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Beyond Usability –
Measuring Aspects of User Experience

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Summary

Over the last decade, there has been growing interest in the topic of User Experience (UX). As technology matured, interactive products became not only more useful and usable, but also fashionable, fascinating things to desire. Traditionally, human-computer interaction (HCI) research has developed quality measures for interactive, goal- and task-oriented technology. Driven by the impression that a narrow focus on interactive products as tools does not capture the variety and emerging aspects of technology use, practitioners and researchers alike are looking for a viable alternative to traditional HCI.

Although the usability definition in the ISO 9241-11 standard (ISO, 1998) already contains the notion of satisfaction, UX is encompassing more than just satisfaction. However, UX research is a still young discipline that incorporates researchers from diverse fields with their differing views. It comes as no surprise that UX theory and definitions are somewhat fuzzy and inconclusive. A common understanding has formed around the notion that UX takes a holistic view that encompasses also non-task related issues, is subjective and emphasizes positive aspects of interaction. The theoretical research frameworks that evolved over the years stress three different aspects of UX: non-task related, hedonic aspects, user needs, and affect and emotions.

In parallel with the emerging research frameworks, a range of new measurement methods was developed. Based on the diverging theoretical basis, there are numerous measurement methods, ranging from mood boards to sophisticated questionnaires, from interviews to physiological measurements. A need for systematic measurement and the development of new measures for UX has been identified.

Based on a model of UX that is described in this thesis, two aspects of UX were found to be important to measure: mood and perceived hedonic quality. Mood plays a central, mediating role in product perception and evaluation. Although there are existing methods to measure mood state, they are not applicable to the interaction phase of human product interaction. The hypothesis states that a changing mood state expresses itself in motor behaviour and that the changes in motor behaviour can be measured. A test environment for the recording of computer mouse actions was developed. Two experiments were conducted with inconclusive results. There are indications that motor expression and affective arousal are connected.

The second measurement method is based on first impressions of products, so called "sensory encounters". Perceived hedonic quality, encompassing aesthetic and symbolic aspects of products, plays an important role in sensory encounters. Hedonic qualities of a product are comprised of the needs for stimulation, identification and evocation. The complex nature of product character has led to the development of a multifactorial measurement method, which applies a projective method with visual and verbal test modules.

Zusammenfassung

Über das letzte Jahrzehnt ist das Interesse am Thema User Experience (UX) stetig gewachsen. Während die Technik langsam den Kinderschuhen entwächst, wurden interaktive Produkte nicht nur brauchbarer und benutzbarer, sondern auch modische, faszinierende Dinge, zu denen eine emotionale Bindung aufgebaut werden kann. Seit langem werden in der die Mensch-Maschinen Interaktionsforschung Instrumente für die Qualitätsmessung von ziel- und aufgabenorientierter Technologie entwickelt. Getrieben vom Eindruck, dass ein zu enger Fokus auf interaktiven Produkten als Werkzeuge die Gesamtheit und die Variabilität von wichtiger werdenden Aspekten der Technologiebenutzung nicht berücksichtigen kann, haben sich Forscher und Praktiker gleichermassen nach Alternativen zur traditionellen MMI umgesehen.

Obwohl bereits die Usability Definition im ISO 9241-11 Standard (ISO, 1998) „Zufriedenheit" erwähnt, umfasst das Konzept der UX doch deutlich mehr. Allerdings ist UX eine noch junge Disziplin, die Forscher und Praktiker aus allen möglichen Gebieten umfasst, mit all ihren verschiedenen Ansichten. Es erstaunt deshalb nicht, dass UX Theorien und Definitionen noch immer unklar und wenig einheitlich sind. Ein gemeinsames Verständnis hat sich herausgebildet, welches UX eine holistische, ganzheitliche Sichtweise zuschreibt, die auch nicht aufgabenorientierte Aspekte berücksichtigt, das die Betonung auf das Subjektive von UX legt und das den Fokus von UX auf den positiven Aspekten der Interaktion sieht. Die theoretischen Modelle, die über die letzten Jahre entstanden sind, betonen drei verschiedene Aspekte von UX: die nicht aufgabenorientierte Sichtweise, die Berücksichtigung von hedonischen, ganzheitlichen Aspekten und Benutzerbedürfnissen, sowie Stimmungen und Emotionen.

Parallel zu den sich entwickelnden theoretischen Modellen wurden eine Reihe von Messmethoden entwickelt. Basierend auf den divergierenden theoretischen Grundlagen sind unzählige Messmethoden entstanden, von Mood-Boards bis ausgeklügelten Fragebögen, von Interviewtechniken bis zu physiologischen Messungen. Trotz dieser Vielfalt konnte ein Bedürfnis nach systematischer Messung von UX ausgemacht werden.

Basierend auf einem UX Modell, welches in dieser These dargestellt wird, sind zwei Aspekte identifiziert worden die für eine Messung berücksichtigt werden sollten: Stimmung und wahrgenommene hedonische Qualität. Stimmungen spielen eine wichtige, vermittelnde Rolle in der Produktwahrnehmung und Produktevaluation. Es gibt zwar bereits einige Methoden für die Messung von

Stimmung, aber die lassen sich während der Interaktion mit einem Produkt nur schlecht oder gar nicht anwenden. Die Grundhypothese für die Entwicklung einer neuen Methode für die Stimmungsmessung besagt, dass sich ändernde Stimmungszustände im motorischen Verhalten zeigen und diese Verhaltensänderungen gemessen werden können. Es wurde eine Testumgebung entwickelt, mit der Mausaktionen an einem Computer aufgezeichnet und ausgewertet werden können. Zwei Experimente wurden durchgeführt, die aber keine klaren Resultate zeigen. Es gibt Hinweise aus dem ersten Versuch, dass ein Zusammenhang zwischen affektiver Erregung und motorischem Ausdruck besteht.

Die zweite Messmethode basiert auf dem ersten Eindruck den man von Produkten bekommt. Diese Eindrücke wurden als „Sensory Encounters" beschrieben, weil sie in erster Linie sinnlich sind. Die wahrgenommene hedonische Qualität von Produkten umfasst ästhetische und symbolische Aspekte von Produkten und spielt eine Wichtige Rolle in Sensory Encounters. Hedonische Qualitäten können weiter unterteilt werden in die Bedürfnisse nach Stimulation, Identifikation und Evokation. Die komplexe Natur des Produktcharakters hat zu einer multifaktoriellen Messmethode geführt, welche einen projektiven Ansatz implementiert mit verbalen und graphischen Testmodulen.

1 Introduction

A goal of Human-Computer Interaction (HCI) research has always been the development of quality measures for interactive products. A well-known and widely accepted quality measure of products in task-oriented settings is *usability*. Over the last decade, a new generation of interactive software and electronic products came into market and the HCI community became aware that performance- and task-oriented measures like effectiveness and efficiency could not accurately predict or explain the attractiveness and market success of these new products. Beginning in the 1990ies and especially in recent years, a whole range of new concepts and measures – like emotional usability (Logan, 1994), pleasure (Jordan, 2000) or hedonic qualities (Hassenzahl, 2001) – were developed to evaluate non-utilitarian qualities of products, subsumed in the research field of *User Experience (UX)*. While these concepts and models are still very diverse, a common understanding of the elements determining UX is taking shape. Unlike Usability, which is concerned mainly with the attributes of the product and the prevention of obstacles and errors, the focus of UX is on the user and the construction of a positive user experience and its expression in the emotions, attitudes and values resulting from the interaction with a product.

1.1 Background

Today, designers and developers have an unprecedented freedom when designing products: advances in material sciences, production technology and logistics, the continuing miniaturisation of components, the increasing speed of computer chips, and the drop of prices for materials and parts have given great freedom when planning and designing products. The global markets for technology and materials have led to technically mature, but also very similar products in respect to functionality, technical standard and price. Examples of this trend are electronic products like mp3-players, mobile phones or computers. Hence, on a global market it becomes increasingly important for companies to differentiate their products with a distinct visible design and the creation of an individual image through marketing and company brand instead of additional functionality or price.

Moreover, consumers and users increasingly express a demand for differentiated design. People like to express their individual lifestyle or their affiliation with the social peer group through products they own and use (Crilly,

Moultrie, & Clarkson, 2004). Clothing, cars, bags or mobile phones have become a projection surface for people's identity. Experiential marketing has picked up this line of thought by stressing that not functionality and features of a product are important to the consumer, but the overall "experience" that people choose after identifying the relevance of a brand or product to their needs. Customers want products "that dazzle their senses, touch their hearts and stimulate their minds" (Lenderman, 2006, p. 18).

While at first sight this experience-centred view seems appropriate for products and devices for a personal, private use only (e.g. games), it applies increasingly to applications and devices in the professional area as well. On the one hand, because interactive appliances and software have become an integral part of our everyday lives that we use to communicate, to entertain us, to gather information and other daily activities. On the other hand, because the clear boundaries between work related and private applications of products start to blur: we use mobile phones and handhelds, email, laptops or the internet and its many services both privately and professionally. There is a shift from performance- and task-oriented systems, we use to get work efficiently and effectively done, to experiences with and through interactive systems that stimulate or please us aesthetically, psychologically, physiologically, socially, intellectually, etc.

Through this shift in interactive system use, the demand of companies for differentiation of their products in more than functionality and the demand of the consumers for individualization, stimulation and use experience, the focus of design and production of products has changed. With these new demands, the need for new quality criteria and methods for quality evaluation of interactive systems has emerged.

Although the HCI community has readily embraced the notion that functionality and performance-oriented measures are not enough to judge the quality of a product, there has been little theoretical underpinning in the field to meet the demands of this change. HCI research has put a lot of effort in the development of methods and tools for usability evaluation, but has only recently started to describe theoretical models that explain the attractiveness of products and the elements that describe the experience before, while and after the use of products. The question is less *how* the system is used, but *why*, and *if*, people like and use certain products (and why not others) and what they gain from using it. An efficient and effective product interaction that leads to a satisfied user seems just not enough. Hassenzahl, Platz, Burmester and Lehner (2000) also criticize the measure of satisfaction within the usability concept:

> *"We are aware that user satisfaction is a part of the usability concept provided by ISO 9241-11. However, it seems as if satisfaction is conceived as a consequence of user experienced effectiveness and efficiency rather than a design goal in itself. This implies that assuring efficiency and effectiveness alone guarantees user satisfaction."*
> *(Hassenzahl, Platz, Burmester, & Lehner, 2000, p. 202)*

Fulton, a game designer, put it concisely in a statement about games and usability: "The easiest game to use would consist of one button labelled *Push*. When you push it, the display says *YOU WIN*." (Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003, p. 886). Nonetheless, usability is a widely accepted quality aspect of interactive products, and it has not become obsolete in "experience design" (Shedroff, 2001), but today people often take it for granted that a product is useful and usable. Moreover, there is evidence (e.g. Hassenzahl, 2004a) that there is a complex interplay between aesthetic and functional attributes of products.

1.2 User Experience

Over the last decade, a range of theoretical models have evolved (e.g. Logan, 1994; Jordan, 2000; Hassenzahl, 2001; Mäkelä & Fulton Suri, 2001; Garrett, 2002; Battarbee, 2004; Mahlke, 2008), trying to grasp the elements of the user-product interaction that go beyond effectiveness and efficiency. They have been published in a new research area referred to as *User Experience (UX)*. However, these models and research frameworks, coming from practitioners and researchers of areas like psychology, design, HCI, ethnography, marketing or philosophy, are far from having a coherent understanding of what user experience actually is. Looking at the historical roots of the term and the diverse professions involved in the development of UX, it comes as no surprise that a consortium[1] of UX researchers collected five fundamentally different coexisting definitions of UX.

Although there are early occurrences of the term "user experience" (e.g. in Edwards and Kasik's "User Experience with the CYBER graphics terminal" (1974)), Norman and Draper were among the first to use it in today's sense in a book on user-centred system design:

> *"This section of the book contains chapters that get directly at the question of the quality of the user's experience. This is of course the*

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[1] COST Action 294 – MAUSE: http://www.cost294.org/

ultimate criterion of User Centered System Design, but most workers approach it obliquely in various ways such as exploring the implementation techniques, or applying existing cognitive approaches."
(Norman & Draper, 1986, p. 64)

While the expression itself disappeared for a few years from the area of user-centred design, the concept was picked up in different contexts (e.g. Carroll & Thomas, 1988; Davis, Bagozzi, & Warschaw, 1992; Logan, 1994) and gradually evolved to the understanding of UX we have today. Katja Battarbee correctly states that in the design domain, experiences have always been addressed (Battarbee, 2004, p. 23), but *Experience Design* has a somewhat different meaning as it describes a hybrid design discipline that focuses on environmental and multi-sensorial design, particularly in the context of digital displays and installations (Knemeyer & Svoboda, 2006).

