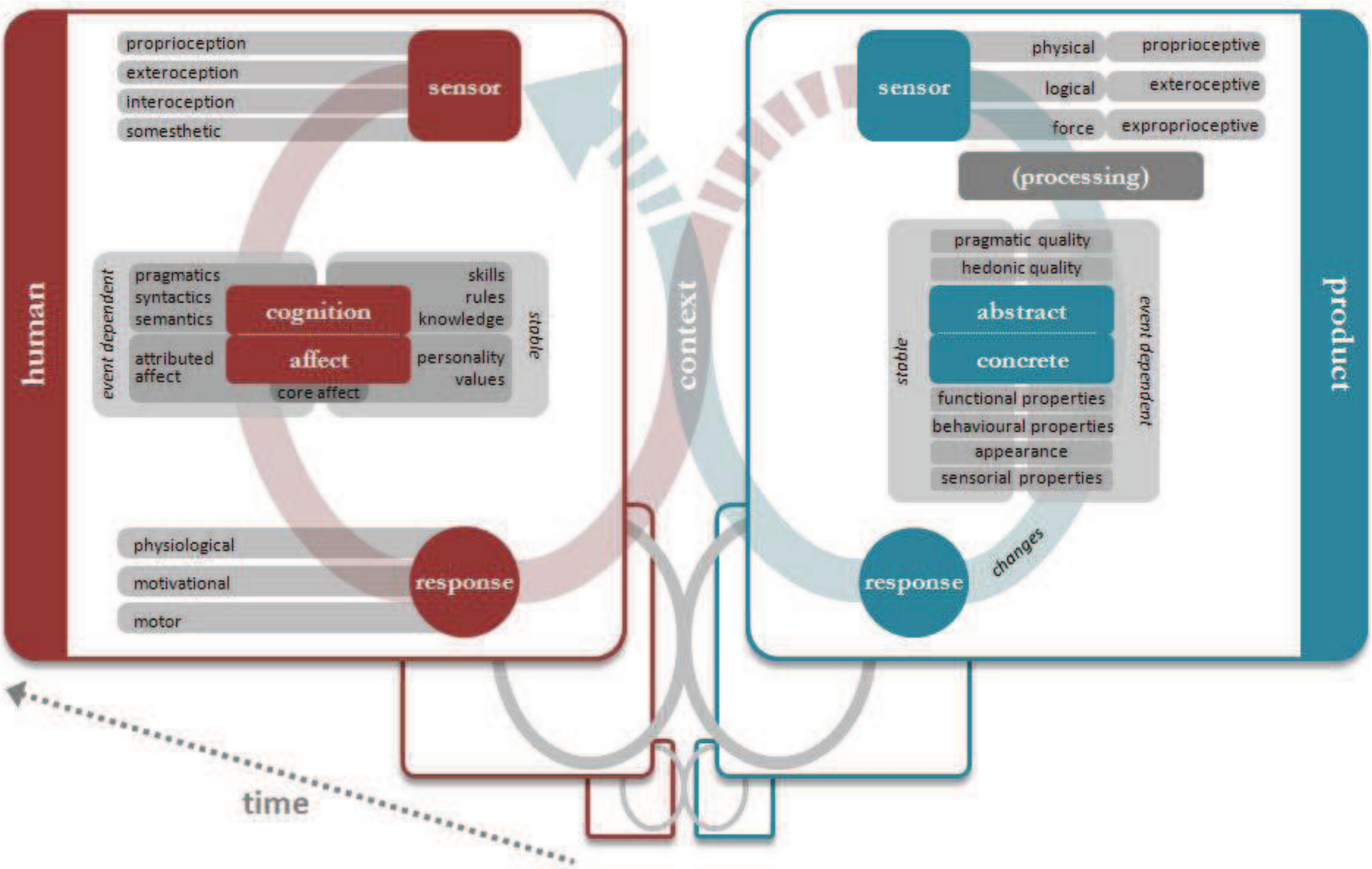


IMAGE 95: A MODEL OF HUMAN-PRODUCT INTERACTION FOR DYNAMICALLY CHANGING PRODUCTS.

5.5 CRITERIA FOR USER EXPERIENCE EVALUATION OF EARLY CONCEPTS

Study 2 of this thesis has shown that it is possible to evaluate the User Experience potential of early concepts. This finding is important since it allows stakeholders to correct User Experience issues way before operable prototypes. The contribution is to have shown the possibility of concept UX evaluations. What's more, this thesis also provides a manageable list of 10 evaluation criteria, in order to enable the conception team to undertake UX evaluations on early concepts. The criteria are:

CORRESPONDENCE WITH BRIEF AND BRAND

ORIGINALITY

AESTHETIC

USEFULNESS

USABILITY

PLEASANTNESS

DYNAMIC (capacity to react on user or environment)

SENSORIAL QUALITY

COMFORT

FEASIBILITY

These criteria can be used in a questionnaire that presents a unified idea sheet for each concept. The criteria are rated on a 5-point Likert scale. Depending on the stage of development of the concept, the conception team has to choose the criteria that are applicable to the concept presentation from the 10 criteria. Usability or aesthetics for example are not always visible in scenario description. When early concepts are evaluated on their User Experience, what is actually evaluated is a User Experience **POTENTIAL**. The persons, who evaluate the proposed concept, imagine the future product. They evaluate it based on their own previous experiences. However the inter-person accordance found in the study shows that this kind of evaluation can provide a reliable indicator to choose from various concepts or to see which of the criteria in a concept need more consideration.

5.6 Designing User Experience through gestures

The perception of dimensions of product appearance like colours, forms and materials has been extensively investigated in the field of design research. In study 1 we saw that User Experience is strongly associated with dynamic product behaviour. That means with interactions between the user, the product and the use environment. Study 3 was therefore designated to the exploration of interaction gestures. It showed that bodily engagement of the designers – through body storming – is an effective means to conceive interaction gestures. Furthermore a comparison between three different interaction modes – mouse, tactile and gestural – had for result that gestural interaction, at the moment, generates the strongest User Experience. Gesture based interfaces are an emerging topic and the findings from this thesis should encourage the interaction design community to pursue the development and implementation of gesture controls in our everyday interfaces in public like ATMs, ticket machines, city maps and domestically like cookers, taps, doors, etc.

5.7 Conclusion of the contributions for research and practice

This thesis contributes design research with two theoretical insights. It could be shown that User Experience evaluations can already be undertaken on early concepts. Furthermore, this thesis showed that evaluation methods so far applied to product appearances can be equally employed to evaluate the User Experience of dynamically changing dimensions like interaction gestures. The thesis furthermore proposes a model that illustrates the mechanisms of User Experience through human-product interaction.

A contribution to design practice comes in form of a list of UX dimensions that draws the attention of the designers to the various factors that potentially influence the User Experience with the final product. A conscious consideration of the most priority dimensions per project from early product design and onward can be suspected to increase the UX value of the generated concepts.

Two tools for UX design practice were furthermore developed and tested in this thesis. Body storming has proven a great means to enhance brainstorming for the definition of human-product interactions. Skippi is a software tool for stakeholders of design practice that brings inspiration and the whole range of UX dimensions into the first stage of product conception. Skippi is purely based on conception words from different dimensions that are linked with each other. Even for practitioners who have no access to Skippi, a work based on word maps is suspected to enrich early design concepts with a larger range of UX dimensions.

A final contribution for both design research and practice is the validated list of hedonic and pragmatic UX criteria that serves as an outline for User Experience evaluations.

6 PERSPECTIVES

Building on the findings of this thesis, this final part proposes four research paths that seem worth a further exploration. The first proposition seeks to refine the list of UX dimensions. The second suggests an experimental setting that could show that UX evaluations of early concepts lead to better final UX designs. The third direction continues the work on Skippi and brings the gesture interface to a virtual environment. The last proposition concerns a new approach for a UX generation tool (Experience Triggers).

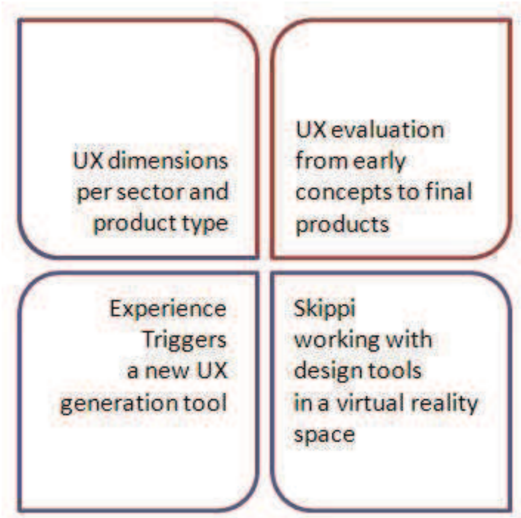


IMAGE 96: OVERVIEW OF THE FOUR POTENTIAL PERSPECTIVES DERIVED FROM THIS THESIS.

6.1 USER EXPERIENCE DIMENSIONS PER SECTOR AND PRODUCT TYPE

As mentioned under contribution 1, this thesis provides designers with a holistic list of dimensions that potentially influence the User Experience and that should therefore be taken into account during product conception. The User Experience dimensions list was constituted from projects of various sectors and product types. Even though most of these dimensions can presumably be found in any kind of product, it cannot be ignored that they are not equally important. There must be a kind of hierarchy of User Experience dimensions that differs between product types or sectors. It would therefore be useful to investigate the relevant UX dimensions for e.g. sport products, consumer electronics, home appliances, fashion, etc. To do so, a method similar to study 1-C could be put into place. Users could be gathered in Focus Groups to discuss about the experience with a certain product type. The accounts could be analysed on UX dimensions based on the list from this thesis. The result could be a specific UX dimensions list that would replace the selection of conception priorities as proposed in step 2 of Image 93. Here too it seems appropriate to distinguish dimensions that are in the focus of concept generation from dimensions that are more relevant for concept evaluation.

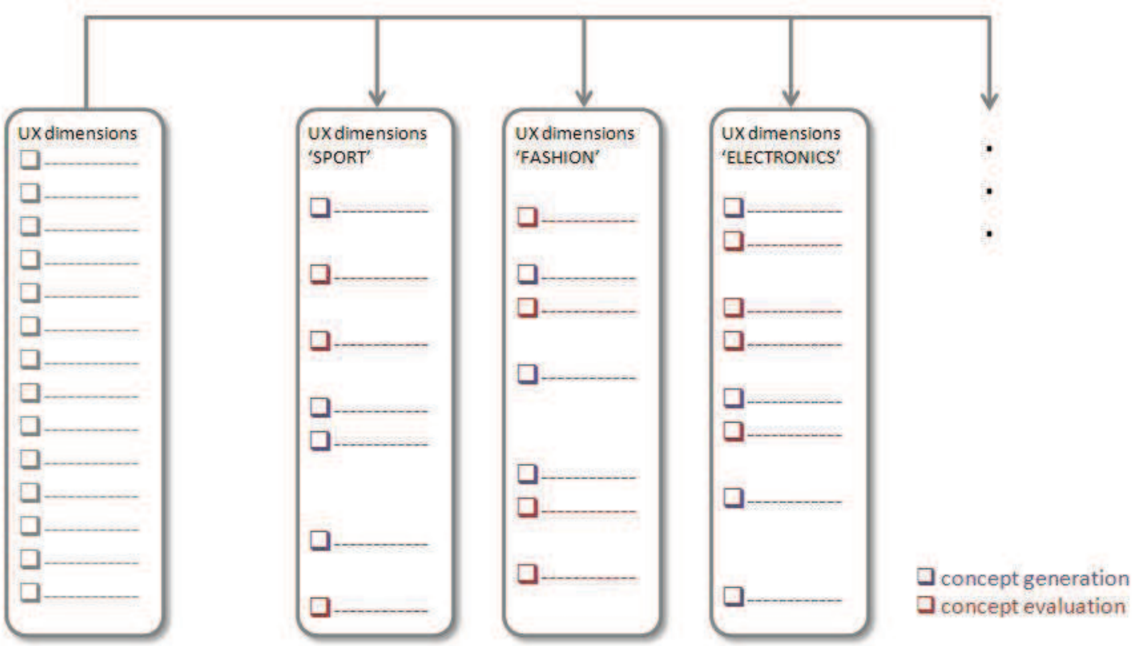


IMAGE 97: DERIVATION OF USER EXPERIENCE DIMENSIONS LISTS PER SECTOR.

6.2 UX EVALUATIONS FROM EARLY CONCEPTS TO FINAL PRODUCTS

Study 2 showed that it is possible to undertake UX evaluations on very early concepts. 29 ideas for an interactive bag were evaluated on their User Experience potential. Now it would be interesting to continue the study by developing several of the ideas into real products and to evaluate their final

User Experience value. If the final products that already scored high at the concept stage still reach high scores at the end of the product development and those with lower scores stay low, the relevance of the concept evaluation could be validated. This would mean that early concepts already contain lots of information to anticipate the final User Experience.

To conduct a seamless User Experience evaluation chain from early concepts to final products seems a very interesting research setting. The results will be highly valuable for the product development community. The earlier in the conception process User Experience issues can be detected, the less costly and complex product modifications will be.

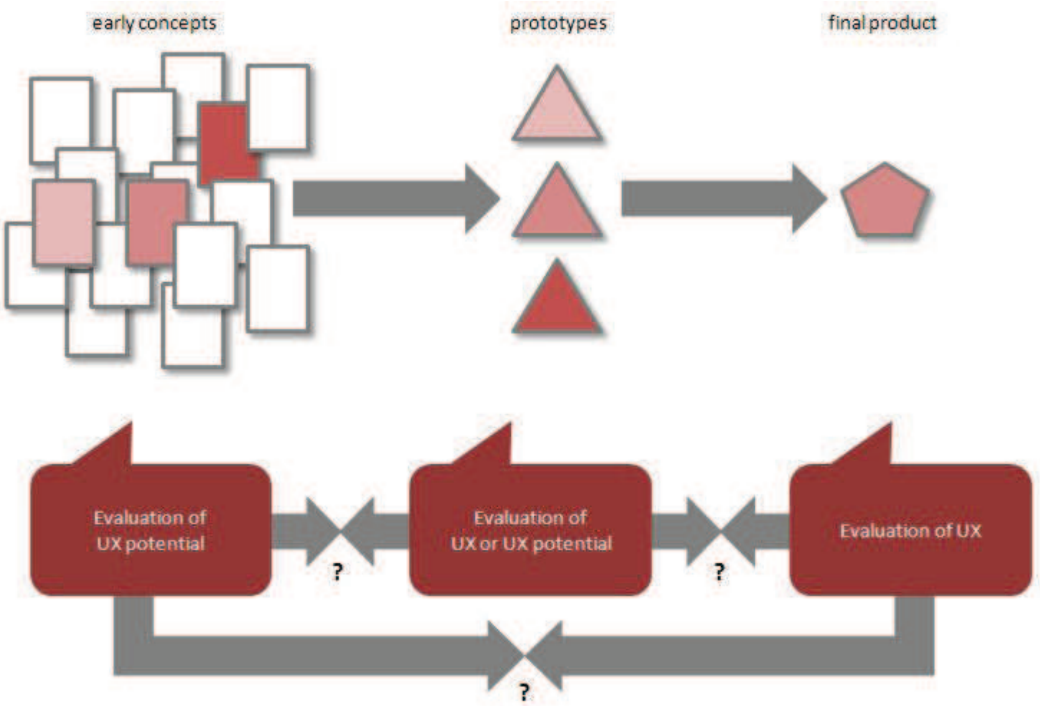


IMAGE 98: AN UX EVALUATION CHAIN FROM EARLY CONCEPTS TO FINAL PRODUCTS.
THE COMPARISON OF THE UX EVALUATIONS PER CONCEPT SHOULD SHOW IF EARLY EVALUATIONS CAN ANTICIPATE THE FUTURE UX CORRECTLY.