Popularized in the HCI community was the term by Donald Norman's self-selected professional title of *User Experience Architect* for his job at Apple Computer Inc. in 1993. Because of Norman's status as a thought leader in the HCI community, this unconventional title raised awareness for the new concept. The link that connects all UX research is the entirely user-oriented perspective on human-product interaction. The quality of a product can be evaluated only from the perspective of the user. UX is a holistic, all-encompassing concept that takes characteristics of the user, the product and the usage situation into account. In addition, UX also emphasises the importance of emotional aspects of the user (emotional experience) as well as the product (emotional expression). Hassenzahl, Law and Hvannberg (2006) emphasise three main aspects where UX is going beyond the traditional usability metrics:

- **Holistic**: Usability focuses on task related (pragmatic) aspects and their accomplishment, whereas UX takes a more holistic approach, including non-task related (hedonic) aspects of product possession and use, such as beauty, challenge, stimulation or self-expression.
- **Subjective**: Having its origin in psychology and human factors, usability evaluation with "objective" measurement methods (e.g. eye-tracking) and rests primarily on observation. UX stresses the "subjective", it is explicitly interested in the way people experience and judge products they use. It may not matter how good a product is objectively, it must also be experienced to have an impact.
- **Positive**: While usability focuses on problems, barriers, frustration or stress and how they can be overcome, UX stresses the importance of positive outcomes of technology use or possession, e.g. positive emotions

such as joy, pride, and excitement or simply value. This does not imply that usability is unessential. It rather emphasizes that *positive* does not necessarily equate with an *absence of the negative*.

Although this sounds like a common understanding of UX, in the existing literature UX "is associated with a broad range of fuzzy and dynamic concepts, including emotional, affective, experiential, hedonic, and aesthetic variables. ... Inclusion and exclusion of particular values or attributes seem arbitrary, depending on the author's background and interest. ... [And] the landscape of UX research is fragmented and complicated by diverse theoretical models with different foci such as emotion, affect, experience, value, pleasure, beauty, etc." (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008, p. 2396). All of this complicates a concise definition of UX.

To illustrate the dilemma of finding a generally accepted definition of UX, take the following five sample definitions from a publication of the previously mentioned COST Action 294 (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008):

> *"All the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they are using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it."*
> *(Alben, 1996)*

> *"User experience is a term used to describe the overall experience and satisfaction a user has when using a product or system."*
> *(User Experience Design (Wikipedia), 2008)*

> *"[UX encompasses] all aspects of the end-user's interaction with the company, its services, and its products. The first requirement for an exemplary user experience is to meet the exact needs of the customer, without fuss or bother. Next come simplicity and elegance that produce products that are a joy to own, a joy to use. True user experience goes far beyond giving customers what they say they want, or providing checklist features."*
> *(User Experience (Nielsen-Norman Group), 2007)*

> *"[UX is] a result of motivated action in a certain context."*
> *(Mäkelä & Fulton Suri, 2001)*

> *"[UX is] a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which*

the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.).”
(Hassenzahl & Tractinsky, 2006)

The definition of UX is an ongoing process in the community and it is not within the scope of this thesis to define UX conclusively. You find an overview of existing UX frameworks and models in Chapter 2 and a framework of UX with the core elements relevant to understand the approach taken in this thesis in Chapter 3. The thesis builds mainly on the definition of Hassenzahl and Tractinsky (2006), but emphasises different aspects of UX. This definition is the most comprehensive and detailed definition, is rooted in HCI and is appropriate to embed the measurement instruments for UX presented in the following chapters.

1.3 Measuring elements of User Experience

Without a commonly accepted definition, it is quite adventurous to think of methods and tools to measure UX. The multitude of theoretical frameworks has led to even more approaches to evaluate the different aspects of UX. Furthermore, the definition of UX – including the user, the product and the usage situation – implies that these three components are included in an evaluation methodology. While the product and its instrumental (e.g. utility, usability) and non-instrumental (e.g. aesthetic, symbolic or motivational aspects) qualities can be controlled by the developer or designer and can be readily evaluated, the transient internal state of the user and the ever-changing context the product is used in are harder to grasp methodologically.

Hassenzahl and Tractinsky (2006) have identified three major perspectives within the multitude of UX approaches:

The thread labelled **beyond the instrumental** predominantly deals with human needs beyond the instrumental. The term *instrumental* stands for aspects of the interaction that deal with the achievement of behavioural goals (in work settings), for reaching the goal of a task. Other authors refer to it as *utilitarian* (e.g. Batra & Ahtola, 1990), *functional* (e.g. Kempf, 1999) or *pragmatic* (e.g. Hassenzahl, 2004a) as opposed to non-instrumental or *hedonic* properties of a product.

The second thread deals with approaches that focus on **affect and emotions**. On the one hand, emotions are seen as an *antecedent* influencing the quality of interaction, e.g. an expressive design or the internal state of the user, on the other hand affect is seen as a *consequence* of interaction, changing the users emotions through interaction with a product.

The third thread looks at UX in a **holistic, non-reductionist** manner. The research in this area tries to look at the experience as a whole and does not decompose the user experience into measurable elements. Research taking this holistic view stresses the temporal and situational character of UX. It is often research from the design field taking this approach and is especially challenging to be evaluated scientifically.

Within these different threads of research can further be distinguished between approaches primarily for formative evaluation (e.g. design, development) and summative evaluation (e.g. of the end product), which often use different methods and tools for UX evaluation. Although the different approaches employ elaborate theoretical foundations, they often lack appropriate methodologies and tools for the evaluation of UX. Chapter 2 outlines a selection of existing approaches and the corresponding evaluation methodologies.

These methods have a number of drawbacks. The holistic view to UX encompasses all aspects of the user, the product and the context, and includes the temporal aspects of all three components. Although it is important for a designer to consider these aspects, it is almost impossible to measure and control it in its completeness. Coming from the traditional HCI field, the knowledge gain and generalization possibilities of e.g. the cultural probes technique seem problematic.

The thread of research concerned with emotions and affect lacks a common understanding of which emotions are actually important in the context of UX. There are different sets of emotions and affective reactions to products that vary considerably, from joy, fun or pride to surprise, amusement, disgust or disappointment. How these exactly contribute to product quality is unclear. The evaluation of emotions poses some additional problems:

- Emotions last only a short time (a few seconds), so measurement has to be precise or retrospective.
- Retrospective assessment can be subject to distortions, e.g. through social desirability or self-deception.
- Emotions are subjective, and although there are instruments to distinguish at least a few emotions objectively from each other, an accurate account of what is felt can only come from the subject itself.
- Emotions are not necessarily conscious; hence, self-assessment of emotions is not always possible.
- It is unclear how many and which distinct emotions humans can feel, which are basic and which are complex emotions (see e.g. Gomez, 2005).

The instruments for evaluation of needs beyond the instrumental are mainly questionnaires, using verbal accounts of product attributes or personal needs and values. As aesthetics is an important component of this thread of UX, it would seem necessary to have visual results of the evaluation as well. Furthermore, where an expert evaluator (e.g. a designer), is able to give precise account of subtle aesthetic attributes of products, a lay evaluator might not be able to explicitly state and label these attributes. Hence, an implicit method would seem more appropriate.

1.4 Scope

The focus of this thesis is the development of new methods for UX evaluation. As stated in the chapter above, existing UX evaluation methods have a number of weaknesses and drawbacks that are addressed in the development of two new evaluation tools.

The first method addresses the measurement of mood state of computer users and belongs to the thread of emotions and affect in UX. It explores the possibility of implicitly capturing the mood state of a user, working on a computer with a standard mouse and keyboard, through the detection of changes in motor behaviour variables. The relationship of emotions and moods is very close (see also Chapter 3.2.1 for details), as mood is a result as well as an influencing factor of emotion. So instead of assessing a small set of distinct emotions retrospectively, the outcome of these emotional episodes, mirrored in the mood of the user, is assessed concurrent with the interaction between the user and the software. Therefore, the approach encompasses the need for a predefined set of distinct emotions, it measures the affective reaction during the interaction and not retrospectively, is objective and not subjective and is implicit and unobtrusive. A detailed description of the method can be found in Chapter 3.2, two experiments concerning the validation of the method are described in Chapter 4.

The second method addresses the evaluation of needs and values beyond the instrumental. It takes up the notion that we use and own products that satisfy certain needs and express values that are important to us. Similar to meeting an unknown person for the first time and evaluating within seconds or minutes if we like the person, what personality we assume he/she has and if we will get along with that person, we make an appraisal of products based on what we see (or hear, or smell, or feel) and decide if the product matches our needs and values. Because this short appraisal is often unconscious, the measurement tool employs an implicit, projective method. It does not only use visual and verbal techniques in the survey, but also has visual and verbal evaluation results. More details about

the premises of the method are laid out in Chapter 3.3, a detailed description of the measurement tool can be found in Chapter 5.

The thesis will not pursue a conclusive definition of UX, as it is an ongoing process within the UX community, but will instead build mainly on Hassenzahl's and Tractinsky's (2006) understanding of UX. An overview of existing models and frameworks for UX is given in Chapter 2. The focus of this thesis is the development of new evaluation instruments for UX from an engineering point of view and although UX builds heavily on psychology, it will only elaborate psychological constructs where necessary and not replicate psychological theories.

1.5 Outline

The remaining chapters are structured as follows:

Chapter 2 presents a selective literature review of existing models and frameworks of UX from different research fields. Implications for measurement of UX are highlighted and where available according measurement instruments discussed.

Chapter 3 describes the methodological foundations and premises for the two measurement methods and presents a UX framework for the context of this thesis. It points to additional and differing views of UX and emphasises the important aspects of the two methods in the context of the framework.

Chapter 4 presents the two experiments conducted for the *mood in interaction* evaluation method, the test setup and the results and discusses the implications of the results.

Chapter 5 describes the tool aimed at evaluating the *perceived hedonic qualities* of products. The content and goals of the different modules of the tool are presented and discussed.

Chapter 6 states the conclusions of the theoretical and practical considerations in the thesis and makes suggestions for further investigations.

2 Existing approaches to User Experience evaluation

A wide range of models and research frameworks for User Experience (UX) exist today. The contributions come from diverse fields such as HCI, design, psychology, marketing or even philosophy and have accordingly diverging viewpoints on the subject. The structure of this chapter follows the simple classification of Hassenzahl and Tractinsky and groups a selection of existing approaches into *beyond the instrumental* (Chapter 2.2.1), *emotion and affect* (Chapter 2.2.2), *the experiential* (Chapter 2.2.3) and other approaches (Chapter 2.2.4). Important aspects of UX, which have led to the development of the two measurement instruments described in this thesis, are highlighted in the context of the respective UX models.

2.1 Introduction

User Experience is rapidly becoming a key term in the world of (interactive) product design. While the HCI community has readily adopted it, it has been critiqued at the same time repeatedly for being vague, elusive or fleeting. The term user experience is – depending on the background and focus of the researcher or practitioner – associated with a wide variety of, even contradictory, meanings. The common denominator of these models and theories is its rejection of the dominant, task- and work-related *usability* paradigm as the exclusive quality measure of interactive products.

Although the ideas represented by UX are important, they are by no means original (Hassenzahl & Tractinsky, 2006, p. 91). Early accounts of quality aspects beyond usability include for example Malone (1981), who mentions *challenge, fantasy and curiosity* as characteristics of motivating instructional environments. Likewise, Carrol and Thomas' (1988) article on *fun* or Logans (1994) concept of *emotional usability*, which complements the "traditional" usability are other early mentions of non-utilitarian quality aspects. Albens (1996) *quality of experience* that includes dimensions like *aesthetic experience* or *needs* is the first in a series of programmatic publications (e.g. Alben, 1996; Hassenzahl, Beu, & Burmester, 2001; Overbeeke, Djajadiningrat, Hummels, & Wensveen, 2002) that started to promote UX in the HCI community. Gradually, more theoretical papers have replaced this literature. Although there is a great diversity of UX approaches, it is indicative of the interdisciplinarity of UX research and a "boost for innovation

rather than a problem" (Wright & Blythe, 2007). The following chapters give an overview of important contributions.

Hassenzahl and Tractinsky (2006), as mentioned in the introduction of the thesis initially proposed the structure used here that is represented in the chapter titles. It is only one possibility to structure UX approaches; other authors have categorized them differently. Mahlke (2008) adopts the categories of *non-instrumental qualities* and *emotion and affect* approaches, but additionally sees *phenomenological* and *design* as relevant perspectives. Battarbee (2004) organises UX theories into three categories: *person-centred* frameworks (what people need), *product-centred* frameworks (design and research checklists) and *focus on the action* (frameworks about interaction), and treats emotions as a separate thread of UX. Strictly speaking not as a categorization, Blythe et al. (2007) propose five bipolar dimensions to characterize UX frameworks (see Table 2-1).

Table 2-1: Five aspects of UX and associated dimensions (Blythe et al., 2007)

Aspect	Content dimension
Theory	Reductive - Holistic
Purpose	Evaluation - Development
Method	Quantitative - Qualitative
Domain	Work based – Leisure based
Application	Personal - Social

Reductive approaches simplify the complexity of experience through measuring individual elements of UX, whereas *holistic* approaches try to capture the experience as a whole. The distinction between *evaluation* and *development* is comparable to summative and formative evaluation. Methods for development focus on the process of creating (designing, developing). The distinction between *quantitative* and *qualitative* measurement is well known and applicable to UX studies as well. Although the boundary between *work* and *leisure* is becoming blurred, work related activities are mainly goal directed whereas in leisure based activities pleasure or fun play a more important role. Increasingly, models address experiences in a *social* context, rather than focusing on the *personal* experience of single persons.