6.3 SKIPPI – WORKING WITH DESIGN TOOLS IN A VIRTUAL REALITY SPACE

The body storming in study 3 generated interaction gestures for about 70 functionalities of the Skippi software. Since the first version of Skippi itself only functions in a 2-dimensional space, a small set of 6 gestures was implemented to test the Hypothesis. However, the vision is to bring tools like Skippi into a 3-dimensional space which would strongly enhance the usefulness of interacting through gestures. In Virtual Reality the words would float in a 3D space around the user. In this condition the user could execute the basic gesture commands for navigation (change view and position in space), selecting a word, grouping words, querying object contents, zooming and changing words position in space (Bordegoni & Hemmje, 1993).

Interaction with gestures in virtual reality is presumed to evoke even stronger User Experiences than the gestures already did in the 2-dimensional version. It would be interesting to compare such an immersive experience to non-immersive ones, and then to see if the immersion also has an impact on the inspirational quality of the tool.

IMAGE 99: SKIPPI IN A VIRTUAL 3-D SPACE, OPERATED THROUGH GESTURES.

Remains the question about the evolution of User Experience over a long time. The study could only provide a first answer for a short time span. In the short time span of 15 minutes per condition (mouse, tactile, gestural) we already saw the effect of habituation which brought the experience with gestures closer to that with classical interaction means like tactile. The novelty plays a very strong part in the User Experience expectations and on first contact. Habituation makes the experience value caused by novelty decrease. Another issue is that User Experience is not an absolute value. Its score always depends on the point of comparison and new technologies usually lift the baseline.

6.4 EXPERIENCE TRIGGERS: A NEW UX GENERATION TOOL

As stated at the end of the State of the Art, most current UX conception tools and methods are made for the evaluation of products. Very few help designers to generate designs for User Experience. The software Skippi, that in this thesis provided the experimental base of the studies, is one proposition for a generation tool. The tested body storming is another proposition. Through exchange with research colleagues, we came across other ideas that could not be put into place within the limits of this thesis. One User Experience generation tool that we imagine are material objects that allow designers to live specific User Experience Dimensions. We call them ‘Experience Triggers’. They are designed to incorporate certain theories related to User Experience. For example a trigger object can transport the value of security. The conception team will manipulate the object and live a ‘security related’ experience through it. This unites conception teams around the same UX goal and puts them into the ‘experience’ state that they seek to generate in their concepts. The idea for the Experience Triggers comes from the insight that practitioners are not familiar with theories, frameworks, or research papers on product emotions, human values, etc. – as gathered in the literature review of this thesis. The trigger objects translate those theories into tangible experiences and make them accessible for designers in practice.

The idea of Experience Triggers has been presented for the first time during a workshop at FLUPA UX DAY 2013 (FLUPA, 2013). The goal was to share the idea, to get practitioners' feedback and to create a first set of trigger objects. The idea will be further explores with the creation of trigger objects by professional product designers and artists. With a start set of triggers at hand, they will be tested as a concept generation tool on a specific brief with stakeholders of product conception.

Image 100: Impressions from the first Experience Triggers Workshop at FLUPA UX DAY 2013.

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8 Index of images and tables

8.1 List of images

8.2 List of tables

SYNTHESE EN FRANÇAIS

LA CONCEPTION AMONT DE L'EXPERIENCE DE L'UTILISATEUR – DE LA GENERATION A L'EVALUATION DES IDEES.

TABLE DES MATIERES

INTRODUCTION

OBJECTIFS

Cette thèse fait partie de la science de conception. Elle porte sur le sujet de l'expérience de l'utilisateur (UX). L'UX des produits est déjà largement analysée en marketing et en ergonomie. Dans cette thèse nous nous demandons comment est-ce que l'on peut concevoir une bonne expérience de l'utilisateur dès les premières phases de conception du produit.

Les objectifs des cette thèse sont de :

- **DEFINIR LES DIMENSIONS QUI CONSTITUENT L'EXPERIENCE DE L'UTILISATEUR;**
- **PROPOSER ET TESTER DES OUTILS POUR CONCEVOIR L'EXPERIENCE DE L'UTILISATEUR;**
- **PROPOSER ET TESTER DES OUTILS POUR EVALUER L'UX DES CONCEPTS AMONTS;**
- **APPLIQUER LES EVALUATIONS UX AUX DIMENSIONS DE L'INTERACTION.**

PROBLEMATIQUE DE LA RECHERCHE

Aujourd'hui il est demandé aux designers de concevoir une expérience pour les utilisateurs. Un bon UX est le résultat de l'interaction entre l'homme et le produit sur une large gamme de dimensions du design comme la forme, la couleur, le matériau ainsi que la qualité sensorielle et sémantique. Bien que l'UX soit devenue un enjeu important pour les entreprises, il existe encore peu d'outils pour sa conception.

Dans cette thèse nous tentons de proposer des outils pour la conception et l'évaluation de l'UX. La question posée est : **COMMENT CONCEVOIR L'UX DES LES PHASES AMONT DE LA CONCEPTION PRODUIT?**

CONTRIBUTIONS

Cette thèse contribue à la science de conception ainsi que l'activité de design par les 5 principaux apports suivants:

- **UNE LISTE DES DIMENSIONS UX COMME OUTIL POUR LA GENERATION DES CONCEPTS**
- **UN MODELE DE L'EXPERIENCE DE L'UTILISATEUR**
- **DES CRITERES POUR L'EVALUATION UX DES CONCEPTS AMONTS**
- **DES CONNAISSANCES SUR LA GENERATION DE CONCEPTS AVEC DES OUTILS LEXICAUX**
- **DES CONNAISSANCES SUR L'UX AVEC DES INTERACTIONS GESTUELLES**

ORIGINALITE

L'originalité de cette thèse repose sur le 4 points suivants:

- **LE POSITIONNEMENT DU SUJET : L'UX EN CONCEPTION AMONT**
- **L'APPLICATION D'OUTILS DE DESIGN PEU CONVENTIONNELS: MOTS-CLES ET MOUVEMENTS CORPORELS**
- **LA COMBINAISON DES DEUX ACTIVITES DE CONCEPTION (GENERATION ET EVALUATION) AVEC DEUX POPULATIONS (CONCEPTEURS PROFESSIONNELS ET UTILISATEURS POTENTIELS)**
- **L'APPLICATION DES OUTILS DE LA CREATIVITE ET DE METHODES DES SCIENCES HUMAINES DANS LES EXPERIMENTATIONS.**

STRUCTURE DU DOCUMENT

Pour aborder le sujet, cette thèse est structurée en 6 chapitres. Nous rappelons dans un premier temps comment l'expérience de l'utilisateur est arrivée dans la société et dans la recherche [**CONTEXTE DE RECHERCHE**]. Ensuite **L'ETAT DE L'ART** nous familiarise avec ce phénomène et nous montre quelques outils existants pour la conception de l'expérience de l'utilisateur. Les limitations dans la recherche actuelle nous amènent à notre **QUESTION DE RECHERCHE** qui est explorée au travers de trois **EXPERIMENTATIONS**. Enfin, nous montrons les **CONTRIBUTIONS** et **PERSPECTIVES** des cette thèse.

1 Contexte de la recherche

Les Image 1 et Image 2 montrent deux produits du même fabricant. L'un date de l'année 1963, l'autre de l'année en cours. L'ancien produit est basé sur la technologie **ANALOGIQUE**. Le produit d'aujourd'hui fait parti du monde **NUMERIQUE**. L'ancien téléviseur a une seule fonctionnalité, tandis que le nouveau produit a des capacités **MULTIFONCTIONNELLES**.

Image 1: TV 1963

Image 2: TV 2013

Dès les années 60 la production de masse offre un grand choix de produits aux **CONSOMMATEURS**. Avec l'arrivé de la connectivité à l'Internet des appareils de consommation dans les années 90, le consommateur est devenu un acteur dans la conception produit. Il est lui-même en position d'adapter les produits à ses envies. Toffler a proposé le terme **PROSUMER** (Gerhardt, 2008).

En conséquence le métier du designer produit est en train de changer. Aujourd'hui il n'est plus seulement attendu du design qu'il propose des liens entre des fonctions et des formes esthétiques. L'équipe de conception doit concevoir **UNE EXPERIENCE POUR L'UTILISATEUR**.

L'expérience de l'utilisateur est définie comme « la perception et les réponses d'une personne qui résultent de l'utilisation ou de l'anticipation de l'utilisation d'un produit, d'un système ou d'un service. » (ISO 9241-210) C'est un sujet émergent. Il apparaît de plus en plus dans des publications, dans les résultats des moteurs de recherche et dans les slogans des grandes marques.

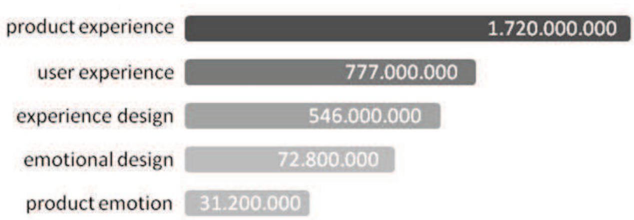


Image 3 : Nombre d'articles sur Google.

Sur une échelle temporelle, la perception humaine des objets a d'abord été traitée par les chercheurs en psychologie cognitive. Avec l'arrivée des ordinateurs dans nos maisons et nos bureaux, le domaine de l'interaction homme-machine s'est développé pour améliorer l'utilisabilité des interfaces numériques. Dans la recherche en design, ce sont d'abord les chercheurs en ingénierie Kansei qui ont exploré les émotions, les sensations et la sémantique portées par un design.
Avec le début du nouveau siècle, Norman et Desmet ont initié une recherche focalisée sur les émotions qu'un produit peut provoquer chez son utilisateur – le design émotionnel.
De son côté, l'ingénierie affective cherche à prédire et à évaluer l'expérience sensorielle de l'utilisateur avec des matériaux et des textures.
Enfin, il y a aujourd'hui de plus en plus de chercheurs qui rassemblent les connaissances des ces 5 mouvements pour étudier l'expérience de l'utilisateur.

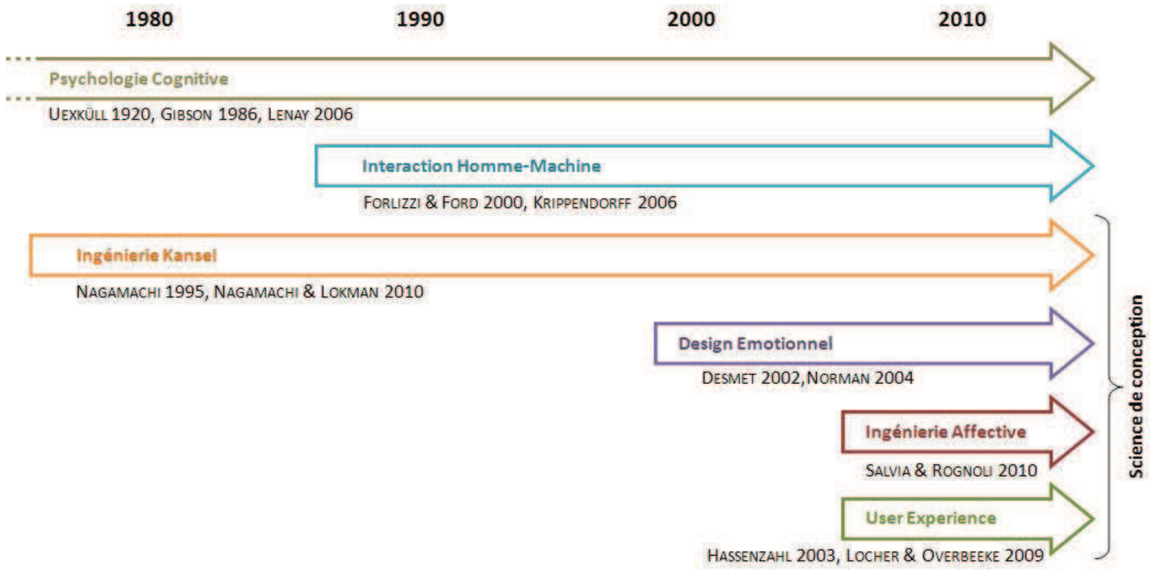


Image 4: Evolution de la recherche dans des domaines liees a l'UX.

De plus en plus d'activités de recherche portent de nos jours sur des sujets liés à l'expérience de l'utilisateur : d'abord parmi les chercheurs en Ingénierie Kansei, qui se trouvent principalement en Asie mais aussi en Europe, mais également parmi les chercheurs en Interaction homme-machine, les chercheurs spécialisés sur le design émotionnel, les chercheurs dans le design sensoriel et enfin les chercheurs qui s'inscrivent directement dans la recherche sur l'expérience de l'utilisateur.
Cette thèse a eu lieu au Laboratoire de Conception Produits et Innovation des Arts et Métiers ParisTech qui s'inscrit dans le domaine du Kansei Design. L'objectif de notre recherche est la modélisation et l'intégration des capacités des concepteurs dans la conception amont. A ce jour, 7 thèses ont été rédigée dans ce contexte, dont 4 sur des projets ANR (Agence Nationale de la

Recherche). Cette thèse s'appuie également sur un projet ANR, nommé Skippi, pour le développement d'un logiciel de conception.

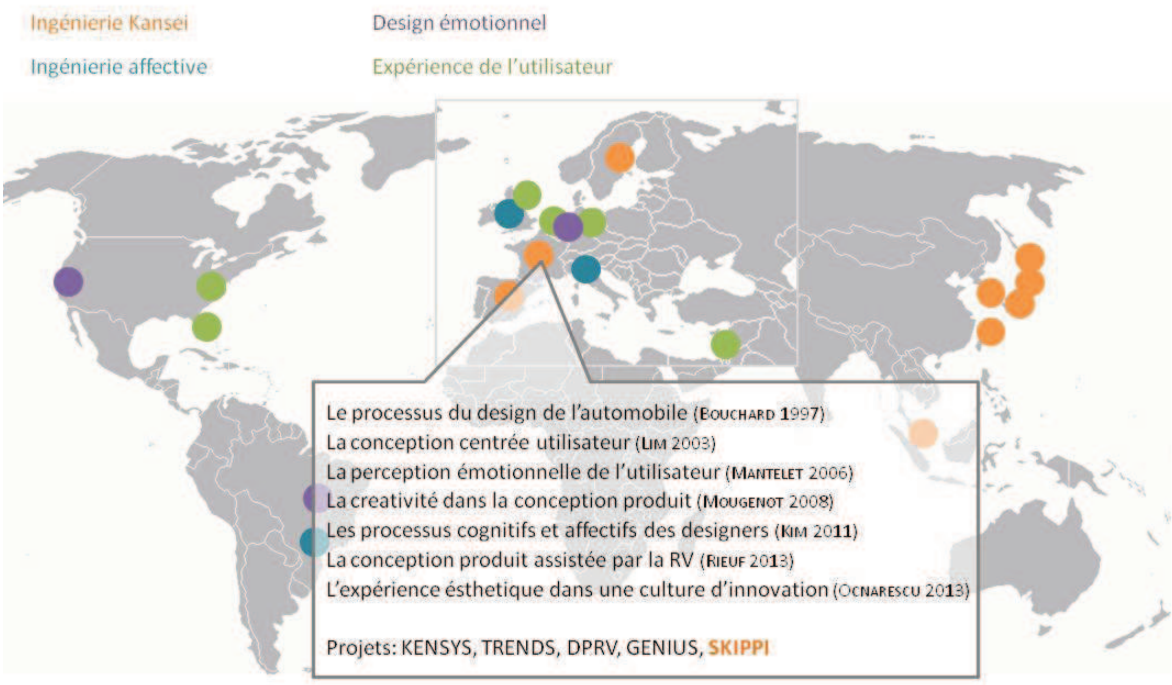


Image 5: Activites mondiaux de la recherche sur la relation utilisateur – produit.

C'est dans notre chapitre sur l'Etat de l'Art que nous regroupons les principaux résultats de la recherche dans ces domaines concernant l'expérience de l'utilisateur.

2 ETAT DE L'ART

L'état de l'art consiste en deux parties. Nous analysons dans un premier temps le phénomène qui se produit lorsqu'un utilisateur interagit avec un produit. Nous découvrons ensuite une sélection d'outils qui peuvent servir à la conception de l'expérience de l'utilisateur.

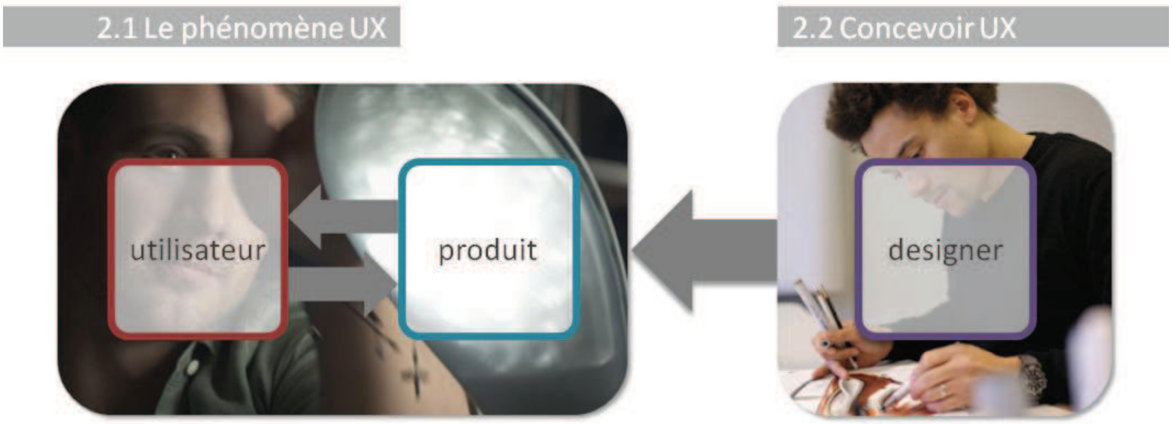


IMAGE 6: 2 PARTIES DE L'ETAT DE L'ART.

2.1 DIMENSIONS DE L'EXPERIENCE DE L'UTILISATEUR

Des produits sont caractérisés par leur couleur, leur matériau, leur forme, leur texture etc. Nous parlons alors des dimensions du design. Leur état, par exemple 'gris' pour la dimension couleur, est appelé sa « propriété » et il peut être caractérisé par des « sous-propriétés », comme la saturation de cette couleur par exemple.

L'utilisateur perçoit les propriétés d'un produit avec son appareil sensoriel. En tant qu'être humain nous avons des capacités d'exteroception (visuel, audio, gustatif, olfactif, somésthetique – toucher, température, douleur), de proprioception (position corporelle, mouvement) et indirectement de chronoception (Amsel, 2005; LaMuth, 2011; Lenay, Gapenne, Hanneton, Marque, & Christelle Genouëlle, 2003).

Ensuite cette information est traitée sur un plan cognitif et un plan affectif. Ces deux plans sont liés entre eux (Bonnardel, 2012). Cognition et affect sont constitués par des éléments stables et des éléments qui dépendent de l'événement de la stimulation. Pour Rasmussen les éléments stables de la cognition sont les compétences, les procédures et les connaissances (Rasmussen, 1983). Concernant les éléments dépendants de l'événement, l'information liée au produit est traité sur un plan sémantique, un plan syntactique (prédiction, planification et coordination des réponses) et un plan pragmatique (évaluation face aux motivations et valeurs de la personne) (Cariani, 2001).

La perception affective se constitue également à partir de facteurs stables comme la personnalité de l'utilisateur et ses valeurs et l'affect qu'il attribue au produit en face de lui. L'interaction avec le produit peut avoir un effet sur l'affect ressenti par la personne (Russell, 2003; Scherer, 2005).

Le résultat du traitement cognitif et affectif de l'information est une réponse qui peut avoir lieu sur un plan motivationnel (un désir de s'approcher ou de s'éloigner), sur un plan physiologique (le battement du cœur, la sueur) et sur un plan moteur (se rapprocher de l'objet et saisir le produit) (Bradley & Lang, 2000; Scherer, 2005).

Aujourd'hui de nombreux produits sont équipés avec des capteurs visuels, de force, de mouvement, etc. Ils permettent au produit de percevoir certains signaux de la réponse de l'utilisateur (Arduino, 2012; Helm, Aprile, & Keyson, 2008; Phidgets, 2012). L'information captée est traitée par le processeur du produit et amène à une réponse du produit.

Cette réponse concerne les dimensions que l'utilisateur peut percevoir. Concrètement elle peut porter sur le plan fonctionnel, sur l'apparence, sur le comportement (Lim, Lee, & Lee, 2009; Mutlu, Forlizzi, Nourbakhsh, & Hodgins, 2006) et sur les propriétés sensorielles (Kirkegaard Rasmussen, Pedersen, Petersen, & Hornbæk, 2012). A un niveau plus abstrait, ces dimensions concrètes portent une qualité pragmatique et une qualité hédonique (Hassenzahl, 2003).

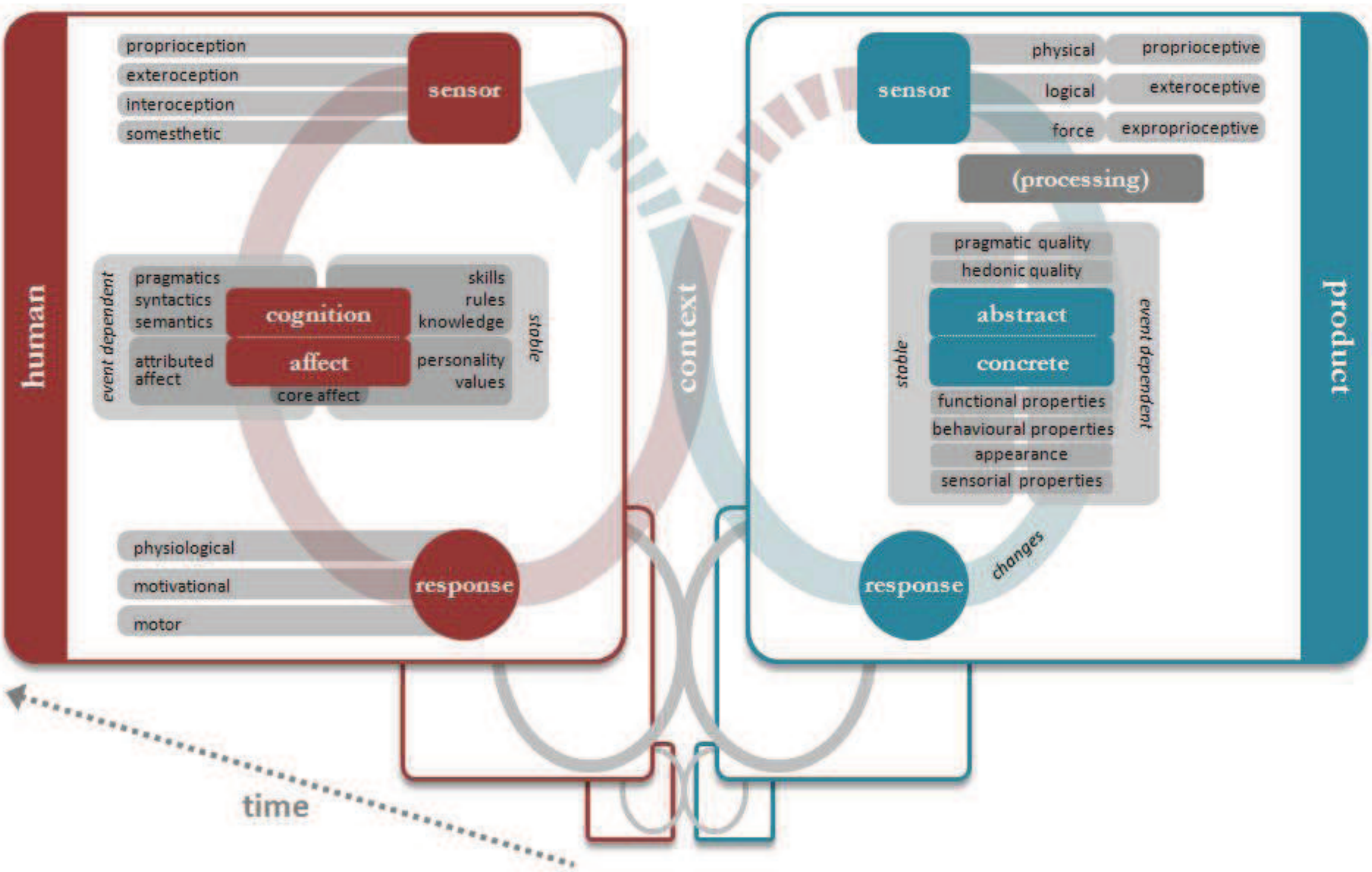


IMAGE 7: MODELE DE L'INTERACTION HOMME-PRODUIT.

La réponse du produit peut ainsi stimuler un nouveau cycle de perception chez l'utilisateur qui résulte en de nouvelles réponses. Comme modélisé par Krippendorff, l'interaction entre l'homme et le produit est donc marquée par des séquences de sensation, de perception et d'action dans le temps (Krippendorff, 2005).

Mais il y a encore une deuxième échelle temporelle. C'est l'UX à long terme. Karapanos a pu démontrer comment l'expérience vécue avec un iphone change entre le moment d'anticipation de l'achat et celui de l'identification après quelques semaines d'utilisation (Karapanos, Zimmerman, Forlizzi, & Martens, 2009). Certaines expériences ne peuvent être vécues qu'une fois, comme la surprise ; d'autres sont suscitées seulement après plusieurs mois d'usage.

Au regard de la complexité des dimensions qui influent sur l'expérience de l'utilisateur, nous constatons qu'il ne suffit plus pour un designer de se concentrer sur la liaison des formes avec les fonctions d'un produit. Aujourd'hui, pour concevoir une expérience, il doit prendre en compte la circularité de l'interaction homme-produit sur plusieurs dimensions dont la qualité pragmatique et hédonique, l'apparence, le comportement, les propriétés sensorielles et fonctionnelles ainsi que la temporalité. Pour cela, il a besoin d'une palette élargie d'outils de conception.

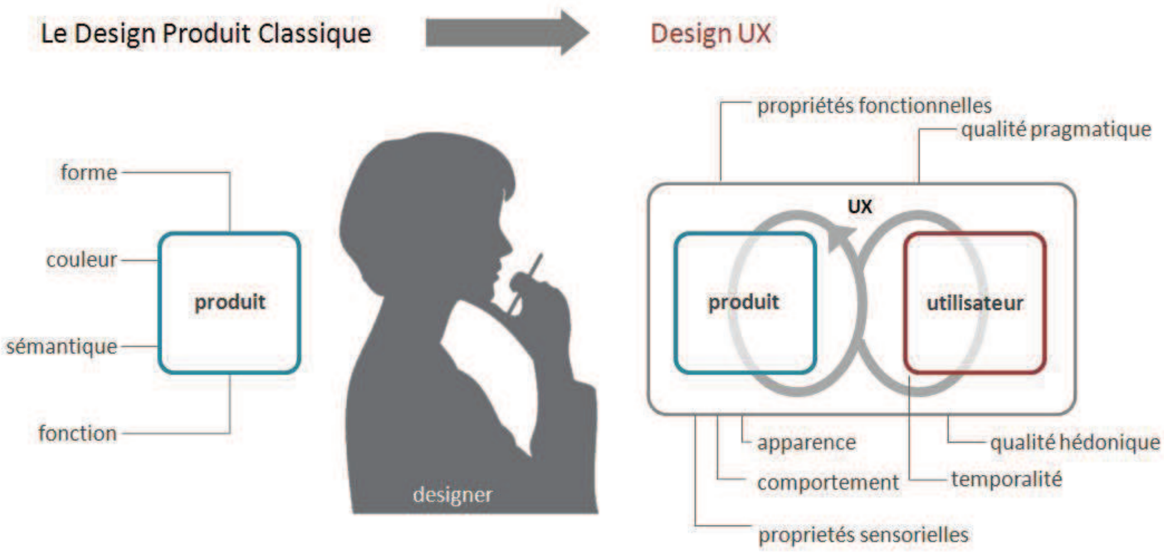


IMAGE 8: DEFI DU DESIGN UX.

2.2 OUTILS POUR LA CONCEPTION DE L'EXPERIENCE DE L'UTILISATEUR

La conception est une première phase dans le processus de développement d'un produit. C'est une phase essentielle car des fautes de conception se révèlent coûteuses une fois le produit entré en production (Folkestad & Johnson, 2001). Anticiper l'expérience de l'utilisateur dès la conception amont doit ainsi donner un avantage concurrentiel.

La phase de conception est constituée de 4 étapes en partie itératives : le recueil d'informations, la génération des idées, l'évaluation des idées et leur communication aux parties-prenantes à la conception. Ces activités se répètent au cours de la conception (Bouchard & Aoussat, 1999; Cross, 2008).

Il existe déjà plusieurs outils dont le designer peut se servir pendant ces 4 étapes de la conception. Certains outils sont devenus des outils standards dans l'activité de design. D'autres outils innovants sont issus du monde de la recherche et attendent encore d'être adoptées par l'industrie.