The aspects Blythe et al. have emphasised will help to comprehend the relative importance of the mentioned UX models and the two measurement instruments presented in this thesis. Within the course of the discussion of UX frameworks in the next chapters, other relevant aspects are highlighted in the context of the particular theory.

2.2 UX models and frameworks

The terms *instrumental* and *non-instrumental* are used here to distinguish between traditional quality aspects (e.g. usability, functionality) and newer aspects (e.g. human needs, emotions). Other authors have referred to instrumental aspects also as *utilitarian* (e.g. Batra & Ahtola, 1990) or *functional* (e.g. Kempf, 1999). In his framework of UX, Hassenzahl (2003) has referred to instrumental and non-instrumental as *pragmatic* and *hedonic* respectively. While most authors include instrumental aspects in their frameworks and consider them as separate but complementing constructs to non-instrumental aspects, hedonic aspects are seen as an affective quality of a product (Chapter 2.2.2) or as non-task related attributes of a product (Chapter 2.2.1).

2.2.1 Beyond the instrumental

The common denominator of these views are the product attributes that fulfil underlying human needs (Hassenzahl & Tractinsky, 2006) and the user experiences that revolve around these needs. Human needs are the drivers for product use and possession. Human needs considered relevant in the context of products range from fun, excitement, appeal, novelty and change (Logan, 1994), challenge, curiosity and emotional connection (Malone, 1981), to surprise, diversion, mystery, intimacy, influencing the environment and understanding and changing one's self (Gaver & Martin, 2000). According to Hassenzahl (2006), two broad categories within the array of human needs relevant in a product context can be distinguished: *competence/personal growth* and *relatedness/self-expression*.

Jordan (2000) argues for a hierarchical organization of needs, similar to Maslow's hierarchy of human needs (Maslow, 1943), in which the satisfaction of a lower level need is a necessary precondition for fulfilment of higher-level needs. Jordan's first level is functionality, the second level usability and the highest level is pleasure. Within the pleasure level, he distinguishes four aspects of pleasure, which draw from earlier work of Tiger (1992): Physio-pleasure is associated with the sensual experience of a user with the product (e.g. touch, smell, taste). Socio-pleasures arise in the relationship with others or the society as a whole (e.g. status, connection). Psycho-pleasure is related to people's cognitive and emotional reactions (e.g. satisfaction of instrumental needs) and Ideo-pleasure pertains to people's values (e.g. aesthetics, taste, personal aspirations). Jordan does not develop any specific measurement instruments in his book, but instead provides an overview of a range of methods rooting in design and marketing

research, such as private camera conversation, focus groups, think aloud protocols, experience diaries, reaction checklists or interviews.

A similar approach to human needs, but specifically coined to interactive products like websites, are Marcus' (2004) six degrees of freedom. The six categories relate to specific product categories or activities: I-ware (me-ware, my-ware) relates to identity and privacy, you-ware (love-ware) to relationships with others, fun-ware to entertainment, buy-ware (sell-ware) is connected to commerce, know-ware (who-what-why-where-when-ware) to information and be-ware (self-aware) to wellbeing and self-enhancement. Marcus neither applies his model to specific examples and connects it to UX, nor does he develop specific measurement instruments for his model.

Margolin (1997) identified four relevant dimensions a designer should focus on to get a better understanding of the needs of a user. It is a purely theoretical construct without any means to evaluate these dimensions objectively. The social dimension refers to ethics and responsibility in the context of society and legislation. The inventive dimension relates to being able to conceive products that will be enjoyed and valued by the user. The operational dimension relates to simplicity and clarity in product design. In the aesthetic dimension, he calls for the importance of aesthetics in product design and criticises designers that consider their aesthetic judgement to be independent of user taste.

Instrumental and non-instrumental qualities

The relative importance of instrumental and non-instrumental qualities, and if they are organized hierarchically are open questions in the UX domain. Some studies could show that instrumental as well as non-instrumental aspects are equally important predictors of product appeal (Huang, 2003; Hassenzahl, 2001). Helander and Tham (2003) coined the expression *Hedonomics* as the connection between ergonomics and hedonics. Although functionality is a necessary precondition for the acceptance of many products, the hierarchical organization of needs and their relative importance may be user (e.g. early adopters vs. late adopters), product (e.g. consumer vs. producer goods) and/or context dependent. The usage context includes the aims of product use. Hassenzahl (2003) states that people can have two different categories of goals in product interaction, do and be goals, with corresponding modes of interaction: goal and action mode. The goal mode is practical and task-oriented, whereas the action mode is for fun and entertainment. These modes try to explain, why things can be irritating at times (in goal directed mode), but at other times exciting, challenging and fun (in action oriented mode).

Hassenzahl (2001) refers to instrumental quality aspects as *pragmatic* aspects and to non-instrumental aspects as *hedonic* aspects and combines in his framework of UX traditional usability measures with aspects that address human needs for social power, novelty and change. In a later publication (Hassenzahl, 2003), he identifies three sub-dimensions of hedonic qualities: stimulation, identification and evocation. Because people strive for personal development, products have to be stimulating. They should provide new impressions, opportunities, and insights. Because individuals tend to express their self through physical objects, their possessions (Prentice, 1987), products should be able to communicate identity. This self-expressive function is entirely social. Evocation relates to the fact that products can evoke memories. In this case, the product represents past events, relationships or thoughts that are important to the individual. The perceived (apparent) product character then leads to consequences: judgments about the product's appeal (e.g., good/bad), emotional consequences (e.g., pleasure, satisfaction) and behavioural consequences (e.g., time spent with the product). Hassenzahl has developed a questionnaire ("AttrakDiff"[2]) to evaluate pragmatic and hedonic qualities of products.

Figure 2-1: Key elements of the model of user experience (Hassenzahl, 2003)

A comprehensive framework that encompasses the perception of instrumental and non-instrumental qualities and emotional reactions of users has been proposed by Mahlke (2008). He includes influencing factors (system, user, and context parameters) and consequences of user experiences in his model, (e.g. acceptance of the system and usage behaviour). Instrumental qualities include utility and usability; aesthetic, symbolic and motivational aspects comprise the non-instrumental qualities; the emotional user reactions finally consist of subjective feelings, motor expressions, physiological reactions, cognitive

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[2] http://www.attrakdiff.de/

appraisals and behavioural tendencies. Although very comprehensive, the framework does not explicitly state how all these elements interrelate with each other. In his three experimental studies, he uses a multitude of measurement instruments: questionnaires (for instrumental, non-instrumental and affective qualities), performance measures (e.g. time or completion rates) and physiological measurements (e.g. heart rate or EMGs).

Aesthetics and visual design

A different thread of research focuses on non-instrumental aspects of appearance, design and aesthetics. Among the first to systematically study the connection between visual aesthetics and usability were Kurosu and Kashimura (1995) who conducted an experiment with 26 different interfaces of automatic teller machines (ATM) and found a high correlation between apparent (perceived) usability and beauty of the interface. Around this time, many studies started to investigate aesthetics and usability. Tractinsky, who doubted the results of Kurosu and Kashimura, replicated the experiment (Tractinsky, 1997) and found similar results. Alben (1996) identified beauty as an important quality aspect of technology experience. Tractinsky, Katz and Ikar (2000) claimed that what is beautiful is usable.

Burmester, Platz, Rudolph and Wild (1999) have studied the influence of aesthetic design on users' quality perceptions by using a traditional version of a user interface and one that was specifically worked over by a designer. People used questionnaires with 23 items to indicate their statements after the presentation of each interface. They found that the designed version received higher ratings with respect to quality impression, apparent usability and superiority.

A study by Park, Choi and Kim (2004) aimed at identifying critical factors that are closely related to the aesthetic fidelity of web pages. They conducted three empirical studies with professional web designers and users. Subjects used questionnaires with 278 terms arranged in bipolar Likert-scales to state their opinion about the websites. They identified thirteen aesthetic dimensions and instructed designers to design example websites with respect to selected dimensions. They found that users rated the quality on a specific aesthetic dimension higher if the designer had focused on it.

A couple of theoretical frameworks deal with aesthetic appreciation of visual stimuli. Lindgaard and Whitfield (2004) position visual aesthetics of interactive systems within an evolutionary context. They apply Whitfield's (2000) collative-motivation model of aesthetics to explain the results of prior experimental research on product preference. This approach combines cognitive and affective

processes to explain aesthetic appreciation based mostly on the prototypical nature of a stimulus ("ancestral, wired-in preferences for specific stimuli", p. 86).

Leder, Belke, Oeberst and Augustin (2004) propose an information-processing stage model of aesthetic processing, derived from an analysis of the appreciation of modern art. According to the model, aesthetic experiences involve five stages: perception, explicit classification, implicit classification, cognitive mastering, and evaluation. The model also differentiates between aesthetics emotion and aesthetic judgments as two types of outputs.

Reber, Schwarz and Winkielman's (2004) approach to understanding aesthetic pleasure is based on the concept of processing dynamics: the more fluently perceivers can process an object, the more positive their aesthetic response. They review variables known to influence aesthetic judgments such as figural goodness, figure-ground contrast, stimulus repetition, symmetry, and prototypicality and trace their ability to change processing fluency. In contrast to theories that trace aesthetic pleasure to objective stimulus features per se, they propose that beauty is grounded in the processing experiences of the perceiver perceiver, which are only partly a function of stimulus properties.

2.2.2 Emotion, mood and affect

Research on affect has gained significant attention over the last three decades. The importance of emotions for a wide range of central processes such as decision-making, perception, cognition, learning, social judgement or behaviour has been acknowledged (e.g. Forgas, 1995; Picard, Affective Computing, 1997; Russell, 2003). In design, emotions have always played an important role, but only recently systematic research about the interrelation of emotions and design has started. One of the pioneering publications to address affect in the field of HCI has been the book "Affective Computing" (Picard, 1997). However, affective computing – computing that relates to, arises from, or deliberately influences emotions (p. 3) – takes a computer perspective and deals predominantly with negative emotions (e.g. stress or frustration). Publications in the field of affective computing deal with mechanisms to detect, prevent and undo negative emotions arising from the interaction of humans with technology.

UX research focuses more on positive emotions like enjoyment, fun, trust or pride and the qualities of products that lead to affective reactions. There are two major perspectives of dealing with affect in UX. One perspective understands emotions as *consequences* of product use (e.g. Desmet & Hekkert, 2002; Hassenzahl, 2003; Tractinsky & Zmiri, 2006; Mahlke, 2008). Emotions are seen as the result of cognitive appraisal processes of the product and the usage situation. Surprise, for example, may be felt if the interaction deviates from

expectations, and could turn into joy in case of a positive appraisal or to frustration, in case of a negative appraisal. The other perspective on emotions in UX sees emotions as *antecedents* of product use and evaluative judgements (e.g. Zhang & Li, 2004; Norman, 2004; Tractinsky, 1997). In line with technology acceptance literature, the role of affect in an individual's evaluation, reaction and acceptance of technology is studied.

Although emotions have received a lot of interest in UX and design ("emotional design"), there are only a few comprehensive frameworks, which encompass products, users and emotions. Often, there are notions of emotions and other affective states, but a theoretical foundation is missing. Some frameworks that incorporate emotions along other aspects have been discussed in the previous chapters (e.g. Hassenzahl, 2006; Mahlke, 2008).

Figure 2-2: Basic model of product emotions (Desmet, 2003)

In the context of product design and evaluation, emotional responses are interesting because they have consequences on buying intention, usage of the product and communication about the product to others. As Desmet (2002) elaborates, seeing, using, owning, and coveting products all elicit different kinds of emotions and emotional responses. Desmet and Hekkert (2002) establish a basic process model regarding the elicitation process of emotions in human-technology interaction that comprises four parameters: concern, product, appraisal, and emotion. The first three parameters, and their interplay, determine if a product elicits an emotion, and if so, which emotion is evoked (see Figure 2-2).

The central implication of the concept of appraisal is that not the event (e.g. interaction with a product) as such is responsible for the emotion, but the meaning the individual attaches to this event. Concerns can for example be needs, preferences, instincts, motives, goals, or values (Scherer, 2001), and can be regarded as points of reference in the appraisal process (Frijda, The Emotions, 1986). Thus, a concern match or mismatch determines the significance of a product for our well-being. Products that match users' concerns are appraised as beneficial, and those that mismatch their concerns are harmful.

Some concerns, such as the concern for safety and the concern for love, are general, others are context-dependent, such as the concern for being home before dark or the concern for securing a good seat for your friend at the cinema.

In a later publication, Desmet (2003) proposed five categories of emotions elicited by products: instrumental, aesthetics, social, surprise, and interest emotions. *Instrumental* emotions (e.g. disappointment, satisfaction) derive from perceptions of whether a product will allow the user to achieve his objectives. *Aesthetic* emotions (e.g. disgust, attraction) relate to appeal, the potential for products to delight or offend our senses. Desmet does not use the term "taste" in this context, but states that the appraisal of aesthetic emotions is based on innate and learned attitudes. *Social* emotions (e.g. indignation, admiration, contempt) result from the extent to which a product can comply with socially determined standards. The product is appraised in terms of legitimacy. *Surprise* emotions (e.g. amazement, pleasant and unpleasant surprises) are driven by the perception of novelty in a design, i.e. the design is sudden and unexpected. Finally, *interest* emotions (e.g. boredom, fascination, inspiration) are elicited by the perception of challenge combined with promise, and all involve an aspect (or lack) of stimulation. Desmet (2002) developed a measurement tool for product emotions called "PrEmo", which visually assesses 14 emotions (7 positive and 7 negative) on a 3-level scale.