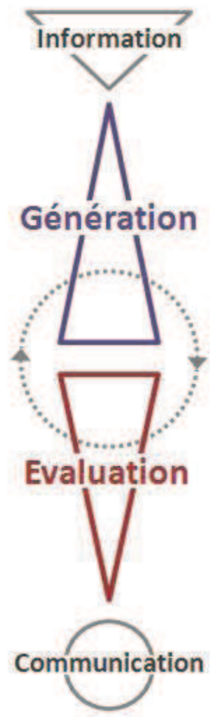


IMAGE 9: PROCESSUS DE CONCEPTION SELON BOUCHARD, AOUSSAT 1999 ET CROSS 2008.

2.2.1 OUTILS POUR LE RECUEIL D'INFORMATIONS

L'obtention d'informations liées à l'expérience de l'utilisateur, peut s'opérer à différents niveaux de connaissance (Bordegoni, 2011; Visser, 2009) :

- le niveau explicite (les gens disent)
- le niveau observable (les gens font)
- le niveau tacite/latent (les gens savent ou rêvent)

En pratique comme en recherche il existe par exemple le « journal d'utilisation ». Le designer peut ainsi demander à un certain nombre d'utilisateurs de tenir un journal sur l'utilisation d'un certain type de produit ou sur une situation dans sa vie quotidienne (Csikszentmihalyi, 1990).

Une autre façon de procéder consiste à inviter un panel d'utilisateurs à créer des collages ou à faire un tri parmi des cartes (Naranjo-Bock, 2012; Stappers & Sanders, 2003).

La recherche pratique également l'analyse de tendances conjointes (ATC) pour étudier les habitudes de consommation. Les tendances sont souvent illustrées sous forme d'images composées (Bouchard,

IMAGE 10 : DES OUTILS POUR LA COLLECTE D'INFORMATIONS UX.

1997; Mantelet, 2006). Il y a aussi des chercheurs qui donnent des objets (design probes) aux utilisateurs et qui s'inspirent de la façon dont ces probes ont été complétées par les utilisateurs (B. Gaver, Dunne, & Pacenti, 1999; Wallace, McCarthy, Wright, & Olivier, 2013).

La méthode la plus couramment pratiquée est l'approche ethnographique. Il s'agit d'observer le comportement des utilisateurs dans leur maison, leur lieu de travail ou autre. Pour rendre cette information tangible, des scénarios sont établis qui racontent « une journée dans la vie de » (Moll, 2006).

2.2.2 OUTILS POUR LA GENERATION DES IDEES

Il est moins évident de trouver des outils qui aident le designer à générer des idées. Un moyen classique de génération d'idées repose sur « la boite à outil de la créativité », comme par exemple les techniques de la purge ou du brainstorming (IDEO, 2013; Prahalad & Ramaswamy, 2004; Sanders & Stappers, 2008; Shulyak, 1998). Les systèmes de l'ingénierie Kansei proposent également – de manière automatique ou semi-automatique – un design ou une tendance en accord avec une expression sémantique ou une émotion envisagée par le designer (Bouchard, 2008; Hsiao, Chiu, & Chen, 2008; Matsubara & Nagamachi, 1997).

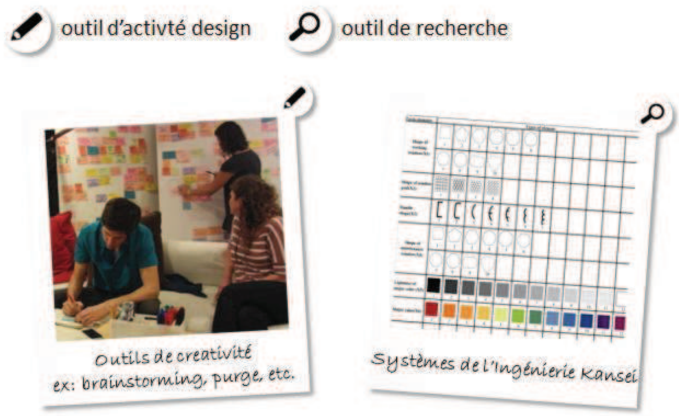


IMAGE 11: OUTILS POUR LA GENERATION UX.

2.2.3 OUTILS POUR L'EVALUATION DES IDEES

Il existe déjà un grand nombre d'outils pour évaluer l'expérience de l'utilisateur. Ces outils peuvent mesurer la réponse de l'utilisateur sur trois niveaux :

1. **UN NIVEAU COGNITIF** : pour cela l'utilisateur remplit des questionnaires à base de différentiels sémantiques ou d'émotions mises en images. L'ensemble des réponses permet d'interpréter l'attitude des utilisateurs face à un produit (Bouchard, Mantelet, et al., 2009; Bradley & Lang, 1994; Desmet, 2002; Osgood, Suci, & Tannenbaum, 1957; Rokeach, 1973; Scherer, 2005; Schwartz et al., 2001).

2. **UN NIVEAU COMPORTEMENTAL :** le comportement moteur du corps et du visage de l'utilisateur est alors observé. Pour cela des appareils comme l'eye tracking ou l'observation vidéo peuvent être utilisés (Freeman, Avons, Meddis, Pearson, & Ijsselsteijn, 2000; Insko, 2003; Karapanos, Zimmerman, Forlizzi, & Martens, 2010; Kim, 2011; Tullis & Albert, 2008)
3. **UN NIVEAU PHYSIOLOGIQUE :** ces mesures permettent au chercheur de mesurer des réactions inconscientes de l'utilisateur au travers de la réponse électrodermale ou la modification du rythme cardiaque (Jenkins, Brown, & Rutterford, 2009; Kim, 2011; Lévy, Yamanaka, Ono, & Watanabe, 2009; Mandryk & Atkins, 2007; Salvia, Rognoli, Malvoni, & Levi, 2010; Tomico, Mizutani, Levy, Takahiro, & Cho, 2008; Tschacher et al., 2012).

Bradley et Lang recommandent une combinaison des ces trois types de mesure pour une interprétation valable (Bradley & Lang, 2000).

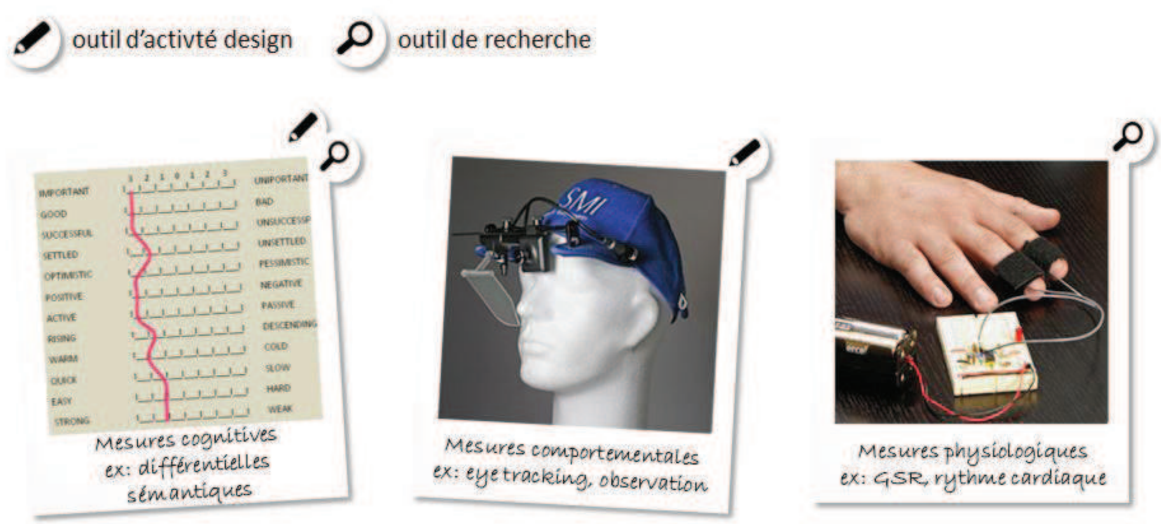


IMAGE 12: OUTILS POUR L'EVALUATION UX.

2.3 LIMITATIONS DANS LA RECHERCHE SUR L'EXPERIENCE DE L'UTILISATEUR

Lors de notre recherche sur les outils de la conception UX, nous avons passé en revue une cinquantaine d'analyses traitant de la relation entre les dimensions abstraites et les dimensions concrètes. Chaque arc dans la graphique ci-dessous (Image 13) montre la relation étudiée dans chacun des articles cités. Ce graphique révèle que la relation entre les dimensions émotionnelles et sémantiques avec des formes et des couleurs a déjà été abondamment traitée. Les sensations suscitées par des matériaux et des textures constituent également un sujet largement traité. Par contre à ce jour **« LES EVALUATIONS DE L'EXPERIENCE DE L'UTILISATEUR N'ONT PAS ENCORE ETE APPLIQUEES AUX DIMENSIONS DYNAMIQUES »** (limitation 1).

Nous constatons également que dans les articles revus **L'EVALUATION DE L'EXPERIENCE DE L'UTILISATEUR** est toujours faite sur des produits finaux mais **PAS ENCORE EN PHASE AMONT DU CONCEPT** (limitation 2). La troisième limitation rencontrée est **« UN MANQUE D'OUTILS D'AIDE A LA GENERATION DE L'EXPERIENCE DE L'UTILISATEUR »** (limitation 3).

Ces trois limitations nous amènent directement à la problématique de notre recherche.

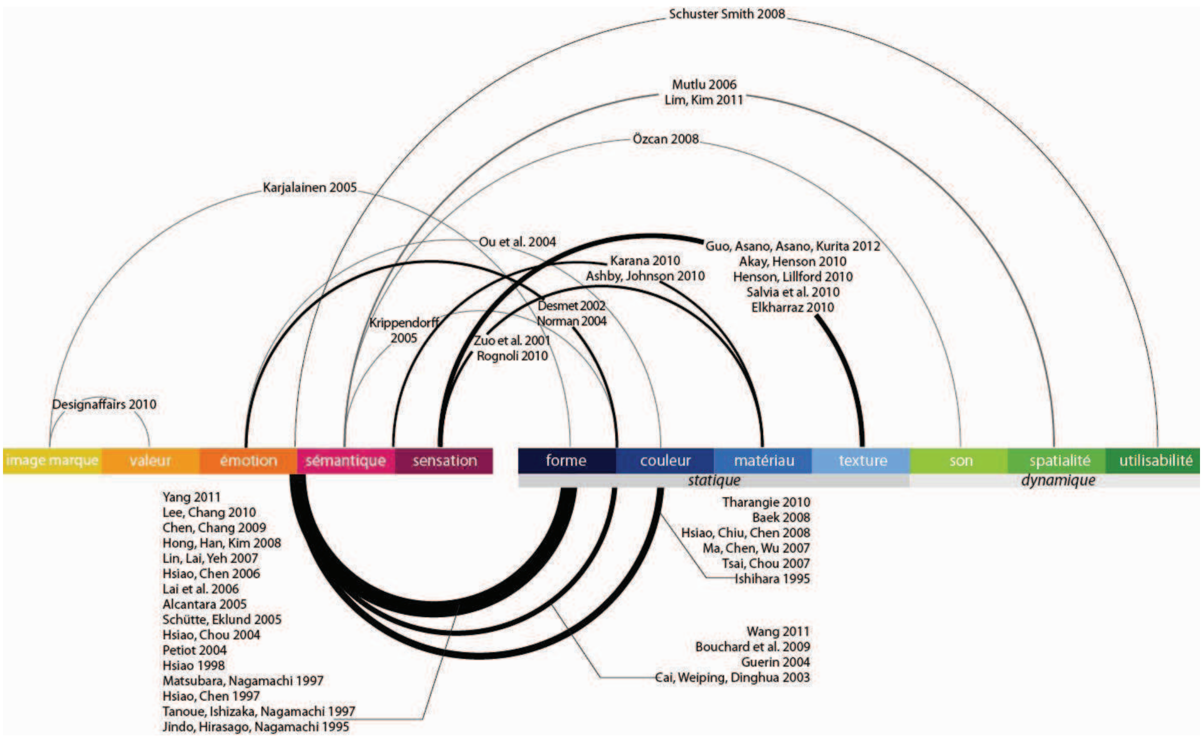


IMAGE 13: RELATIONS ENTRE DIMENSIONS ABSTRAITES ET CONCRETES TRAITES DANS LES ARTICLES DE RECHERCHE.

3 PROBLEMATIQUE DE LA RECHERCHE, HYPOTHESE ET SOUS-HYPOTHESES

Cette thèse a pour but de proposer des outils et une méthodologie pour la conception amont de l'expérience de l'utilisateur. Nous nous demandons ainsi :

COMMENT CONCEVOIR L'EXPERIENCE DE L'UTILISATEUR DES LES PHASES AMONT DE LA CONCEPTION DU PRODUIT?

Pour répondre à cette question, nous avons une hypothèse globale: **« POUR CONCEVOIR L'EXPERIENCE DE L'UTILISATEUR, LE DESIGNER DOIT PRENDRE EN COMPTE UNE LARGE GAMME DE DIMENSIONS DU DESIGN PENDANT LA GENERATION AINSI QUE L'EVALUATION DES CONCEPTS AMONTS. »**

En lien avec cette hypothèse, nous proposons 3 sous-hypothèses:

Sous-hypothèse A: **« DES OUTILS DE DESIGN QUI TRAITENT DES DIMENSIONS KANSEI PEUVENT AMELIORER L'UX DES CONCEPTS GENERES. »**

Sous-hypothèse B: **« LES EVALUATIONS UX PEUVENT ETRE APPLIQUEES DES LES PREMIERES CONCEPTS. »**

Sous-hypothèse C: **« LES EVALUATIONS UX PEUVENT ETRE APPLIQUEES AUX DIMENSIONS DYNAMIQUES COMME LES GESTES DE L'INTERACTION. »**

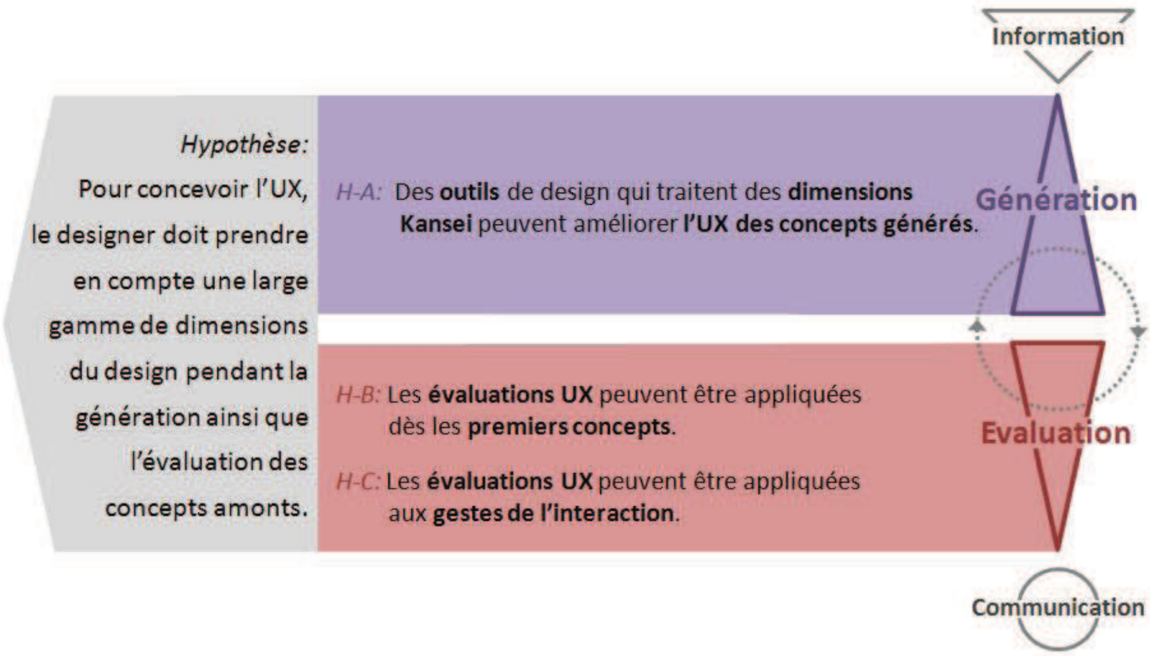


IMAGE 14: HYPOTHESE GLOBALE ET SOUS-HYPOTHESES DE CETTE THESE.

Pour tester ces hypothèses, nous avons mis en place 3 expérimentations.

4 EXPERIMENTATIONS

4.1 PROJET SKIPPI – TERRAIN DES EXPERIMENTATIONS

Le terrain de nos expérimentations a été le projet Skippi sur lequel s'appuie cette thèse. Il s'agit d'un projet ANR pour le développement d'un logiciel pour la conception amont des produits. Ce logiciel comporte une base de données lexicales, dont les mots font partie des dimensions « Kansei », « produit » et « process ». Les mots sont liés entre eux et servent d'inspiration aux designers, ou à leur proposer de nouvelles orientation. Par exemple si le designer cherche à concevoir un produit luxueux, il peut mettre ce mot au centre de sa recherche dans Skippi et le système lui proposera par exemple le matériau 'cuir' et le procédé 'broderie'. Voici quelques reproductions de l'interface du logiciel Skippi.

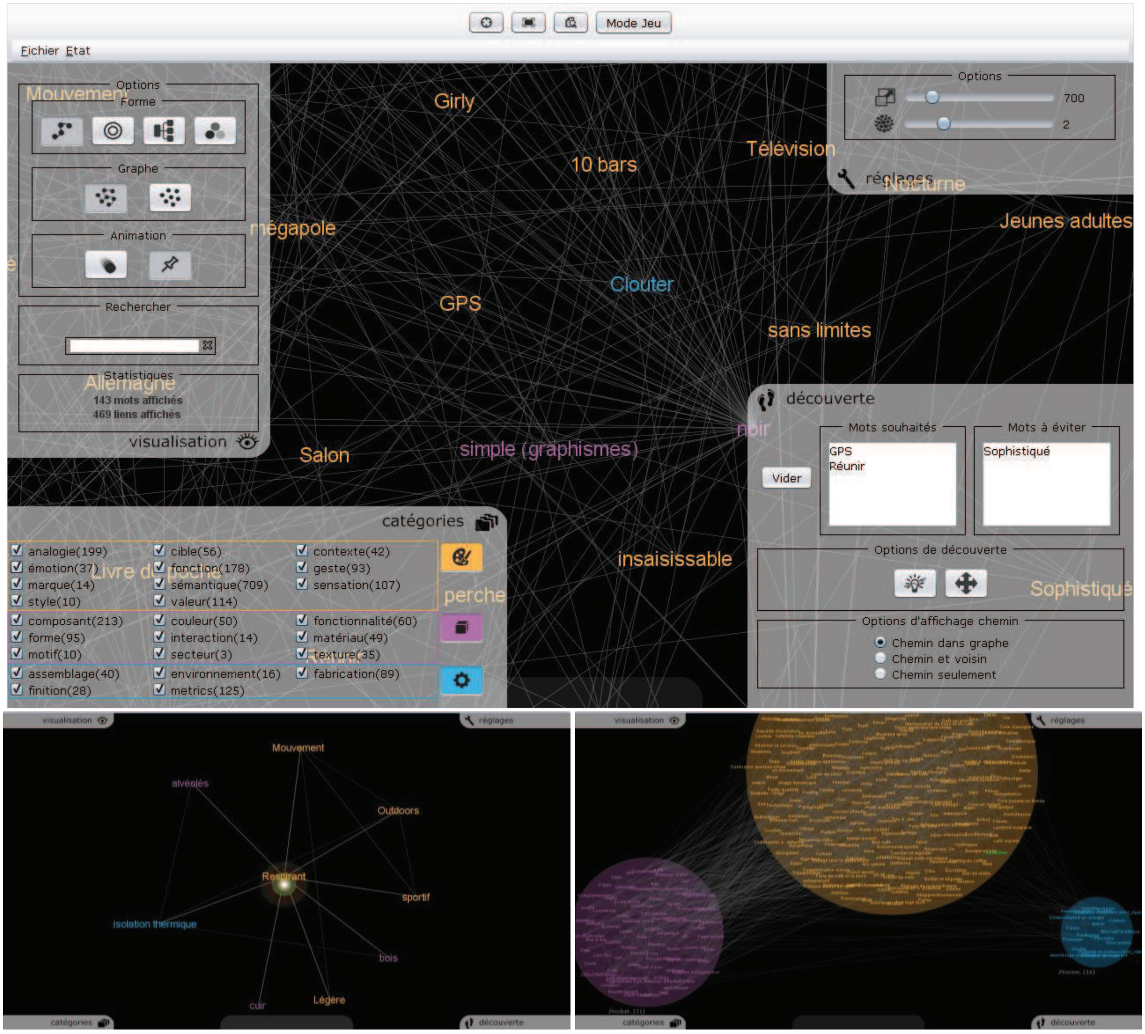


IMAGE 15: CAPTURE D'ECRAN DE SKIPPI

4.2 Ensemble des experimentations

Trois expérimentations ont été mises en place dans le cadre de cette thèse. La première a servi à identifier la gamme des dimensions du design qui constituent l'expérience de l'utilisateur. Dans la deuxième expérimentation nous avons testé l'impact d'un outil comme Skippi sur la génération des concepts (sous-hypothèse A). Elle nous a également permis faire des évaluations des concepts amont (sous-hypothèse B). La troisième expérimentation a eu pour objectif de générer et d'évaluer l'UX d'une interaction (sous-hypothèses A et C).

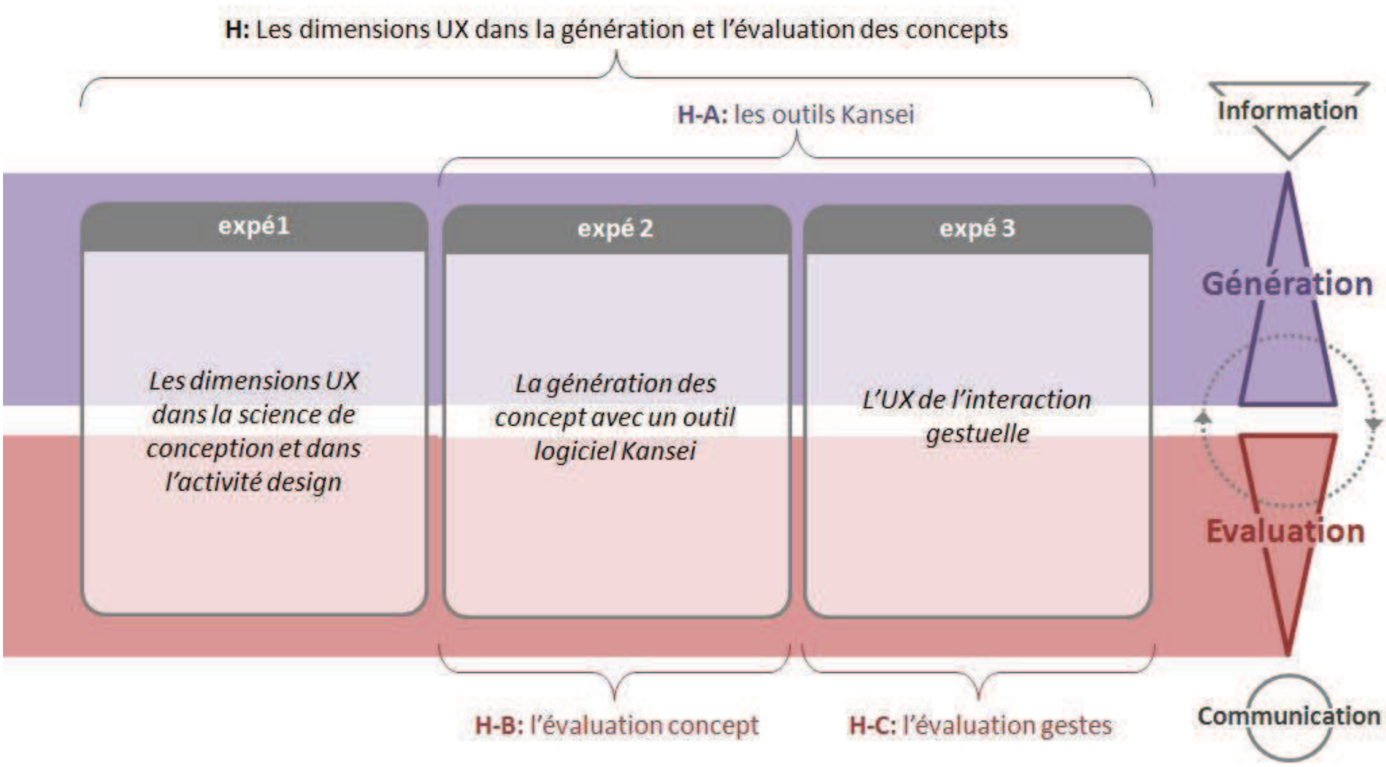


Image 16: Les trois experimentations.

4.3 Experimentation 1

Objectif : L'expérimentation 1 a eu pour but d'établir une liste exhaustive des dimensions qui influencent l'expérience de l'utilisateur.

Méthode globale : Cette expérimentation s'est déroulée en 3 parties. Nous avons cherchée les dimensions de l'UX

1-A actuellement traitées dans la science de conception,

1-B présentes dans des concepts de designers

1-C perçues par l'utilisateur

4.3.1 EXPERIMENTATION 1-A

Objectif : L'expérimentation 1-A a eu pour objectif d'établir une première liste des dimensions UX.

Méthode : Pour cela nous avons choisi 9 modèles liés à l'expérience de l'utilisateur issue de notre Etat de l'Art : (Bouchard, Kim, & Aoussat, 2009; Crilly, Moultrie, & Clarkson, 2004; Forlizzi & Ford, 2000; Hassenzahl, 2003; Kirkegaard Rasmussen et al., 2012; Krippendorff, 2005; Locher, Overbeeke, & Wensveen, 2009; Rooij, Broekens, & Lamers, 2013; Schifferstein & Hekkert, 2008).

Les dimensions présentes dans ces modèles ont été **EXTRAITES, GROUPEES ET POSITIONNEES** pour créer une liste hiérarchique (voir Image 17).

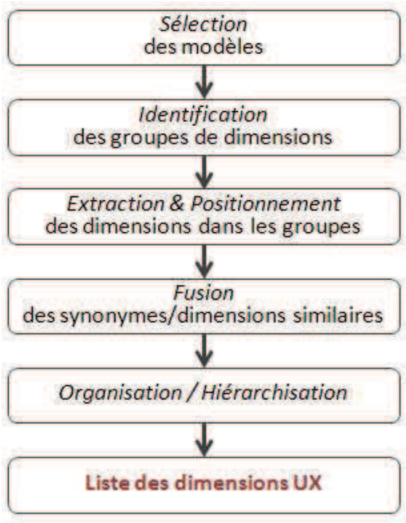


IMAGE 17: DEMARCHE DE L'EXPERIMENTATION 1-C.

4.3.2 EXPERIMENTATION 1-B

Objectif : L'expérimentation 1-B a eu pour objet de compléter la liste des dimensions UX (issues de la science de conception) avec des dimensions prises en compte par des concepteurs.

Méthode : Nous avons fait une expérimentation en deux parties. Dans la première partie les concepteurs se sont rétrospectivement exprimés sur des projets de design. Dans la deuxième partie ils ont entrepris une conception fictive sur la tâche: « concevoir une cafetière communicante pour Adidas ». Chaque exercice a duré 60 minutes. Le protocole a été suivi par 8 designers et 2 ingénieurs (2 ♀ 6 ♂, $\bar{x}$ = 35 ans). Une analyse lexicale des verbalisations de la partie 1 et des mots-clés sur les

IMAGE 18: APERÇUS DE L'EXPERIMENTATION 1-B.

post-it notes de la partie 2 a permis d'affiner la liste des dimensions UX.

4.3.3 Experimentation 1-C

Objectif : Dans cette troisième étape nous nous sommes intéressées au point de vue des utilisateurs sur l'UX des produits.

Méthode : Nous avons initié deux groupes, l'un avec 5 participants (2 ♀ 3 ♂, $\bar{x}$ = 28ans) et l'autre avec 6 participants (1 ♀ 5 ♂, $\bar{x}$ = 29ans). Les participants avaient amené avec eux des produits considérés comme réussis au niveau UX. Au total 14 objets ont ainsi été discutés. Les mots-clés de ces verbalisations ont été extraits et utilisés pour enrichir la liste des dimensions UX.

Image 19: Objets étudiés.

4.3.4 Resultats de l'experimentation 1

Nous avons obtenu une liste contenant trois niveaux. Au premier niveau les dimensions sont réparties entre des dimensions liées à l'humain (p.ex. la cible, cognition et affect, le système moteur), des dimensions produit (la fonction, le caractère, les propriétés sensorielles, l'apparence, le comportement, etc.) et des dimensions du contexte de l'utilisation (la culture et la situation (endroit, heure)).

- Nous avons trouvé que certaines dimensions n'apparaissaient qu'en recherche mais pas encore dans l'activité de design : notamment le système sensoriel, la qualité de la production et les facteurs sociaux (en gris dans le Tableau 1.)
- D'autres dimensions n'apparaissent qu'en activité de design mais pas encore dans la recherche : en particulier le nom et le type de produit, les propriétés fonctionnels et le processus de production (en italiques dans le Tableau 1.)

- Les deux parties de la sous-expérimentation 1-B avec les concepteurs a démontré que des dimensions telles que le caractère du produit, l'apparence et le process de production apparaissent très peu dans la conception amont. (Voir la comparaison entre partie 1 et partie 2 dans le Tableau 1.)

- L'analyse des données des utilisateurs a montré que les dimensions les plus marquantes pour leur expérience sont l'affect, les gestes moteurs, les propriétés sensoriels et le comportement du produit.