Norman (2004) defines three levels of information processing: first the "prewired", automatic *visceral* level; second the *behavioural* level, which involves brain processing and controls everyday activities; and third the *reflective* level for contemplative processing. The visceral level marks the start of affective processing by making rapid judgments on what is good or bad. Processes on the visceral level are biologically determined and relate to instinctive attraction to form, colour and the resulting bodily reactions. The behavioural level is the site of most human behaviour. Its actions are reinforced or inhibited by the reflective layer and can enhance or inhibit the visceral layer. Behavioural responses deal with use and functionality, and the interfaces and objects that people for example touch, grip and drive. While the reflective level does not have direct access to neither sensory input nor the behavioural control, it watches over, reflects upon, and tries to bias the behavioural level. Reflective responses deal with matters of identity and culture that are associated with products. Although Norman proposes that different aspects of emotions play a role on all three levels, it remains unclear how these emotions arise from the interaction with a product.

Rafaeli and Vinali-Yavetz (2004) develop a similar model of the relationship between the qualities of physical artefacts and the emotions they elicit. This model suggests that artefacts are analyzed according to three conceptually

distinct aspects: instrumentality, aesthetics, and symbolism. They discuss three different mechanisms of emotion elicitation, each based on one of the three quality dimensions: hygiene, sensory and associative mechanisms.

A different view on affect in UX, rooted in technology acceptance literature, present Zhang and Li (2004). They showed perceived affective quality to be a predictor of perceived usefulness, perceived ease of use and ultimately of behavioural intentions. This is in line with previous research (Davis, Bagozzi, & Warschaw, 1992), which reported an impact of perceived enjoyment on technology acceptance. Affective quality (Russell, 2003), however, is a construct closely tied to an object or a stimulus, and is the ability of this stimulus to change (core) affect. This is different to the models presented above that understand affect and emotions as states of the user.

A range of theoretical UX models focus on the design for specific emotion-related phenomena (e.g. fun, pleasure, engagement, motivation, flow). These are interesting concepts, but they are difficult to conceptualize and measure. The previously mentioned framework of Hassenzahl (2003) deals with *pleasure* and *satisfaction* as consequences of product experiences. The term *engagement*, as used by Laurel (1991), describes a positive, first person interaction experience that people can have with computers. Carroll and Thomas (1988) argued for the consideration of *fun of use* in interactive system design. Brandtzæg and Følstad (2001) describe aspects of enjoyment, building on a demand-control-support model for good and healthy work. Finally, Csikszentmihalyi (1990) focuses on the optimal experience and the concept of flow in interaction, which is also widely acknowledged in psychological literature.

2.2.3 The experiential

The experiential perspective of UX takes a holistic view on experience and emphasizes (in contrast to the other two perspectives in the previous chapters) the situatedness and the temporal character of UX. Nonetheless, a clear distinction from the other two perspectives is often not possible, as these models frequently include needs and emotions.

In this view, user experience has been described as the spark between what has happened in the past and what is expected in the future. This is the simplest of the models. For Mäkelä and Fulton-Suri (2001), experiences are motivated actions in a context, which are influenced by past experiences and in turn shape future expectations. They break down the moment of experiencing to elements that can be analyzed: context, motivations and actions. They postulate that action is influenced both by motivational level needs (why someone is doing something) and action level needs (how something is accomplished in the moment), which

may be emotionally directed. The motivational level of action is entangled with thinking about identity, roles or values, and action level needs connect with usability and tasks.

Forlizzi and Ford (2000) point out that designers can only design situations rather than neatly predicted outcomes. Beside the user's personal appraisal of a situation, there are other factors that are beyond control when designing: different cultural backgrounds, prior experience as well as emotional states which cause different subjective interpretations of a certain moment. They introduce four concepts relevant to understand the quality of an experience: sub-consciousness, cognition, narrative, and storytelling. Sub-conscious experiences do not compete for the user's attention and thinking processes. Cognition is used to represent experiences that require users to think about what they are doing. The narrative concept represents experiences that have become meaningful for the user. The set of features and affordances of a product offers such a narrative of use. In turn, a user interacts with some subset of features, based on usage situation, prior experience and current emotional state to make a unique and subjective story.

Experience can also be described in a less dynamic fashion. For McCarthy and Wright (2004), experience is composed of four strands: sensory, emotional, spatio-temporal and compositional strands. This means that all experience has a structure that happens in space and time and is sensory as well as emotional. As Forlizzi and Ford (2000) attempted to describe how experience changes, this view emphasizes what is common to all experience. In addition, they discuss six sense-making processes that relate to experience: anticipating, connecting, interpreting, reflecting, appropriating and recounting.

Battarbee (2004) introduces the concept of co-experience to consider experiences constructed in social interaction. Co-experience is understood as an experience that users themselves create together in social interaction. Together Forlizzi and Battarbee (2004) present an approach to incorporate the concept of co-experience into the framework proposed by Forlizzi and Ford (2000).

The frameworks that take an experiential position resist the reduction of experience into single factors or processes and look at experience as a unique combination of various elements over time, which makes it difficult to conceptualize these models for research. The complexity of experiences and their changing nature lead to unique events that are hard to repeat and to create and even harder to evaluate quantitatively. Therefore, evaluation methodology is made up mainly of qualitative methods, such as interviews, storytelling, cultural probes or expert appraisals.

2.2.4 Related evaluation approaches

Two more models related to UX are mentioned here to complement this overview. Although thematically close to UX, they are concerned with the development of products rather than the evaluation of UX. Both methods are strongly linked to practice.

Kansei engineering (e.g. Nagamachi, 2001) was founded 30 years ago, as an ergonomics and consumer-oriented technology for producing goods and products. Kansei engineering is a method that attempts to identify the feelings that customers seek and enables engineers to create products and suggest these feelings in their look and feel. Feeling, here, is a crude translation of the Japanese concept of kansei, which means something like the psychological feeling or image of a product. In a systematic engineering and testing process, products are designed to support the image the manufacturer wants aims for.

Interaction designers who focus on designing digital content address a particular subset of product interaction in their frameworks. Rooted in user-centred design, Garrett (2002) offers a model of information design that structures the elements of websites that influence in his view the "user experience". The design of user experience happens on five levels: strategy, scope, structure, skeleton and surface. Strategy relates to user needs and site objectives; scope to functional specifications and content requirements; structure to interaction design and information architecture; the skeleton encompasses aspects of information design (interface and navigation) and the surface corresponds to the visual design.

His model is more an instruction of how to proceed when planning a website (or the presentation of other electronic content) than an actual UX framework, although he calls his publication "The elements of User Experience".

2.3 Measuring UX

The previous chapters on existing UX frameworks have made evident that UX is an ill-defined, complex construct that encompasses aspects of the user's inner state, characteristics of the product and the usage context. These multiple facets of UX and the different aims of the researchers trying to get a hold of experiences have led to a multitude of measurement and evaluation methods that are presented in the following chapters. Measures for hedonic qualities and user needs, for affect, and briefly for the experiential are presented. Instrumental measurement instruments (e.g. usability measures) are not within the scope of

this thesis. Beforehand, some important considerations concerning UX evaluation are discussed.

2.3.1 Measurement considerations

While some HCI researchers and practitioners believe that constructs like fun, love, beauty or happiness cannot be measured, others are convinced that it is necessary to find means to make UX aspects operational. It is possible to measure almost anything, but the concern is whether the measure is meaningful, useful and valid.

Objective vs. subjective

The debate on objective vs. subjective measurements has animated many HCI discussions. As UX evaluation stands in the tradition of usability evaluation, this debate is not exclusive to UX research. Given the subjective nature of UX, it would seem feasible to use subjective measurements. However, some constructs cannot be clearly categorized as objective or subjective. To illustrate this dilemma, look at three views on *beauty* (see Mulder & van Vliet, 2008): 1) the objectivist's view, which regards beauty as a property of an object that is able to produce pleasurable experiences in a perceiver. Typical features of beauty in this view are balance and proportion, symmetry, complexity, (figure-ground) contrast and clarity, and the golden section; 2) the subjectivist's view, which regards beauty as a function of idiosyncratic qualities of the perceiver - "beauty is in the eye of the beholder". A typical argument is the social constructivist's emphasis on the historically changing and culturally relative nature of beauty; 3) the interactionist's view, which regards beauty as emerging from patterns in the way people and objects relate. UX will need subjective and objective measures and the dispute is not only which type of measure is more appropriate, but also whether and how they are related and under which conditions.

Design vs. evaluation

Designers and developers need a continuous feedback during the phase of creating a product to employ an optimal user experience. The methods needed in a retrospective evaluation of product appeal and the methods needed for a prospective and continuous feedback during the design process are fundamentally different. During development, it is often not possible to "measure", because there might only be a sketch or a wireframe model that does not exhibit the product features in a way that it can be tested with potential users. Designers and developers need inspiration, whereas the evaluator needs an objective estimation of the final products appeal. These different requirements are mirrored in the theoretical frameworks presented in the last chapter.

It is related to the distinction made in instructional design between formative and summative assessment. Summative assessment is characterized as assessment *of* learning and is contrasted with formative assessment, which is assessment *for* learning (Summative assessment (Wikipedia), 2008). Likewise, UX needs methods for formative evaluation that help improve and form ideas during the design phase, and methods for summative evaluation, which provide information on the product's efficacy and its ability to evoke the expected user experience.

Formative evaluation of UX is particularly difficult, because it needs to link product or design features to the actual experience. The design of a product is complex and it is difficult to manipulate single features without changing the character of the product fundamentally. Park, Choi and Kim (2004) for example have identified 13 aesthetic dimensions and 256 corresponding distinctive visual elements of web pages. Researchers also strive to connect product features and qualities to emotional responses and these further to attitudes, actions and experiences (see e.g. Rhea, 1992). Moreover, this becomes increasingly difficult: the more the qualitative richness of the product and context is included, the less transferable the individual findings are (Roto, 2006).

Temporal aspects

Although strictly speaking UX describes the experience *while* interacting with a product, the matter of investigation starts before even the first contact with the product and lasts beyond the actual use. UX is not a static measure (e.g. a momentary emotion), but changes over time and influences the next experiences. The user has a history, which shaped his needs and expectations, her ability to cope with a certain situation, his knowledge about the world of products and how to handle them, and she has a future that is shaped by the experience with the product. In addition, the usage context and the environment are changing as well, and influence the experience even when not interacting (e.g. through advertising).

While this actual experience is important, it is, due to its complex, situated and temporal nature, very difficult to address by measurement. Some frameworks (e.g. McCarthy & Wright, 2005) incorporate the temporal nature of UX, but cannot properly transfer the model into measurement tools. Roto (2006) suggests to compartmentalize the process and to look at UX before, during and after interaction. She names the phase before the actual interaction *expected UX*, the phase after the interaction *overall UX*. The expected UX is formed by brand image, advertising, friends or knowledge acquired prior to interaction. Expected UX significantly influences UX during the interaction. Separating the different

phases of experience facilitates the development of measurement instruments, as the emphasis on what to measure can be shifted from phase to phase.

Implicit measurement

Temporal aspects are not only relevant when deciding *what*, but also *when* to measure. The evaluation of a user's experience during interaction is the key element to understand the connection between product attributes and the user's experience. Self-reports during the interaction phase pose problems as they might interrupt the flow of the interaction. Furthermore, the momentary state of the user becomes conscious which might not be desired. Retrospective evaluation on the other hand, is interesting because it provides summary judgements about the overall quality of an experience (Hassenzahl & Ullrich, 2007). However, retrospective evaluations are not simple averages or sums of all the prior moments encountered during interaction, they rather reflect peak moments during the experience, especially when subjective feelings (e.g. emotions, pain) are concerned. Furthermore, the interest of UX research in retrospective measurements can be doubted, as they reflect past experiences (e.g. satisfaction) and are not an indicator of future behaviour.

In conclusion, there is a need for UX measurement concurrent with the interaction, but it should be implicit to avoid bias of the evaluation and disturbance of the interaction. For retrospective measurement, Desmet (2002) argues that the best way to understand emotions elicited by a product's appearance is by non-verbal means, although both verbal and non-verbal self-reports are subject to the general tendency of people to modify their emotional reporting increasingly over time. For retrospective measurement, an implicit, projective method seems appropriate.

Perceived/expected vs. experienced/observed

Related to the debate about subjective vs. objective measurement is the question, whether perceived qualities of products or actually experienced qualities are more relevant and if expected UX (as intended by the designer) or actually observed UX (as experienced by the user) are the same. Several UX frameworks stress aspects labelled "perceived XY", e.g. perceived affective/hedonic quality, perceived ease of use or perceived usefulness. The focus of UX on the subjective, personal experience justifies this emphasis. For UX, the perceived quality is more important than the objective quality, e.g. if a user perceives the system as easy to use, the objective ease of use is irrelevant (as long as it is not a self-deception of the user). Often, it is easier to assess the perceived quality rather than the experienced quality by measurement tools.