TABLEAU 1: DIMENSIONS UX EN RECHERCHE ET EN ACTIVITE DESIGN, AVEC DES EXEMPLES ET L'OCCURRENCE DES DIMENSIONS DANS DES CONCEPTS.

dimension		part 1 621 words	part 2 489 words	example properties (from the study)
human		85	81	
target user		17	23	
	single / group	3	8	couple, family, individual
	occupation	4	7	worker, senior executive CEO, golfer
	age	5	6	45+, child, young adult
	gender	1	0	woman
	cultural background/living environment	3	1	cosmopolitan, Londoner
	personal taste / aesthetic sophistication	1	2	fashion victim, MTV fan
sensory system / state		0	0	
stable cognition & affect		35	29	
	cognitive contents (knowledge, experience/memories)	0	1	memories
	personality / disposition	4	3	rebel, optimist, opinion leader
	motivations/values/concerns/needs	29	25	trust, authenticity, sustainability
event dependent cognition & affect		2	0	
	core affect	2	0	fun, sad
	perceived character	0	0	
motor system / state		33	29	
	actions/behaviours	10	17	erase, go to page…, leave, look at, taste
	interaction gesture	19	10	push, wink, lift-off, scratch, shake, strike
	posture / body	4	2	sitting, head, spine,
product		423	327	
product sector		2	1	cosmetics, bricolage, sport
product type		2	2	smart phone, shower gel, coffee maker
product name		1	1	Binder, Café' in
function/practical purpose		14	53	classification, decoration, communication
functional property		23	15	stable, breathable, unbreakable, hermetic
feature		98	90	
	functionality	29	19	video call, illumination, thermal isolation
	content	9	14	information, sport news, city map, horoscope
	sensory capacities	6	7	acceleration, voice recognition, heart rhythm
	composition/component	41	34	battery, arm, body housing, screen, handle
	technology	11	14	3G, Bluetooth, GPS, Wi-Fi
	position	2	2	inside, external
intended character		109	76	
	affective	15	4	surprising, reassuring, pleasant, funny
	aesthetic	6	0	phantasy, pretty, aesthetic, elegant
	semantic	50	35	urban, sporty, masculine, industrial
	analogy/symbolic	24	31	monolith, pocketbook, water drop, cosmetic flask
	brand style/objective	9	2	internationality, innovation, rupture
	style	5	4	retro-cool, murdered-out
sensorial property		5	11	warm, soft, hard, odoriferous
static appearance / structural property		142	57	
	material	21	14	stainless steel, carbon, wood, cotton
	texture	5	2	grained, smooth, plaited
	viscosity/elasticity	1	1	flexible, stiff, ductile
	colour	31	11	white, red, dark blue, golden, elastomer
	graphic/detail/label	27	10	arabesque, little squares, floral
	form/geometry	45	12	asymmetric, curved, circular, straight
	dimensions/size/volume	11	4	compact, huge, long
	weight	1	3	ultra-light, light, weight-reduced
behaviour/action		11	14	
	visual response	8	5	diagonal movement, reflection, rotation, light
	sonorous response	2	3	clack, creak
	tactile response	1	0	inertia, vibration
	olfactory/gustatory response	0	5	perfume, odour, taste
	response speed	0	1	quick
production method	*fabrication, assembly, finishing*	16	7	injection moulding, weaving, engraving
production quality	tolerances, finishing, ageing	0	0	
context		52	70	

cultural factors/references		25	23	
	similar products/brands/activities	16	11	stationeries, Apple, athletics, architecture
	clichés/stereotypes	6	9	made in China, Tuareg, science fiction
	trends/fashions/tastes/conventions	3	3	tradition, fashion wear, fashionable
situational factors		27	47	
	viewing time	0	0	
	related products/features/things	7	27	Facebook, soap, MP3 player, back pack
	place	9	8	bar, workshop, library, outdoors, street
	time	6	6	Sunday, summer
	event/activity	5	6	promenade, soccer,
social factors		0	0	

Avec cette première expérimentation, nous validons la première partie de notre hypothèse globale: « Pour concevoir l'expérience de l'utilisateur, le designer doit prendre en compte une large gamme des dimensions design ». Les deux expérimentations suivantes se concentrent les questions de la génération et de l'évaluation des concepts amont.

4.4 Experimentation 2

4.4.1 Objectif

La deuxième expérimentation a servi à tester un outil Kansei – Skippi – (sous-hypothèse A) et des évaluations des concepts amont (sous-hypothèse B).

4.4.2 Methode

Dans un premier temps, nous avons testé l'impact du logiciel Skippi sur la qualité UX des concepts amont. Pour évaluer l'impact de Skippi sur ces concepts, l'étude a été conduite avec deux groupes de 7 concepteurs, dont l'un a travaillé **AVEC** le logiciel Skippi et l'autre **SANS** ce logiciel. Le cahier des charges était de « concevoir un sac interactif pour la marque Diesel » en 60 minutes environ. Les

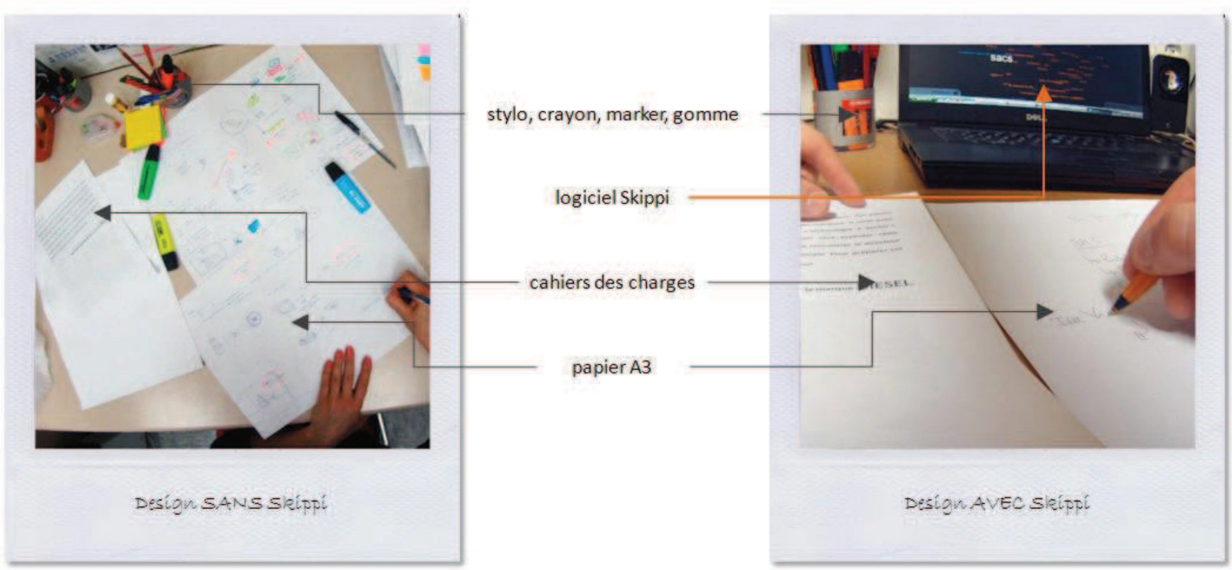


Image 20: Equipements de l'experimentation 2 –Avec ou sans Skippi.

productions ainsi obtenues ont été analysées sur la base des mots-clés mis en exergue.

Dans un deuxième temps, une évaluation de ces productions a été conduite. Pour rendre les idées comparables, 29 fiches idées ont été établies à partir des 54 productions de nos 14 participants. Les fiches idées avaient toutes la même charte graphique (Image 21).

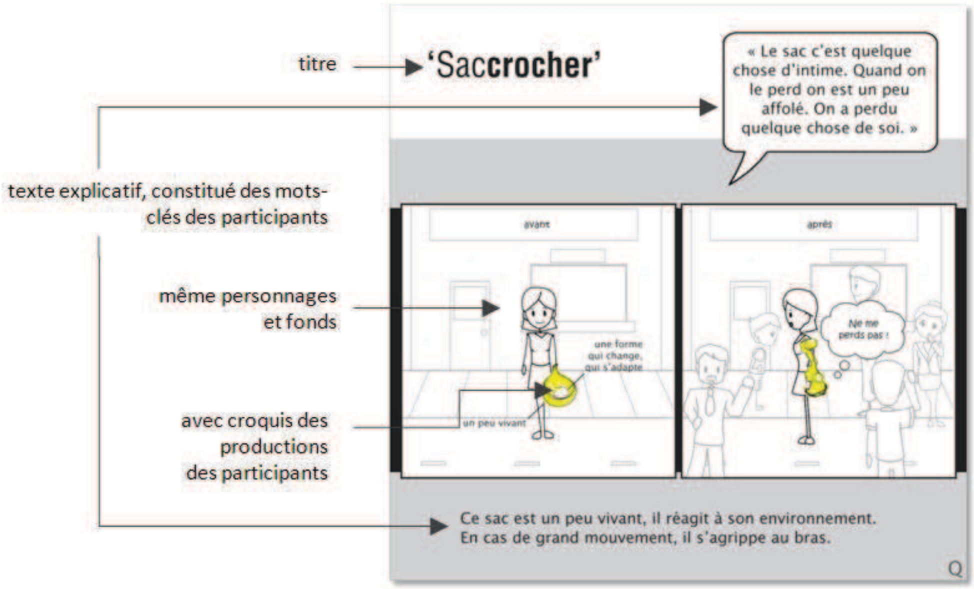


IMAGE 21: EXEMPLE DE FICHE IDEES, EXPERIMENTATION 2.

Par la suite, ces 29 fiches ont été incluses dans un questionnaire (échelle Likert de 5-points) sur 7 critères des l'expérience de l'utilisateur. Ces critères ont été constitués à partir des résultats de l'expérimentation 1-C et de critères proposés par 2 experts en design.

Les critères retenus pour le questionnaire étaient les suivants :

1. l'accord avec le brief et la marque
2. l'utilité
3. la praticité
4. la plaisance
5. le dynamisme
6. la faisabilité
7. l'originalité

3 autres critères n'ont pas pu être évalués car l'information ne figurait pas dans les fiches idées :

1. l'esthétique
2. la qualité sensorielle
3. le confort

Ce questionnaire a été rempli par un jury de 6 experts en design et un jury de 7 utilisateurs 'cible Diesel'.

4.4.3 Resultats de l'experimentation 2

Si nous comparons les productions des participants 'sans et avec Skippi', nous constatons d'abord que :

- les participants avec Skippi ont eu plus de facilité à produire des idées uniques. 6 des 7 participants avec Skippi ont eu au moins une idée unique. Sans Skippi seulement 3 des 7 participants ont pu générer une idée unique.
- Ensuite, concernant la profondeur de la présentation des idées, il apparaît que 4 sur 7 participants sans Skippi ont fourni des croquis des scenarios et les 3 autres quelques croquis du produit. Dans le groupe avec Skippi les formats de présentation sont très divers. Ils vont d'une cartographie par mots-clés jusqu'au dessin détaillé du produit avec la définition de toues ses dimensions essentielles. Globalement, les productions réalisées avec Skippi révèlent ainsi une plus grande profondeur.
- L'analyse des mots-clés dans des verbalisations et sur des productions montre un nombre deux fois plus important de descripteurs sémantiques dans les productions avec Skippi.
- La marque Diesel se retrouve dans l'ensemble des productions des participants avec Skippi alors qu'elle n'est mentionnée que dans 2 productions sur 7 des participants sans Skippi. Plusieurs participants sans Skippi ont en effet indiqué verbalement qu'ils avaient oublié la marque en cours de conception.
- Dans les commentaires libres, les participants avec Skippi disent que Skippi leur a permis de s'émanciper de leur univers d'idées.

  "Skippi donne un point de vue impersonnel, un certain détachement" (P6);

  "…ça ouvre l'horizon pour des idées non-exploitées et ça accélère la génération des idées en stimulant l'imagination avec des mots proposés." (P1)

Un effet moins favorable de l'utilisation de Skippi a cependant pu être observé avec un participant designer novice dont la production s'est limitée à une production de mots-clés, ce qui n'est pas le but de Skippi.

Par ailleurs, concernant le nombre de mots-clés générés et l'évaluation des idées sur les critères de l'UX, aucune disparité notable n'a été observée entre les deux groupes de participants : l'utilisation de Skippi n'a pas favorisé de meilleurs résultats dans ces domaines (Image 22). Le t-test de Student a en effet montré que la différence entre les deux groupes sur la plupart des critères n'a pas été signifiante. Elle est plus forte entre les individus d'un même groupe qu'entre les groupes eux-mêmes.

Nous ne pouvons donc pas valider la sous-hypothèse A selon laquelle « Les outils design qui traitent les dimensions Kansei peuvent améliorer l'expérience de l'utilisateur potentiel des concepts générés. » Mais un autre outil de génération UX est testé dans l'expérimentation 3.

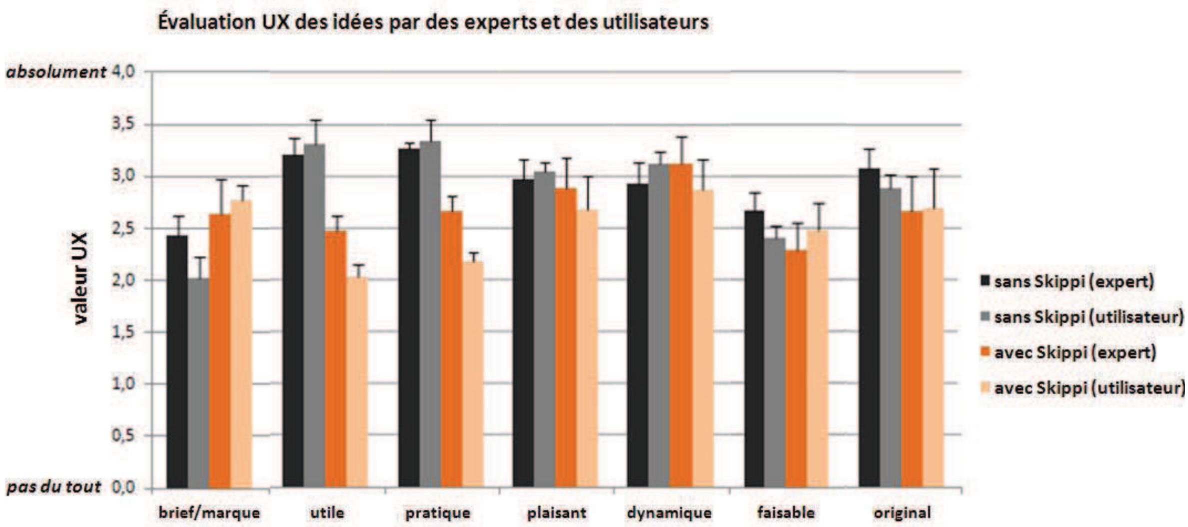


IMAGE 22: VALEURS DE L'EVALUATION UX SUR 7 CRITERES (ECHELLE LIKERT DE 0(MIN) A 4(MAX)).

L'évaluation UX des idées conçues s'est cependant traduite par un niveau d'accord satisfaisant entre les membres du jury d'experts comme entre ceux du jury d'utilisateurs. Tous arrivent à un alpha de Cronbach qui dépasse 0,7. Les évaluations des utilisateurs suivent en outre la même tendance que celles des experts. Ce résultat valide notre sous-hypothèse B selon laquelle il « il est possible d'appliquer des évaluations UX aux concepts amonts. »

4.5 EXPERIMENTATION 3

4.5.1 OBJECTIF

La troisième expérimentation est centrée sur le design de l'interaction de Skippi. Elle porte d'une part sur la génération des gestes d'interaction et d'autre part sur l'évaluation de ces gestes en comparaison avec d'autres modes d'interaction plus classiques.