The other issue mentioned, if expected UX and actually observed UX match, is relevant for designers, as it feeds back information about how well the intended design could evoke the desired UX. It is difficult to design *for* UX, because not just the product determines the experience, but also the user and the usage context have to be considered, but defy control. The validity and reliability of measurement instruments for the design phase can be improved by continuous comparison with instruments that measure the observed UX.

Granularity of measurement

UX can be analyzed on different granularity levels. An example of a detailed granularity level is the UX of a single key click. For example: Was the key easy to press? Were the tactile, auditory, and visual feedbacks pleasurable? A higher level of granularity is a use case: Did the user achieve his goals by using the system the previous time, and did he enjoy that use case? On an even higher level, we can investigate the relationship between the product and the user, even after he has replaced the product with a new one. All these different granularity levels provide useful information about UX, and can be used for different purposes. If we want to improve a specific product detail, we can create several alternative designs of that detail and apply the smallest granularity level to evaluate the different designs. If we want to understand which features work well for different users in different contexts, we apply the use case analysis level. If we want to understand the value and importance of a product to the user, we apply the overall relationship level. It would also be interesting to see how the user experiences aspects on a lower level correlate with the overall UX.

2.3.2 Measuring affect

Larsen and Fredrickson (1999) point out that every emotion measurement method has its strengths and weaknesses and that when measuring emotions a working definition of emotions should be the basis to choose relevant methods. The multi-component model proposed by Scherer (1984) with its five aspects subjective feelings, physiological reactions, motor expressions, cognitive appraisals and behavioural tendencies serves as a structure for the presentation of emotion measurement approaches (a more detailed discussion of affect, emotion and mood can be found in Chapter 3.2.1).

Subjective feelings

Clinical psychology has a long tradition of affect measurement. There exist literally dozens of affect inventories: verbal descriptions of an emotion or emotional state, rating scales, standardized checklists, questionnaires or semantic and graphical differentials. Subjective ratings are based on the

assumption that people to some degree are aware of their emotions and are able to describe them (Mehrabian, 1995).

One such self-assessment technique emerged from research on the measurement of meaning. The semantic differential scale by Osgood (1957) has influenced both measurement methods and emotion theories (e.g. the dimensional emotion theory (Mehrabian, 1996)). The semantic differential was developed for the investigation of the linguistic meaning of words. Osgood divided language into three main dimensions of meaning: Evaluation, Potency and Action. On those dimensions are different simple bipolar keyword couples placed. Individual profiles are made by asking people to rate the object of interest with those bipolar word couples on the three dimensions. The semantic differential can be adapted by using different word lists. A wide variety of questionnaires and interview techniques exist.

The Semantic Differential Scale devised by Mehrabian and Russell (1974) consists of a set of 18 bipolar adjective pairs that generate scores on the valence, arousal and dominance scales. There are several examples that translated this approach into scales of varying item numbers and affective dimensions. The Brief Mood Introspection Scale (BMIS) is a mood adjective scale with an item sample of 16 adjectives, 2 selected from each of eight mood states: happy, loving, calm, energetic, fearful/anxious, angry, tired, and sad (Mayer & Gaschke, 1988). The Mood-State Introspection Scale (MIS) is a 62-item adjective checklist with 10 mood subscales. The Russell Adjective Scale (RAS) is a 58-item adjective checklist with 11 subscales designed to measure factors of mood (Russel, 1979).

The affect grid (Russell, Weiss, & Mendelssohn, 1989) is another semantic questionnaire to assess emotional states. In contrast to SAM (see below), the affect grid is a single scale questionnaire. It consists of a 9 x 9-matrix that is surrounded by eight adjectives describing emotions. Additionally, the adjectives are arranged by the dimensions valence and arousal, like the ones in Russell's circumplex model of emotion (Russel, 1980). Individuals are instructed to rate their emotional state by setting a cross in one field of the matrix.

The Self-Assessment-Manikin (SAM), devised by Lang (1980), is designed to assess the dimensions of valence, arousal and dominance/control directly by means of three sets of graphical manikins (see Figure 2-3 for valence and arousal dimensions). The manikins represent five states from happy to unhappy, excited to calm and being in control to being controlled. Individuals rate their feeling either on a manikin or in the space between two manikins, which results in nine graduations per dimension.

Figure 2-3: The scales valence (top) and arousal (bottom) of the Self-Assessment-Manikin (Lang,1980)

Desmet (2002) presented an extended adaptation of this approach (Figure 2-4). It builds on the premise that emotions elicited by product design are typically of low intensity and have a mixed character. The PrEmo tool depicts 14 animations of a cartoon character. The character expresses seven positive emotions, i.e. inspiration, desire, satisfaction, pleasant surprise, fascination, amusement, admiration, and seven negative, i.e. disgust, indignancy, contempt, disappointment, dissatisfaction, boredom, and unpleasant surprise. The non-verbal assessment is supposed to reduce intercultural differences, especially those that result from semantic verbalizing of emotions.

Figure 2-4: The PrEmo measurement tool (Desmet, 2002)

The majority of existing UX research uses some form of questionnaire to assess the emotional state of subjects. Either a verbal or a graphical differential with one or more items, or statements indicating an affective state (e.g. "I find using this system to be enjoyable", Zhang & Li, 2004, p. 644) that is rated as how much it applies to the current state of the subject. 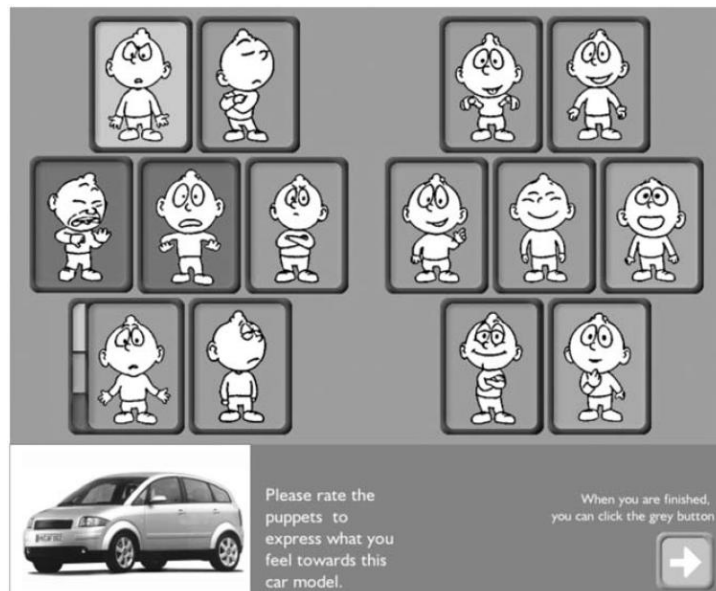Several studies have also used open questions (e.g. McCarthy & Wright, 2005; Tractinsky & Zmiri, 2006), where subjects could indicate their affective state in their own words. Data is in these cases analyzed qualitatively. One notable exception is the approach of Mahlke (2008), who incorporated measures for subjective feelings, physiological reactions and motor expression.

Physiological reactions

Over the past few decades, empirical work has provided evidence for a correspondence between a number of physiological variables (e.g. skin conductance, heart rate, facial muscle activity, cortical activity, startle reflex or eye blink magnitude) and the emotional dimensions of valence and arousal (e.g. Ekman, Levenson, & Friesen, 1983; Bradley & Lang, 2000; Bradley, Codispoti, Cuthbert, & Lang, 2001; Gomez, 2005). Physiological signals can provide information regarding the intensity and quality of an individual's internal affect experience.

One possible measure of physiological correlates of emotions is skin conductance, also known as electrodermal activity (EDA). It is a measure of the hydration in the epidermis and dermis of the skin. The physiological basis of SC is the activity of the eccrine sweat glands. These glands have a wide distribution over the body surface, but are especially concentrated in the palms of the hands and the soles of the feet. In psychophysiological research, EDA is typically recorded from the surface of the hand. Common parameters are skin conductance response (SCR), skin conductance level (SCL). Eccrine glands in the skin of the hand respond only weakly to heat but strongly to psychological and sensory stimuli. The sweating to psychological stimuli has sometimes been termed "arousal" sweating. Previous research suggests that the magnitude of SCR and SCL covary with the arousal level of the subject, regardless of their valence (e.g. Lang, Greenwald, Bradley, & Hamm, 1993).

Another way to gain information on physiological activation is to record heart activity by an electrocardiogram. There are a variety of parameters for analyzing and interpreting the raw signal. Common time-related parameters are heart rate, inter-beat-interval, and heart rate variability (Fahrenberg, 2001). Heart rate (HR) is one of the most studied physiological measures in emotion research, but its behaviour is far from being fully understood. Both the direction of HR change

(acceleration vs. deceleration) and the effects of emotion have varied based on the experimental paradigms and the type of mental processing (for a detailed overview see: Gomez, 2005). To summarize, it can be said that heart activity seems to be a more reliable indicator for arousal and mental workload than for emotional valence (see Fahrenberg, 2001).

The correlations between affect and breathing parameters are gaining increasing interest in psychophysiological research. Respiration can be measured as the rate or volume at which an individual exchanges air in their lungs. Rate of respiration and depth of breath are the most common measures of respiration. Results of several studies (e.g. Bloch, Lemeignan, & Aguilera, 1991; Gomez, 2005) suggest that arousal increases respiration rate while rest and relaxation decreases respiration rate. (Negative) valence causes irregularities in the respiration pattern.

Other research suggests that pupillometry is a good indicator for autonomic responses and mental workload. The more demanding a process is, the larger the pupil is supposed to be (Beatty, 1982). Hess and Polt (1960) found a significant correlation between dilatation and the valence of a stimulus.

Physiological signals are measured with a wide variety of instruments and sensors. Unfortunately, using physiological signals requires specialized and frequently expensive equipment and technical expertise to run the equipment which makes this method suitable for lab experiments but not for applied use. Sensors are attached directly to the body, which can be considered obtrusive or even invasive by many subjects. Additionally, it can be quite difficult to separate confounding factors influencing physiological reactions in order to attribute significant changes to the experimental variable (Kramer, 1991).

Motor expressions

Motor expressions include facial expressions, gestures, posture, body language, motor behaviour (e.g. hand muscles, head movements) or voice modulation. Motor expression measurement methods are based on the fact that the body usually responds physically to an emotion (e.g. changes in muscle tension, coordination, strength, frequency) and that the motor system acts as a carrier for communicating affective state. Especially promising for these methods is that people also use many of signals in everyday life to evaluate the affective state of other people. In contrast to physiological measurement, methods in this area can often be applied in a non-invasive way. The three most prominent of these methods are face recognition, electromyography (EMG) and voice intonation analysis, which both have been investigated in many research projects (for an overview see Cowie, et al., 2001).

The Facial Action Coding System (FACS) is based on the analysis of 44 facial muscles (Ekman & Friesen, 1978). A trained person categorizes the observed pattern of activity in respect to six basic emotions fear, anger, joy, disgust, grief, and surprise. To gain reliable information, FACS requires an intensive training. Computerbased, automatic analysis of facial expression does not yet lead to comparable results (e.g. Cohen, Sebe, Chen, Garg, & Huang, 2003).

Electromyography (EMG) measures muscle activity by detecting surface voltages that occur when a muscle is contracted. Over the last decades, EMG has been widely used in emotion research to investigate facial muscle activity. One advantage of facial EMG is its ability to detect minimal changes in muscle contractions that can be hardly identified by simply looking at faces. In isometric conditions (no movement) EMG is closely correlated with muscle tension (Stern, Ray, & Quigley, 2001), this is, however, not true for isotonic movements (when the muscle is moving). When used on the jaw, EMG provides a very good indicator of tension in an individual due to jaw clenching (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 1993). Facial EMG studies have found that activity of the corrugator supercilii muscle, which lowers the eyebrow and is involved in producing frowns, varies inversely with the emotional valence of presented stimuli and reports of emotional state. The activity of the zygomaticus major muscle, which controls smiling, is positively associated with positive emotional stimuli and positive affect (Cacioppo et al., 1993).

Another approach based on measuring motor expressions is the analysis of speech characteristics, like speed, intensity, melody, and loudness. Empirical research suggests that these qualities are highly correlated with affect, and are therefore reliable indicators for emotional reactions (Schuller, 2006). Automatic speech analysis requires advanced methods for recording, preparing and analysis of data.

Body postures and gestures have been analysed both manually (through observation) as well as automatically (through video analysis). Grammer, Honda, Schmitt & Juette (1999) have developed video analysis software for frame-by-frame extraction of motion differences. They have found that body movements correlate to courtship behaviour, depression and affect in general (e.g. Juette, 2001).

Affect measurement through motor expression is very promising. Chapter 4 presents the development and verification of a new method based on mouse actions of computer users. A more detailed overview of methods for the analysis of motor expression, especially in respect to HCI, is discussed in Chapter 3.2.

Cognitive appraisals

To assess cognitive appraisals, both quantitative and qualitative methods are available. As a quantitative approach, the GAF (Geneva Appraisal Questionnaire) by Scherer (2001) measures retrospectively the quality of an emotional episode as antecedent of a relevant connoted event. The items of the GAF represent the five dimensions of Scherer's component process model of emotion: intrinsic pleasantness, novelty, goal/need significance, coping potential, and norm/self compatibility (Scherer, 2001). In addition, the questionnaire contains questions on the timing and the social context of the emotional experience and the event, as well as questions on intensity, duration, and regulation of the emotional experience. The GAF is a rather long questionnaire and therefore the application of the original version in human-technology interaction is less suitable.

A qualitative approach to assessment of cognitive appraisals servers the thinking aloud method. People are encouraged to state and describe every emotional reaction they feel during interaction with a product. The statements are recorded, reduced in respect to the focus of research, and analyzed by a qualitative procedure. To prevent disturbing interactions between usage and assessment, the thinking aloud method can be applied retrospectively, e.g. by presenting a video (Mahlke, 2008).

Behavioural tendencies

The measurement of performance and behaviour has a long tradition in HCI research. Central indicators of performance are speed of reaction (e.g. the time required for single input operations or completing a defined goal), the accuracy of reaching a goal or the number of errors made. Findings of Partala and Surakka (2004) indicate that behavioural data is related to EMG values. The results demonstrate that low activation of the corrugator supercilii muscle is related to a high rate of successful and goal conductive reactions with a usable designed system.

In humans, often the overt action is missing in an emotional episode. The body mobilizes for a response without actually conducting the action. Adrenaline flows and the cardiovascular system moves oxygen to the gross muscles in preparation. In this sense, emotions are often dispositions to action, rather than the actions themselves (Frijda, The Emotions, 1986; Lang, 1995). When a stimulus prompts the execution of an action procedure, preparatory metabolic changes occur in muscles and glands. Measurement of these changes could until recently only be done by invasive methods (e.g. analysing metabolites in the blood), but increasingly non-invasive methods become available (e.g. skin

temperature measurement with infrared sensors; blood flow in certain brain regions through PET (positron emission tomography) scans).

In HCI, behavioural tendencies can be detected for example by the force of clicking a mouse-button (Ark, Dryer, & Lu, 1999) or by analysis of the movements while selecting and moving icons on a touch-screen (Wensveen, Overbeeke, & Djajadiningrat, 2000). In design research, products with enriched emotional content have been investigated in respect of the behavioural reactions they impose on users (Djajadiningrat, 1998).

2.3.3 Measuring hedonic qualities

Most UX models incorporate non-instrumental qualities in some form, as the overview of UX frameworks in Chapter 2.2 has shown. Although there is an intensive theoretical discussion of non-instrumental aspects and their application to design and HCI, only a few approaches provide validated measurement instruments for a quantitative or qualitative evaluation. This fact complicates further research on their importance and interplay with other aspects of user experience.

A clear distinction between measures of hedonic qualities and measures for more experiential approaches (see next chapter) cannot be made, because experiential approaches often include hedonic qualities. Furthermore, visual aesthetics and symbolic aspects are closely related, but are often separately mentioned in publications. Hence, the categorization of the following chapters is somewhat artificial, but tries to give a basic structure to the measurement approaches presented.

A category of its own would be user needs and expectations. While hedonic qualities are always aspects of the product, needs are concerns of the user and essential determinants of the outcome of an evaluation of instrumental and non-instrumental qualities of the product. Human needs are the drivers for product use and possession. In Chapter 2.2.1, a range of needs considered relevant in the context of products was presented. Although human needs are central elements of most of the presented UX frameworks, not the needs themselves are object of evaluation, but how well the product can meet these needs and expectations. A discussion of the interrelation of needs and product qualities can be found in Chapter 3.

Symbolic aspects

Symbolic aspects represent the meanings or associations a product elicits in a user. Hassenzahl, Burmester and Koller (2003) developed an online

questionnaire ("AttrakDiff"[3]) that assesses three dimensions of product qualities: a *pragmatic* (instrumental) quality, a first hedonic quality *stimulation* and a second hedonic quality *identification*. Additionally, they included a measure for overall attractiveness of the product. The questionnaire is based on the UX framework of Hassenzahl (2003), but leaves out a third hedonic quality aspect, *evocation*. The questionnaire uses randomly presented bipolar word pairs, such as "inviting-rejecting", "likable-disagreeable", "confusing-clear" or "exceptional-common". Multiple items are combined to one of the three quality measures.

Rafaeli and Vilnai-Yavetz (2004) collected through interviews with experts (for design and communication) statements, which belong to one of three categories: instrumental, aesthetic and symbolic. The qualitative analysis confirmed that statements about products belong mainly to one of these categories. A typical "symbolic" statement was for example "green symbolizes nature, symbolizes environmental friendliness". Tractinsky and Zmiri (2006) built – based on the findings of Rafaeli and Vilnai-Yavetz – a questionnaire assessing three similar dimensions: aesthetics, symbolism and usability. Item referring to the symbolic dimension include: "communicates desirable image", "represents likeable things", "creates positive associations".

Mahlke (2008) distinguishes an associative and a communicative dimension within symbolic aspects of products. He mixes items of Hassenzahl's AttrakDiff questionnaire with a selection of items he made up himself. Rubinoff (2004) uses in his evaluation method a dimension called "branding" which includes items for aesthetic and symbolic qualities.

Aesthetic aspects

The fields of fine art and design, as well as psychology have a long tradition of evaluating aesthetics. Where in art, quantitative methods are of lesser relevance, psychology has approached aesthetics primarily perceptually. Most psychological work related to aesthetics has focused on perceptual features (Leder, Belke, Oeberst, & Augustin, 2004), but for the context of UX, studies showing a connection of perception and emotion are of particular interest. According to Frijda (1989), aesthetic experiences can be seen as affectively positive. Concerning the development of the affective state due to aesthetic experience, the affective state at the beginning of an aesthetic experience is particularly important. Konečni and Sargent-Pollock (1977) found that the emotional state of the participants was a good predictor for ratings of pleasantness in that positive judgments were made under conditions of positive mood. Moreover, aesthetic experience might also change the affective state.

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[3] http://www.attrakdiff.de/

Various approaches to the assessment of visual aesthetics of products take an HCI or design perspective. Kleiss and Enke (1999) for example used 18 pairs of bipolar attributes to assess the visual appearance of automotive audio systems, such as "stylish-functional", "revolutionary-established", exciting-boring", etc.. In a similar study, Park, Choi and Kim (2004) identified 13 aesthetic dimensions in the design of web sites. Nonetheless, like in other approaches some of the items also represent instrumental and symbolic qualities.

Schenkman and Jönsson (2000) modulated seven aesthetic aspects to assess visual aesthetics: complexity, legibility, order, beauty, meaningfulness, comprehension, and overall impression. Each variable is only represented by one item and the names of the concepts seem somewhat ambiguous.

Lavie and Tractinsky (2004) present a comprehensive approach to the measurement of visual aesthetic. They developed a questionnaire based on four empirical studies that consists of two main dimensions of visual aesthetics, which they labelled *classical aesthetics* and *expressive aesthetics*. The classical aesthetics dimension relates to aesthetic notions that presided from antiquity until the 18th century. These notions emphasize orderly and clear design and are closely related to many of the design rules advocated by usability experts today. The expressive aesthetics dimension is manifested by the designers' creativity and originality and by the ability to break design conventions (Lavie & Tractinsky, 2004, p. 269). To measure each of the dimensions they give a five-item scale. Hassenzahl (2007) criticizes that the dimension of expressive aesthetics measures more symbolic or motivational aspects that are conveyed by visual attributes than directly focusing on aesthetic aspects.

2.3.4 Measuring the experiential

Methods in this category include a great variety of qualitative, eventually less systematic evaluation strategies that try to measure certain or even all aspects of a user experience. Some of the methods have been used in HCI (e.g. observation or task analysis) and marketing (e.g. focus groups) for a long time. In an attempt for completeness, some methods are mentioned here, but it would go beyond the focus of this thesis to discuss them in detail.

Fisher and Sanderson (1996) propose to use conversation analysis, verbal and non-verbal protocol analysis and discourse analysis to capture the experience. In a recent overview, Ardito, Costabile, Lanzilotti and Montinaro (2007) have proposed some methods to evaluate games

- Direct Observation and Video Analysis for examining behaviour
- Focus groups to capture first impressions and opinions
- Essays and drawings analysis

- Motivational patterns, e.g. the Task Status Display (TSD) pattern

Csikszentmihalyi and Larson (1987) have developed the Experience Sampling Method (ESM). The experiences, thoughts, and feelings of a number of people at random moments during the day are sampled as they go about their daily activities. Participants in an ESM study carry an electronic pager and fill out reports and questionnaires when they are notified.

The cultural probes technique (Gaver, Dunne, & Pacenti, 1999) is intended more as an inspiration for designers than an evaluation of existing products. Subjects receive a kit with different tools to capture experiences in it, e.g. a photo camera, dream recorder, notebook, etc. People describe their experiences and attitudes towards their life, similar to the ESM of Csikszentmihalyi and Larson. A similar approach is the technology biography of Blythe, Monk and Park (Blythe, Monk, & Park, 2002).

Some more systematic and acknowledged approaches include:

- Attribution: a description of the product with adjectives: the product is sporty, elegant…
- Comparison: a comparison of the product with something else: animal, profession, artefact...
- Negation: attributes that do not fit with the design
- Sensation: effect of the product on the five senses: how would the product smell, taste, feel…?
- Narration: a story describing the product emotion: every story contains symbols and memories which can be related to the product
- Projection: a description not of the object itself, but of the user, buyer, owner of the product
- Product Personality Assignment (PPA): A method (Jordan, 1997) to relate product design to human personality types, using the Myers-Briggs Type Indicator
- Mood board: a mood board is a collage of images, corresponding to the expression of the product
- Visual positioning: systematic approach of a mood board; subjects are questioned and respond with their own or pre-defined images

3 Method

The last chapter has shown that there is a great variety of UX theories and frameworks available. The associated measurement methods are not very sophisticated or take a too abstract approach, compared to traditional usability evaluation methods. Furthermore, it is unclear, how these measures feed back to user experiences.

The aim of this thesis, as stated at the beginning, is the development of new evaluation methods for UX. In order to do this, the measurement has to be grounded in a theory, and aspects of the theory have to be identified that are a) relevant for the construct, and b) measureable. This chapter starts with the presentation of a UX framework that assists to embed the two measurement instruments into a context. Important elements are emphasised and examples illustrate the practical meaning of the framework. The two measurement methods are presented and the elements they measure are highlighted. In Chapters 3.2 and 3.3, methodological aspects are presented and discussed.

3.1 First impressions and affective reactions

The UX model described here was inspired by ideas of different frameworks presented in the last chapter and integrates and extends them to a new model. Especially the terminology and the basic distinction of pragmatic and hedonic qualities of products are borrowed from Hassenzahl's framework of UX (for details see, Hassenzahl, 2003).

3.1.1 A UX framework

Figure 3-1 shows an overview of the proposed model with its key elements. At the beginning of the user experience process, the user perceives the *product's features* (e.g. layout, content, functionality, interaction capabilities). He combines them with his personal expectations, needs or standards to form the *perceived product character* (e.g. innovative, comprehensible, or professional*)*. The product character is a high-level description, similar to the character we attribute to people (Janlert & Stolterman, 1997). It summarizes a product's qualities, e.g. novel, interesting or useful, and thus reduces complexity. The perceived product character is constructed automatic and in just a moment, and it triggers strategies for handling the product (Hassenzahl, 2003). The product character consists of groups of *pragmatic* (e.g. utility, functionality) and *hedonic* (e.g. stimulation, novelty, identification) qualities. Pragmatic attributes are connected to the users'

need to achieve behavioural goals. Above all, goal achievement requires utility and usability. In this sense, a product that allows effective and efficient goal-achievement is perceived as pragmatic (or possesses perceived pragmatic quality). In contrast, hedonic attributes are primarily related to the users' self and emphasize individuals' psychological well-being. The hedonic function of products can be further subdivided into providing stimulation, communicating identity, and provoking valued memories.