4.5.2 METHODE

Pour générer un set de gestes d'interaction, nous avons mené une séance de créativité. La génération des gestes a été faite à partir de l'outil **BODY STORMING**. 8 concepteurs ont été invités à imaginer et mimer les gestes de l'interaction pour les 79 fonctionnalités de Skippi. Ensuite ces gestes ont été transcrits en image ou séquence d'images. Certaines fonctionnalités ont suscité jusqu'à 8 idées de gestes différents. Il a été nécessaire d'en faire un classement selon leur valeur UX et ensuite selon leur faisabilité.

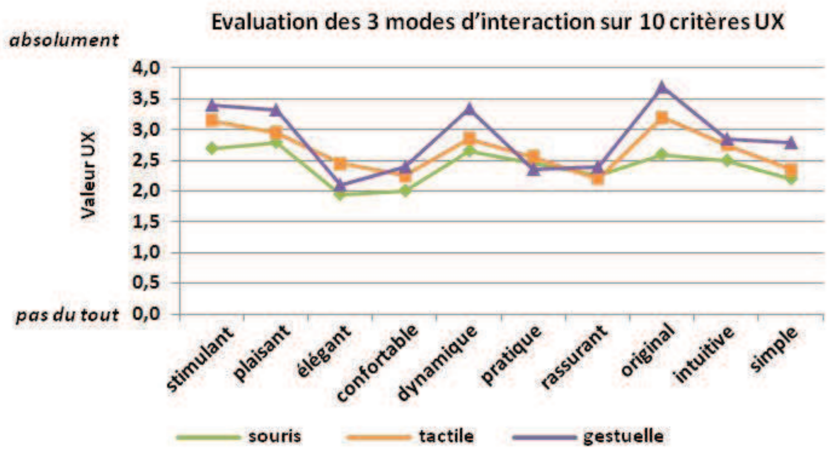
6 gestes ont été retenus et intégrés dans le prototype de Skippi pour l'évaluation de cette expérimentation. 3 modes d'interaction ont été comparés : l'interaction avec la souris informatique, l'interaction tactile et l'interaction gestuelle. Il a été demandé aux participants (1) d'observer l'interaction, (2) de tester certaines fonctionnalités et (3) d'explorer ensuite librement les différentes interactions.

Après chaque activité les participants ont rempli un questionnaire sur les 10 critères UX (stimulant, plaisant, élégant, confortable, dynamique, pratique, rassurant, original, intuitif, simple). Pendant l'interaction gestuelle nous avons également enregistré leur réponse électrodermale et une vidéo de leur mouvement. L'évaluation a pris 60 minutes. Le protocole a été suivi par 21 utilisateurs.

4.5.3 Resultats de l'experimentation 3

La comparaison des 3 modes d'interaction nous amène aux résultats suivants :

- L'interaction gestuelle a obtenu le score le plus élevé pour tous les critères UX (stimulant, plaisant, confortable, dynamic, rassurant, original, intuitif, simple) sauf pour les critères 'élégant' et 'pratique'.
- Au total, l'interaction gestuelle atteint le meilleur résultat en terme d'évaluations UX, suivi par l'interaction tactile, à enfin par la souris informatique. En classement direct, les utilisateurs trouvent l'interaction tactile la mieux adapté à l'interface de Skippi, suivie par les gestes et la souris. Ils considèrent que l'expérience de l'utilisateur est la plus riche avec l'interaction gestuelle, mais dans une situation de travail les gestes ne leur semblent pas encore aussi pratique que le tactile.



Choix direct
de préférence d'interaction

rang	points	interaction
1.	42	tactile
2.	40	gestuelle
3.	38	souris

Image 23 : Valeurs de l'evaluation UX sur 10 criteres (echelle Likert de 0(min) a 4(max)) vs Choix direct de preferences d'interaction.

Les questionnaires ont été répondus en 3 temps : (1) Après l'observation, (2) après le premier contact et (3) après l'exploration libre.

- Il ressort de cette évaluation en 3 temps que la valeur UX des trois modes d'interaction a tendance à converger à terme. Ainsi, après seulement 15 minutes d'interaction l'effet de nouveauté et le préjugé sur l'UX disparaissent.

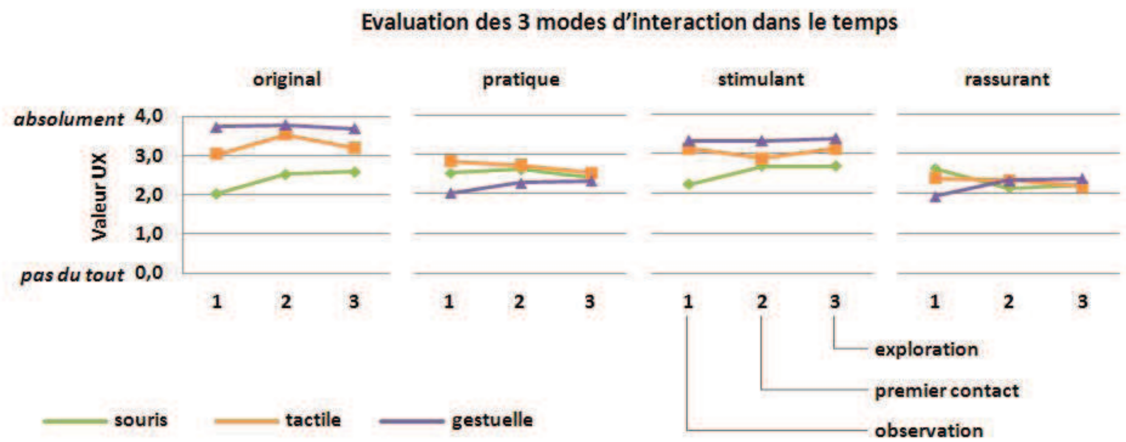


IMAGE 24: VARIATION DES VALEURS DE L'EVALUATION UX DANS LE TEMPS POUR LES 3 MODES DE L'INTERACTION.

L'expérimentation nous a également permis de recueillir des retours sur chacun des 6 gestes pratiqués. Il s'agit des gestes suivants:

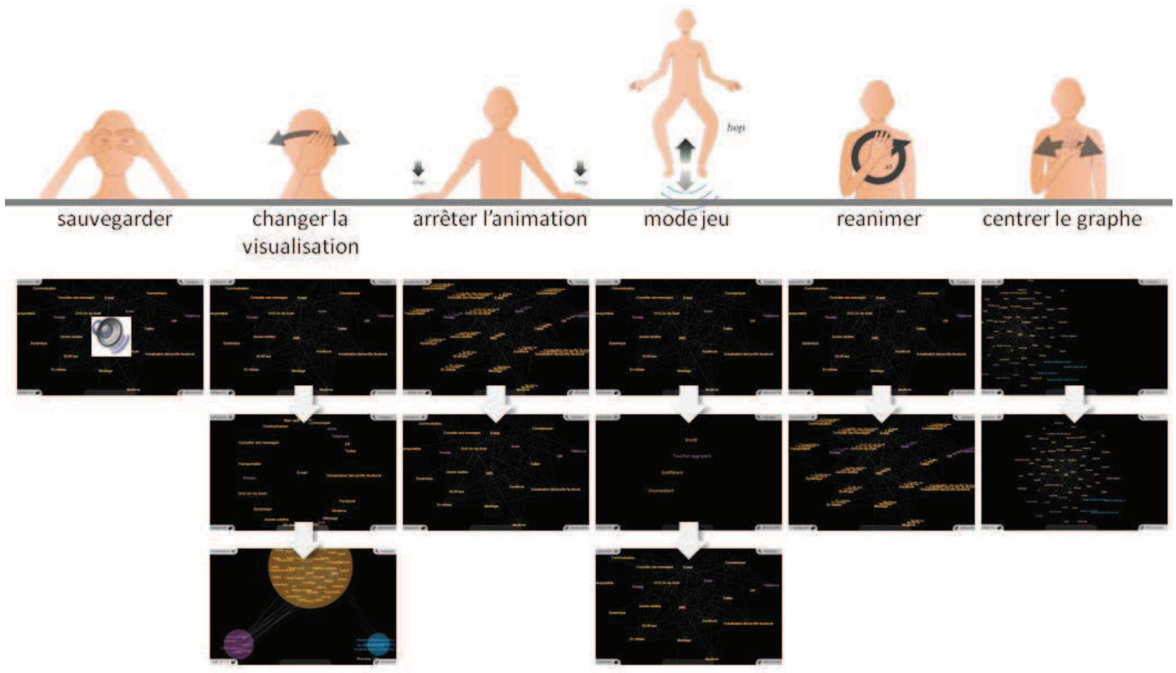


IMAGE 25: 6 GESTES EVALUES DANS EXPE 3.

IMAGE 26: COMPARAISON DES RESULTATS D'EVALUATION POUR LES 6 GESTES D'INTERACTION.

Les valeurs UX obtenus par geste sont équivalentes à leur classement direct, sauf pour les deux derniers. Les gestes pour 'sauvegarder l'état' et 'changer la visualisation' ont obtenus un meilleur score et un meilleur classement dans le questionnaire.

- Ce résultat est corroboré par les réponses électrodermales des participants : nous avons vu une réaction de stimulation pour tous les participants pour les gestes 'sauvegarder', 'changer la visualisation' et 'mode jeu'. 75% des participants ont réagit sur 'arrêter l'animation' et seulement 50% sur les deux autres.
- Dans le cas de 'centrer' la moitié des réactions se sont produites suite à un problème d'interaction. Ce geste a effet eu le taux d'échec le plus important. 'Sauvegarder l'état' et 'mode de jeu' n'ont jamais causé d'échec.

L'enregistrement vidéo nous a permis de coder le comportement des participants au niveau de la précision, de la vitesse et de l'amplitude de leurs mouvements. La matrice de corrélation montre une corrélation positive entre le sucés d'exécution du geste avec une bonne précision et une corrélation négative du sucés avec une grand vitesse du mouvement. La précision est positivement liée à une vitesse et à une amplitude moyenne. Une grande vitesse et une large amplitude ne sont pas favorables à la précision. Au travers du questionnaire nous avons aussi obtenu de l'information sur le type de personnalité de nos participants (introverti, extraverti ou normal). Nous observons que les personnes extraverties ont tendance à effectuer des mouvements d'une grande vitesse et d'une large amplitude.

Les bons scores obtenus par la plupart des gestes confirment l'effectivité de l'outil 'body storming' et en cela notre sous-hypothèse A. En outre, la bonne cohérence entre les résultats des trois types de mesure valide notre sous-hypothèse C que « Les évaluations UX peuvent être appliquées aux dimensions dynamiques comme les gestes de l'interaction. »

4.6 SOMMAIRE DES EXPERIMENTATIONS

Les trois expérimentations nous ont permis de valider l'hypothèse globale : **POUR CONCEVOIR L'EXPERIENCE DE L'UTILISATEUR, IL EST EN EFFET NECESSAIRE QUE LE DESIGNER PRENNE EN COMPTE UNE LARGE GAMME DE DIMENSIONS PENDANT LA GENERATION AINSI QUE LORS DE L'EVALUATION DES CONCEPTS.**

Nous avons pu élargir le champ des **EVALUATIONS UX SUR LES CONCEPTS AMONT** et **SUR LES DIMENSIONS DE L'INTERACTION**. Ce qui a validé les sous-hypothèses B et C.

Pour la génération des idées, nous avons testé 2 outils – **SKIPPI** et **BODY STORMING**. Les outils ont montré certains effets positifs sur la conception mais la sous-hypothèse A reste à explorer plus avant avec d'autres outils de génération d'idées.

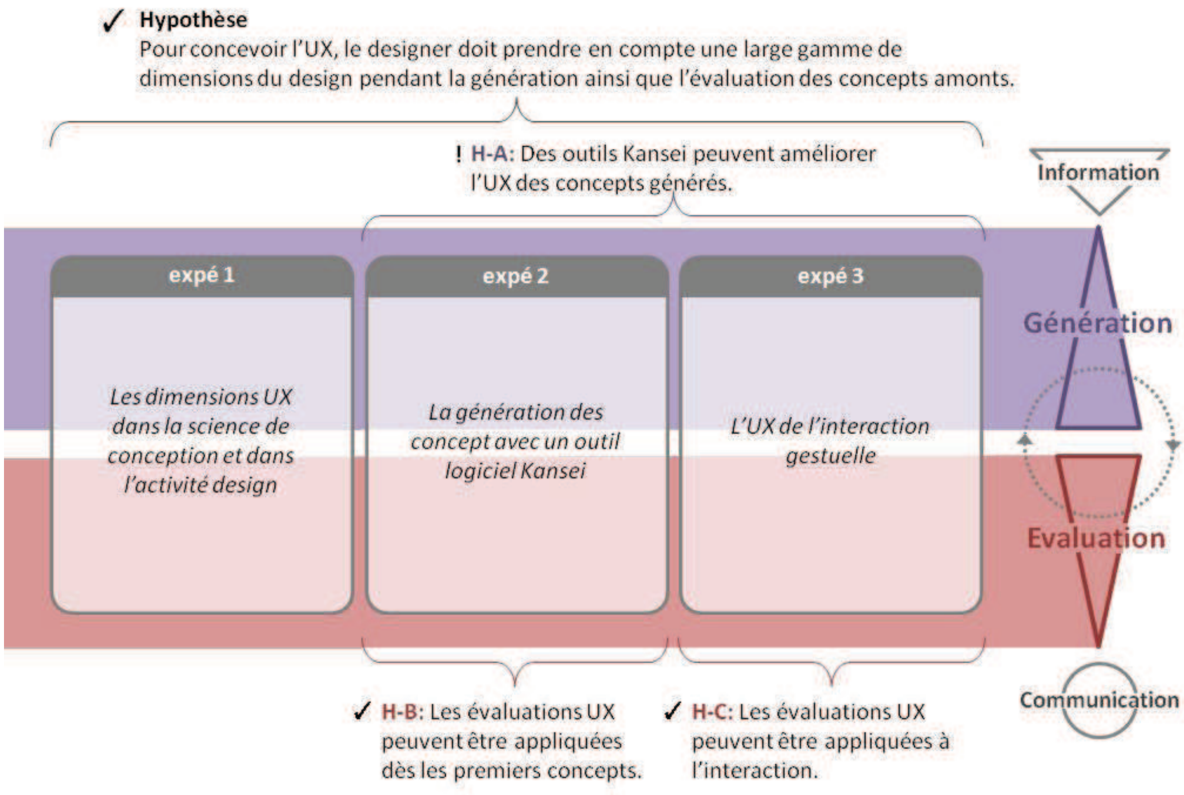


IMAGE 27: SYNTHESE DES EXPERIMENTATIONS ET HYPOTHESES VALIDEES.

5 APPORTS DE CETTE THESE

Cette thèse contribue à la recherche en design ainsi qu'au design pratique. Nous avons réuni ces contributions en un modèle pour la conception UX. Les apports prennent la forme d'outils, d'apports théoriques et d'un modèle UX.