The relative importance of pragmatic and hedonic qualities can change over the course of the experience.
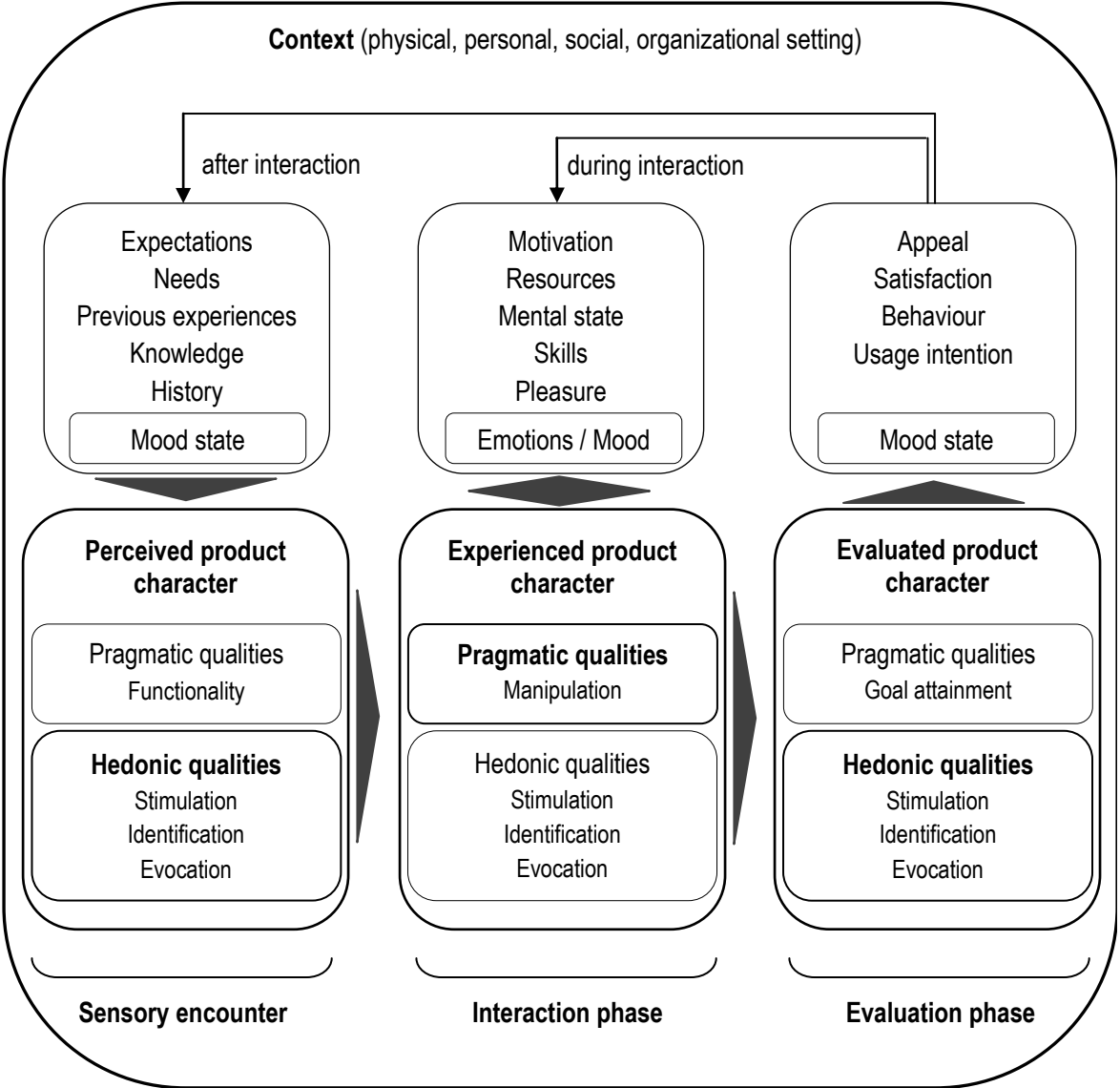

Figure 3-1: Elements of the UX model and phases of evaluation

The first encounter with a product (i.e. seconds to minutes, depending on the product) is purely sensual and is named here *sensory encounter* (MacDonald, 2001; 2002).

The next phase is the actual *interaction phase* with the product, e.g. buying a good on a website or driving a car. The user will modulate the product character to an *experienced product character* from qualities and product features that he experiences, based on his motivation, resources, skills or mood state. The relevant product qualities might be the same as during sensory encounter, or might be different qualities if they were not perceivable or were of minor importance during the first phase. The experience with the product will continually feedback to motivation, mood state or resources and will eventually elicit emotions.

Finally, after the interaction or during breaks in the interaction phase, the product is retrospectively evaluated in the *evaluation phase*. The perceived product character is compared to the experienced product character, some features are valued more important than others retrospectively and product is evaluated if it fulfils the current or future needs. This evaluation leads to consequences: affective state might be maintained or changed (e.g. satisfaction, good or bad mood), explicit evaluations (e.g. judgements of appeal, beauty, goodness), or behavioural consequences (e.g. usage intention, approach/avoidance). The consequences of a particular product character are not necessarily always the same, but are moderated by the specific usage situation. Individuals might find a product novel, but do not necessarily evaluate it as appealing. In other words, evaluation of hedonic or pragmatic qualities can potentially lead to a positive outcome, but does not have to.

The three phases have similarities to Norman's 3-level theory of human behaviour (Norman, 2004) that integrates affective and cognitive processes. In each level, the world is being evaluated (affect) and interpreted (cognition). The lowest level processes takes place at the reaction (or visceral) level, which surveys the environment and rapidly communicates affective signals to the higher levels. The routine (or behavioural) level is where most of our learned behaviour takes place. Finally, the reflection level is where the highest-level processes occur. The important role of affect in human behaviour is that our thoughts normally occur after the affective system has transmitted its information (Tractinsky & Zmiri, 2006).

While Norman's levels are hierarchical and parallel processes, the three phases of constructing product character are sequential. In the sensory encounter phase, aesthetics play an important role. Although aesthetics are not explicitly highlighted in the model, they are part of pragmatic, but especially

hedonic quality attributes of the product. Aesthetic evaluations may take place on all three levels or phases, but there is evidence that first aesthetic impressions are formed immediately at a low level (sensory encounter phase) and precede cognitive processes (e.g. Zajonc & Markus, Affective and Cognitive Factors in Preferences, 1982; Norman, 2004). Those first impressions may persist and correlate highly with later evaluations of interactive systems (Tractinsky, Katz, & Ikar, 2000; Tractinsky, Cokhavi, & Kirschenbaum, 2004; Fernandes, Lindgaard, Dillon, & Wood, 2003). Instrumentality considerations (i.e. pragmatic qualities) are most likely to take place at the routine level (interaction phase). The model stresses the importance of pragmatic qualities during interaction. Considerations of the artefact's symbolism (hedonic qualities) are likely to occur at the reflective level (evaluation phase).

The outcomes of the evaluation feed back to the expectations, needs, history or moods of the user, influencing the next experience with the same or a different product. However, they can also feed back to an ongoing interaction, e.g. working for days or month with a computer in an office workplace.

An example application of the framework

For a better understanding, let us take a look at an example. A person, e.g. Brad, is interested in buying a new car. He has been looking through brochures of car companies, has seen advertising on TV and has been talking to a friend about his experiences with cars [input: knowledge, history, previous experiences]. He actually needs a car that takes him to work every day [input: needs], but he also likes to make a statement about his social status with the car [input: expectations]. The car dealer presents him a new Volkswagen (VW) model [context: social]. Brad likes the dark colour because it looks elegant [perceived product character] and since he is in a good mood [input: affect/mood], the sporty style of the VW springs to his eye [hedonic quality: identification]. It reminds him of his first car he had when he was young [hedonic quality: evocation]. And he is surprised of the new design of the back lights that he has never seen before like this [hedonic quality: stimulation]. The car dealer mentions the reliability of the engine to Brad [pragmatic quality: functionality]. Brad constructs mentally a perceived product character of the car.

Then, he can test drive the VW. The leather interior supports the notion of an elegant, noble car [hedonic quality: identification]. Brad likes the quiet sounds of the engine, and that the car speeds up very quickly. He also notices the clear arrangement of meters on the dashboard [pragmatic quality: functionality/manipulation]. He is surprised how unexpectedly unconstrained the gears can be shifted [hedonic quality: stimulation]. The smell of the new interior

reminds him of happy moments driving around in a new car [hedonic quality: evocation]. Good that he is such an experienced driver [input: skills/knowledge], it makes driving around a real pleasure [feedback: emotions]. This is a car to his taste [experienced product character]. Brads mood is even getting better [feedback: mood] when he notices the passers-by that admire him in his car [context: social; hedonic quality: identification; feedback: motivation]. His mood gets worse when the engine wouldn't start after a stop in front of a red traffic light [pragmatic quality: functionality; feedback: mood]. But he finally makes it back to the car dealer.

Brad is unsure of the reliability of the car because the engine has once not started [pragmatic quality: goal attainment]. He finds the car dealers promise of reliability not true and is not satisfied [consequence: satisfaction]. He decides to wait with his purchase [consequence: usage/purchase intention]. All in all, he does not really like the car now [consequence: appeal; evaluated product character], although he really enjoyed the envious looks of the passers-by [consequence: pleasure/enjoyment; hedonic quality: identification; context: social]. He spent another two hours evaluating cars, and he really needs a new car, that makes him feel a little depressed [consequence: mood; feedback: needs/previous experiences/mood; context: personal].

The example should have illustrated the basics of the UX framework presented. In the following, two important aspects – the moderating aspect of affect, emotions and mood and hedonic qualities – will be discussed in more detail. Mood and hedonic qualities are the elements of UX that will be measured by the methods developed within the scope of this thesis.

3.2 The mediating effect of mood and affect in interaction

3.2.1 Affect, emotion, mood

Before continuing with details of the UX framework, the terms affect, emotion and mood should be clarified. The terms affect, emotion and mood are often used interchangeably without a clear definition (Forgas, 1995). The term *affect* is used here as a higher-level label and the most generalized of the three terms. It may be used to refer to both emotions and moods (Forgas, 1995). This is consistent with the understanding in related research (e.g. Brave & Nass, 2003; Russell, 2003). An emotion has the properties of a reaction: it often has a specific cause, a stimulus or preceding thought, it is usually an intense experience of short

duration - seconds to minutes - and the person is typically well aware of it. On the other hand, a mood tends to be subtler, longer lasting, less intensive, more in the background, giving the affective state of a person a tendency in positive or negative direction. Moods tend to be nonspecific compared to emotions, which are usually specific and focused on an identifiable person, object or event. In psychological research, it has been shown that mood affects memory, assessment, search strategy (e.g. in e-commerce), judgment, expectations, opinions and motor behaviour (e.g. Derbaix & Pecheux, 1999).

In contrast to emotions, people may not be aware of their mood until their attention is drawn to it. Moods tend to bias which emotions are experienced, lowering the activation thresholds for mood-related emotions or serve as an "affective filter". A series of discrete emotions, on the other hand, can become the cause of a more enduring emotional state (e.g. Aboulafia, Bannon, & Fernstrom, 2001; Brave & Nass, 2003). In other words, distinct emotional episodes result in changes of mood state. Hence, it is important to consider the biasing effect of moods, e.g. in UX studies: subjects in a good mood are likely to experience positive emotions, subjects in a bad mood experience more likely negative emotions.

Core affect and affective quality

In the context of UX, the concepts of affect introduced by Russel (2003) might be more useful, as they distinguish clearly between emotion, mood (feeling) and the objects that might lead to changes in affect.

Core affect refers to a neurophysiological state that is consciously accessible as a simple, non-reflective feeling that needs not to be directed at anything (Russell & Feldman Barrett, 1999). Core affect is considered to be primitive, universal and ubiquitous, it lasts over the course of time and is always present (Diener & Iran-Nejad, 1986). Although core affect is not necessarily consciously directed at anything, it can become directed, as when it is part of an emotional episode. Core affect has also been called affect (Watson & Tellegen, 1985), mood (Morris, 1989), and feeling (Russell, 2003).

Empirical research found that core affect, can be described by two independent dimensions, the degree of pleasantness (valence: pleasure-displeasure) and the degree of activation (arousal: sleepy-activated). *Valence* summarizes how well one is doing, the extent to which one is feeling good or bad. *Arousal* refers to a sense of mobilization or energy, the extent to which one is feeling engaged or energized.

Affective quality is the ability to cause a change in core affect (Russell, 2003). Whereas core affect exists within the person, affective quality exists in the

stimulus. Objects, places, and events all have affective quality. They enter consciousness being affectively interpreted. The perception of the affective quality of the stimuli typically becomes conscious at any one time, then influences subsequent reactions to those stimuli (Russell, 2003).

Perceived affective quality is an individual's perception of an object's ability to change his or her core affect. It is a perceptual process that estimates the affective quality of the object. It begins with a specific stimulus and remains tied to that stimulus (Russell, 2003). Perception of affective quality has been called other terms such as evaluation, affective judgment, or affective reaction, and it is considered a ubiquitous and elemental process (Zajonc & Markus, Affective and Cognitive Factors in Preferences, 1982; Russell, 2003).

It is worth noting that core affect can change without reference to any external stimulus, and a stimulus can be perceived as affective quality with no change in core affect - as when a depressed patient admits that the sunset is indeed beautiful but cannot alter a persistently depressed mood (Russell, 2003). The contributing factors to a person's core affect can be numerous, either internally (factors within the person) or externally (stimuli in the environment). From an HCI perspective, the connection between a person's affect and the possible affect-eliciting quality of a product is interesting. Perceived affective quality is a construct that makes such a connection. In addition, one thing that is very attractive or affect evoking to one person may not be so to another. Perceived affective quality reflects this subjectivity.

3.2.2 Affect in UX

UX research stresses the importance of emotions and psychological research could show that they are fundamental aspects of human beings, influencing perception, cognition, behaviour, judgement or decision-making (e.g. Forgas, 1995; Russell, 2003). The proposed model of UX shows that mood and emotions are also important in the view of the author, but maybe in a different sense than other UX frameworks understand the influence of affect in user-product relationships.