Reprenons le processus de conception. Nous avons une équipe de design qui cherche à concevoir un produit avec une bonne expérience de l'utilisateur. Pour cela ils suivent les 4 étapes de la conception. D'abord il faut s'informer sur le sujet, la cible, les objets existants, etc. Ensuite le designer génère les premières idées. Pour effectuer la génération d'idées favorables à l'UX, cette thèse propose 3 outils :

- **UNE LISTE AVEC DES DIMENSIONS DE L'EXPERIENCE DE L'UTILISATEUR** (issue de l'expérimentation 1)
- **LE LOGICIEL SKIPPI** (expérimentation 2 et 3)
- **LE BODY STORMING** (expérimentation 3)

D'autres outils attendent d'être explorés pour cette activité de conception.

Une fois les premières idées générées, le concepteur doit évaluer ses idées pour choisir et avancer dans sa conception. Nous avons vu qu'il était possible de faire les **PREMIERES EVALUATIONS UX SUR DES CONCEPTS AMONT** et pas seulement au stade des prototypes ou des produits finaux.

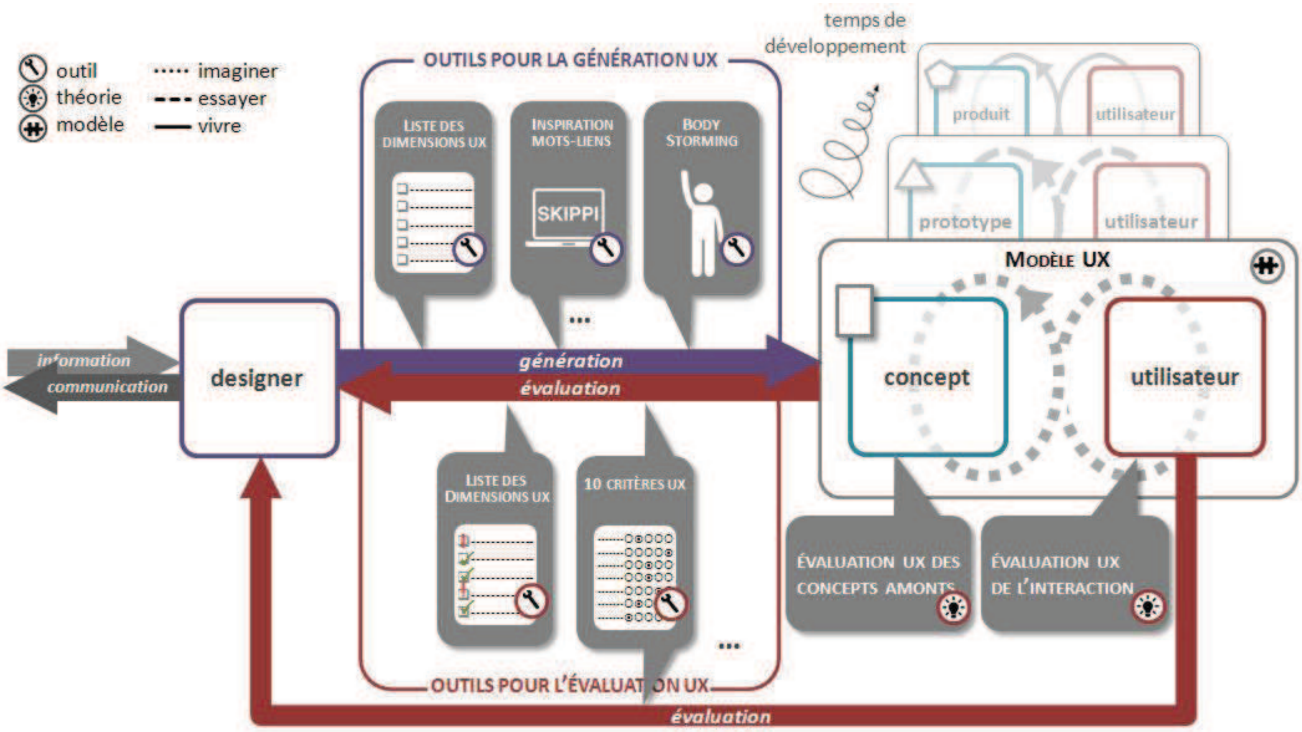


IMAGE 28: MODELE DE LA CONCEPTION POUR UX INTEGRANT LES APPORTS DE LA THESE.

L'évaluation peut d'abord être faite en auto-évaluation par le designer lui-même. Pour cela, nous proposons un **RETOUR A LA LISTE DES DIMENSIONS UX**. Elle lui permet de vérifier la prise en compte ou l'absence de certaines dimensions dans son concept. Il peut aussi effectuer des évaluations avec des utilisateurs potentiels. Pour cela, cette thèse fournie **UNE LISTE DE 10 CRITERES UX** (appliquée dans les expérimentations 2 et 3) qui permet de conduire cette évaluation. Ces critères sont

- **LA COHERENCE AVEC LE BRIEF ET LA MARQUE**
- **L'UTILITE**
- **LA PRATICITE**
- **LA PLAISANCE**
- **LE DYNAMISME**
- **LA FAISABILITE**
- **L'ORIGINALITE**
- **L'ESTHETIQUE**
- **LA QUALITE SENSORIELLE**
- **LE CONFORT**

Nous encourageons également les concepteurs à appliquer des méthodes d'**EVALUATION** pas seulement sur l'apparence du produit mais aussi **SUR LES DIMENSIONS DE L'INTERACTION**.

Une fois qu'un concept est choisi, il est communiqué aux autres membres de l'équipe de développement produit ou aux clients.

6 PERSPECTIVES

Une thèse répond à certaines questions mais elle met également au jour de nouvelles questions à résoudre.

Nous proposons 3 directions pour poursuivre nos recherches

1. Dans cette thèse nous avons établi une liste des dimensions UX. Elle est très complexe et nous avons conscience que toutes les dimensions ne seront pas aussi pertinentes d'un projet à l'autre. Pour une application pratique, il sera utile d'identifier les dimensions UX prioritaires par secteur de produit.

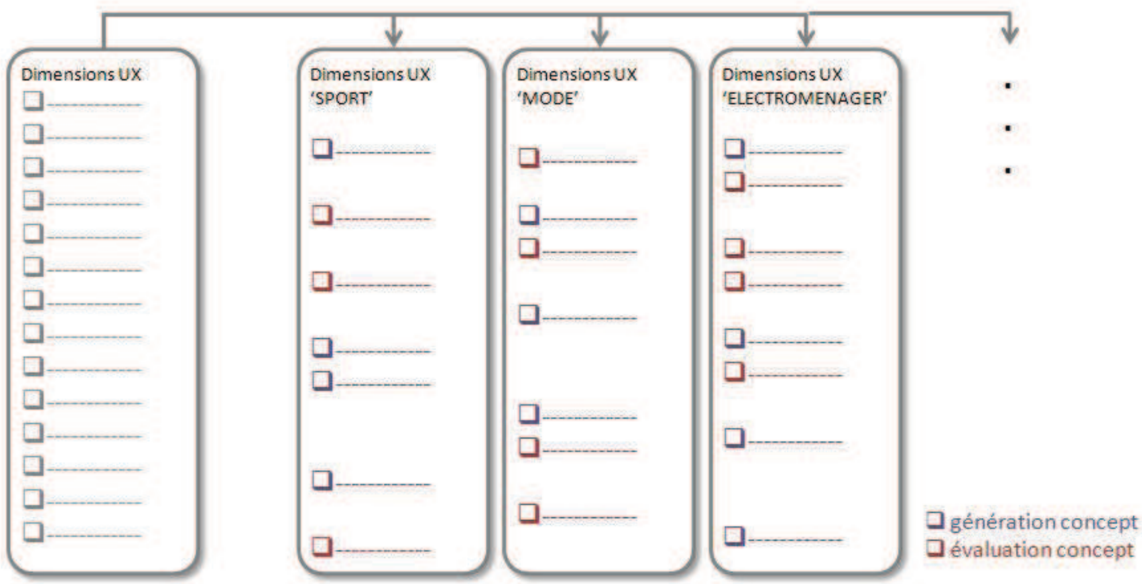


IMAGE 29: PERSPECTIVE 1, DECLINAISON DES DIMENSIONS UX PAR SECTEUR DE PRODUIT.

2. Nous avons appliqué des évaluations UX aux concepts amont. Les résultats ont montré la possibilité d'évaluer les premières idées sur beaucoup de critères UX. Néanmoins, nous ne savons pas encore si les concepts avec un bon score UX deviendront vraiment des produits avec un bon UX. Idéalement il conviendrait de mettre en place une chaîne d'évaluations UX allant des concepts amonts jusqu'au produit final pour valider l'effectivité des évaluations amonts.

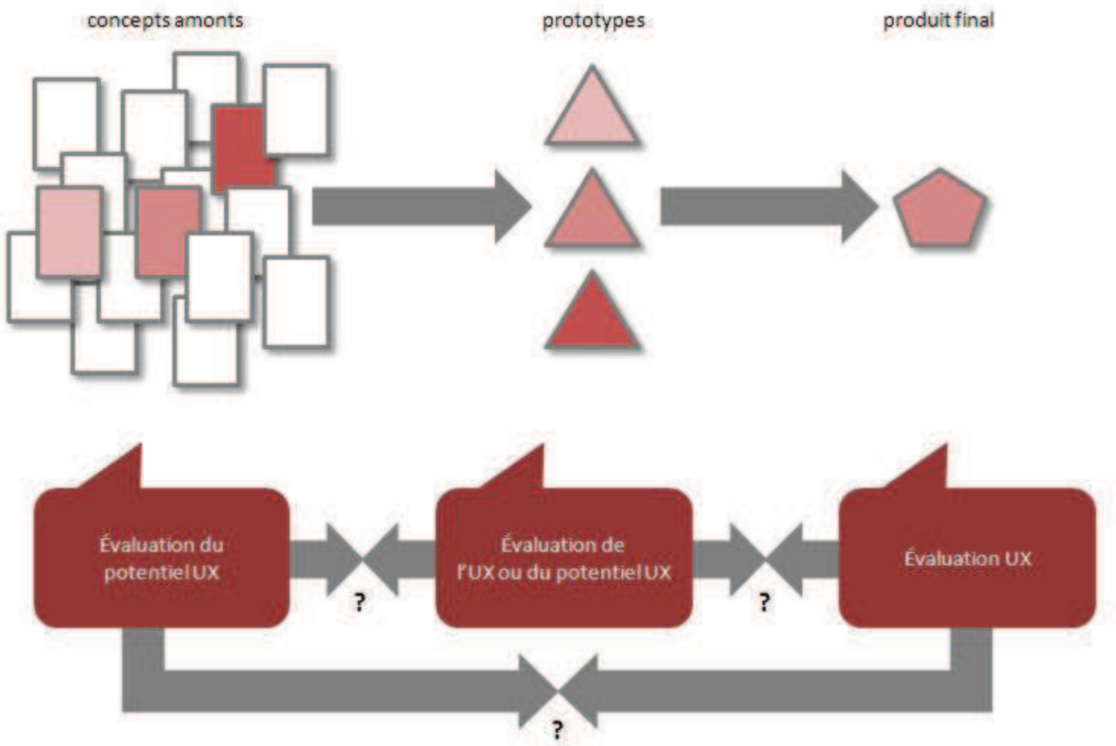


IMAGE 31: PERSPECTIVE 2, CHAINE D'EVALUATIONS UX DES LES CONCEPTS AMONTS ET JUSQU'AU PRODUIT FINAL.

3. Comme troisième perspective, nous envisageons de continuer le développement des outils pour la génération de l'UX. Une idée qui a émergé au sein d'un groupe d'amis chercheurs porte sur l'utilisation des 'expérience triggers'. Se sont des objets conçus pour les concepteurs. Chaque objet incorpore une dimension de l'expérience. La prise en mains de tels objets doit permettre à l'équipe de design de réunir ses efforts autour de la même vision de l'expérience pour le futur utilisateur.

IMAGE 30: APERÇUS DU 1ER SEMINAIRE "EXPERIENCE TRIGGERS" A FLUPA UX DAY 2013.

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8 IMAGES ET TABLEAUX

L'EXPERIENCE DE L'UTILISATEUR DANS LA CONCEPTION AMONT:

DE LA GENERATION A L'EVALUATION DES IDEES

RESUME : L'expérience de l'utilisateur (UX) est devenue une préoccupation majeure pour la conception de produits. Aujourd'hui, il existe différents outils pour l'évaluation de l'expérience de l'utilisateur sur l'apparence des produits finaux. Très peu d'outils et de méthodes permettant d'anticiper l'expérience de l'utilisateur au cours de la conception amont existent. Cette thèse explore le large éventail de dimensions en conception qui constituent potentiellement l'expérience de l'utilisateur. Les propriétés dynamiques des produits apparaissent comme un facteur important. Dans les expérimentations, un logiciel basé sur des mots et des liens d'inspiration, ainsi que la technique 'body storming' sont testés comme un moyen de génération de l'expérience utilisateur. Les concepts et les gestes d'interaction produits sont ensuite évalués par une combinaison de questionnaires et de mesures comportementales et physiologiques. Les résultats des expérimentations montrent premièrement qu'une large gamme de dimensions de conception doit être considérée dès la conception amont, deuxièmement qu'il est possible d'appliquer les évaluations UX sur les premiers concepts et troisièmement que les évaluations UX peuvent également être effectuées sur les propriétés dynamiques comme les gestes d'interaction. Cette thèse apporte aussi un nouveau modèle sur l'expérience de l'utilisateur et une liste de dimensions en conception pour la recherche en design et pour les designers.

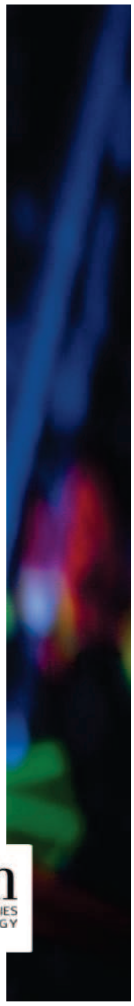
Mots clés : expérience utilisateur, conception produit, interaction gestuelle, conception amont, évaluation concepts, Ingénierie Kansei.

BRINGING THE USER EXPERIENCE TO EARLY PRODUCT DESIGN:

FROM IDEA GENERATION TO IDEA EVALUATION

ABSTRACT: The User Experience (UX) has become a major concern for the design of consumer products. Today exist various tools for the evaluation of static properties of final products on their User Experience value. However, very few tools and methods are available that allow anticipating the future User Experience during the first stages of product conception. This thesis explores the wide range of design dimensions that potentially form the experience of the user. Dynamic product properties emerge as an important factor for User Experience. In the studies a software based on inspiration words and links, as well as the technique body storming are tested as a new means of User Experience generation. The produced early concepts and interaction gestures are then evaluated through a combination of questionnaires, behavioural and physiological measurements. The study results show firstly that a wide range of design dimension needs to be regarded to design for User Experience, secondly that it is possible to apply UX evaluations on early concepts and thirdly that UX evaluations can also be done on dynamic properties like interaction gestures. This thesis furthermore contributes design research and practice with a new model on the mechanism of User Experience and a list of design dimensions for early product conception.

Keywords : user experience, product design, gesture interaction, early design phase, design evaluation, Kansei Engineering.



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