In Chapter 2.2.2 it has been noted that there are two major perspectives of dealing with affect in UX. One perspective understands emotions as *consequences* of product use, as the result of cognitive appraisal processes of the product and the usage situation. The other perspective on emotions in UX sees emotions as *antecedents* of product use and evaluative judgements. The presented framework adds a third perspective that sees affect as a *mediator* between perception, experience and evaluation of product use.

The interplay of emotions and moods with cognition and perception is complex. Zajonc (1980) showed that valenced affective reactions can be instantaneous, automatic, and without cognitive processing. Current HCI research understands the emotional view as opposed to traditional usability research that stressed cognition, but contemporary psychology understands emotions and cognition as integral parts of each other (Hassenzahl, 2004b). Complex emotions like joy, satisfaction or pride require cognitive processing. Satisfaction, for example, is the consequence of comparing an event's outcome (e.g. product use) with one's expectations (Ortony, Clore, & Collins, 1988). Therefore, complex emotions as a consequence of the evaluation of a product must be part of any UX framework. However, the process of evaluation feeds back to the affective state while interacting, but also influences future perceptions and experiences. Cognitive and affective experiences are linked reciprocally (Scherer, 2001). Discrete emotions, as noted in the last chapter, can become the cause of a more enduring emotional state (mood) and moods tend to bias which emotions are experienced.

As the concept of core affect shows (Russell, 2003), there are also longer lasting, non-reflective feelings, which are not directed at anything and are always present. These mood states at the beginning of an experience can affect the quality of information processing according to Forgas (1995). Positive affect, for example, supports a holistic mode of processing, which is based on activation of wide semantic fields in memory, in contrast to negative affect that leads to a more restricted processing. Mood is therefore an important mediator for experiences.

Another issue of UX models concerns the connection of product attributes and emotions and whether an emotional experience can actually be designed or not. Hassenzahl (2004b) argues that designers can shape, but not determine an emotional experience. Emotions are too ephemeral. Often emotional design is understood as the attempt to induce emotions through a particular product, but the most fundamental discrete emotions (e.g. love, hate, liking) are only momentary and largely dependent on context. The emotional state of a computer user for example is usually not oriented towards the device itself, but to the overall activity in general (either work activity or pleasure), where the computer or software is merely a mediating tool between the motive and the goals of the user. For this reason, one and the same action or situation may lead to various and even contradictory emotional colouring. Therefore, objects or products should not be seen as affective themselves (Aboulafia, Bannon, & Fernstrom, 2001). This implies that affect measurement should not take place on the product level, but on the level of the user.

3.2.3 Towards a measurement instrument for mood in UX

The measurement of affect in UX poses a number of problems as the discussion of the framework just has shown. It is unclear whether the measurement of complex emotions as outcome of an evaluation would be more important or the measurement of mood influencing the perception and changing over the course of the experience. The development of a new measurement method seems appropriate, considering the following aspects:

- Discrete emotions last only a short time (a few seconds to minutes), so measurement would have to be precise or retrospective.
- Retrospective assessment can be subject to distortions, e.g. through social desirability or self-deception.
- The change of affect during interaction is as important as the emotional consequences of product evaluation.
- It is unclear how many and which distinct emotions humans can feel, which are basic and which are complex emotions.
- Affect is subjective, and although there are instruments to distinguish at least a few emotions objectively from each other, an accurate account of what is felt can only come from the subject itself.
- Affect is not necessarily conscious; hence, self-assessment of affect is not always possible.
- Describing affect verbally can be ambiguous and difficult, if mixed or complex emotions are involved.
- Mood as an antecedent, consequence and mediator of different affective and cognitive processes appears to be a central aspect in UX.

The method developed therefore addresses the implicit measurement of mood state during interaction. It explores the possibility of implicitly capture the mood state of a user, working on a computer with a standard mouse and keyboard, by detecting changes in motor behaviour variables through mouse movements. Instead of assessing a small set of distinct emotions retrospectively, the continuously changing result of emotional episodes, mirrored in the mood of the user, is assessed. The measurement is concurrent with the interaction between the user and the software.

Chapter 4 presents two experiments that tested the implication that mood and motor expressions are actually connected and presents the results of the feasibility study. In the next chapter, a short literature review is presented that explores empirical research regarding motor expressions and affect.

3.3 Sensory encounters and hedonic qualities

3.3.1 Hedonic and pragmatic qualities of products

The presented UX model assumes that two distinct groups of qualities, namely *pragmatic* and *hedonic* qualities, can describe product characters. Pragmatic qualities are connected to the users' need to achieve behavioural goals. Primarily, goal achievement requires utility and usability. In this sense, a product that allows for effective and efficient goal-achievement is perceived as pragmatic (or possesses perceived pragmatic quality). In contrast, hedonic attributes are primarily related to the users' self. They can be further subdivided into *stimulation*, *identification* and *evocation* (Hassenzahl, 2003).

Stimulation, novelty, and challenge are prerequisites of personal development (i.e. the propagation of knowledge and development of skills), which in turn is a basic human need (e.g. Csikszentmihalyi, 1975; Schwartz & Bilsky, 1987). Products have to provide new impressions, opportunities and insights.

Identification addresses the human need to express one's self through objects. This self-presentational function of products is entirely social; individuals want to be seen in specific ways by relevant others (e.g. Prentice, 1987; Wicklund & Gollwitzer, 1982). Using and possessing a product is a means to a desired self-presentation.

Products can represent past events, relationships or thoughts that are important to the individual. When products can provoke memories, they have hedonic qualities. Souvenirs, for example, are a product category that provides only hedonic value by keeping memories of a pleasant place or time alive.

A product can therefore be perceived as pragmatic because it provides effective and efficient ways to achieve behavioural goals. Moreover, it can be perceived as hedonic because it provides stimulation by its challenging and novel character, identification by communicating important personal values to relevant others or evocation because it evokes memories.

3.3.2 Sensory encounters

The first encounter with a product (i.e. seconds to minutes, depending on the product) is purely sensual (visual, auditory, tactile or olfactory) and is named therefore *sensory encounter* (MacDonald, 2001; 2002). Although aesthetic aspects are not explicitly mentioned in the framework, they are implicitly included in the product character and the product qualities. Hedonic aspects encompass aesthetic and symbolic aspects. Aesthetics play an important role in product evaluation, especially on the first impression, but a human will not just "purely"

perceive colours or forms, he will make sense of it. Pragmatic (instrumental) qualities play only an inferior role in sensory encounters. Sensory encounters are comparable to meeting a person for the first time. We decide within seconds to minutes if we like the person, if we will get along with him/her and what we can expect of the person. We instantly create a "personality" from elements that we can perceive.

Social scientists have shown that people also associate the physical appearance of products with personality attributes (Dion, Berscheid, & Walster, 1972). Desmet (2003) suggests that objects can be associated with user groups or institutions, which are the objects of social appraisal. In the UX framework presented, the product character is constructed from pragmatic and hedonic qualities (with a less significant role for pragmatic quality). Janlert and Stolterman (1997) refer to character as a "coherent set of characteristics and attributes that apply to appearance and behaviour alike, cutting across different functions, situations and value systems - aesthetical, technical, ethical - providing support for anticipation, interpretation and interaction." (p. 297).

Researchers in the area of marketing and consumer behaviour concluded that the aesthetic quality of a product influences consumers' attitudes towards the product. For example, Bloch (1995) claimed that the "physical form or design of a product is an unquestioned determinant of its marketplace success" (p. 16). Gladwell (2005) propagates the "magic" of the first impression and presents different examples how the sensory encounter determines later evaluation.

To sum up: the sensory encounter is an important determinant of later product evaluation. People succeed in constructing a product character (or personality), before the actual interaction starts.

3.3.3 Towards a measurement instrument for hedonic qualities

As in chapter 2.3.3 on the measurement of hedonic qualities was discussed, there are only a few existing methods to assess hedonic aspects of products. And even the few that exist, measure either purely aesthetic aspects or use simple verbal questionnaires with a small number of items.

The aim of chapter 5 of this thesis is the presentation of a new measurement instrument for the perceived product character that is constructed during sensory encounter. There is a need for a new method, because a number of limitations of existing methods had been identified:

- Aesthetics are very important during sensory encounter, but nevertheless, existing methods apply verbal methods. A mix of verbal and visual methods would improve the explanatory power of the method.

- Verbalization of a product character is yet more difficult, because the process of constructing the character is mainly subconscious. An indirect, projective method would be more appropriate.
- Moreover, the assessment of the product character might be distorted or biased when made conscious. The measurement tool should account for that and take a playful approach.
- Product character is complex. With an over simplistic method it is not possible to grasp the complete character. It should be measured multifactorial.
- Often, the aim of the methods is to relate product features to product character (e.g., round corners make the product look feminine). Although this might be a long-term goal, the interplay of single elements making up the character of the product is too complex. To capture product character in its completeness poses enough difficulties for the moment. Ideal would be a method that feeds back inspirations to designers anyway.
- Methods do not account for the subjective nature of product character. Objective results are important, but subjective information might be appropriate, too.
- The existing methods are very static. The requirements of different product groups (e.g. cars, furniture, chocolates, software) might be very different and the product character of a car has to be described differently than the character of a software. The measurement tool should therefore be flexible and modular.
- The perceived product character might be influenced by culture, demographics or time. So it is important to include information on the subjects in a test-tool.

The method presented in chapter 5 therefore addresses the measurement of the perceived product character during a sensory encounter. Although it encompasses all aspects of the product character, specific emphasis is put on the hedonic quality *identification*. Because the sensory encounter is short and often unconscious, the measurement tool employs an implicit, projective method. It uses visual and verbal techniques in the survey, and provides visual and verbal results. It uses a playful, pleasurable approach, and supplies designers with visual and verbal inspirations. The measurement tool is made up of different modules to guarantee flexibility and provide qualitative and quantitative results.

4   Study 1: Mood in interaction

Two experiments were designed to investigate the effects of induced mood in the affective dimensions valence and arousal on motor-behavior parameters while completing a computer task. Film clips were used as affect elicitors. The task was an online-shopping task that required participants to shop on an e-commerce website for office-supplies. 76 subjects participated in the first experiment using a between groups design, 32 subjects participated in the second experiment using a within groups design. To begin with, all participants viewed an emotionally neutral film clip. Then, they were presented with one out of four emotional film clips: a positive valence high-arousal, a positive valence low-arousal, a negative valence high-arousal, and a negative valence low-arousal clip. Computer-mouse movements of subjects during the task were recorded to log-files. Movement parameters from 12 categories were calculated and statistically analyzed. In experiment 1, a significant effect of arousal on movement parameters could be found, no effect was found for valence. In experiment 2 these findings could not be replicated, no effect was found for valence or arousal.

4.1 Introduction

The need for new mood measurement methods for UX research, especially concurrent with interaction, has been identified in chapter 3.2. The basic idea for the new method was to use mood dependent changes in motor expression of the hand while manipulating a computer. There is evidence in the research literature that a connection between motor expression of the hand and mood exists (Wallbott, 1982; de Meijer, 1989; Wallbott, 1998; Juette, 2001; Zacks, 2004; Hartmann, Mancini, & Pelachaud, 2006; Ahmed & Traore, 2007). The following feasibility studies explore, which movement parameters would be suitable for an automatic analysis and if the correlation between movement parameters and mood would be statistically relevant.

An extensive literature research has been made to find existing parameter sets for the analysis of movements. Although some studies found movement parameters correlated with depression, frustration or suitable for authentication, concise results of which movement variables are interrelated with valence and arousal were not available. One aim of the study is therefore to collect possible movement parameters that describe the quality of movement and to select those that are supposed to be correlated with valence and arousal.

To get appropriate samples of differing mood states, we induced mood in the laboratory with film clips. Films are often used as affective elicitors because they can induce a wide range of affective responses (Gross & Levenson, Emotion elicitation using films, 1995). There is an ongoing discussion about whether artificially induced mood can be equated with natural mood state, but for practical reasons – to get a large enough sample with a wide variety of mood states – film clips as affect elicitors were used.

The second aim of the study was to test the assumption that mood dependent changes in motor expression, translated from hand movement to movements of a mouse cursor on the screen, can be analyzed and show statistically relevant differences. To investigate this aim, the subjects conducted a shopping task at the computer, while their mouse activity was recorded. The task intended to be affectively neutral to change the induced mood as little as possible.

In parallel to the recording of mouse parameters, physiological data (respiration, electrodermal activity, heart rate, and electromyography) was recorded by another research group (see Gomez (2005) for results).

4.2 Method – Experiment 1

4.2.1 Design

The experiment applied a between-group design. The four different mood states PVHA, PVLA, NVHA, and NVLA (P=positive, N=negative, H=high, L=low, V=valence, A=arousal) serve as a between group factor (independent variable).

4.2.2 Subjects

Participants were 76 volunteers (39 men and 37 women). The mean age was 24 years, ranging from 17 to 35. Most participants were undergraduate students. Entry criteria for the study included good general health and German as mother tongue.

4.2.3 Mood induction

All participants viewed two film clips. The first clip was the same for all participants and was labelled "neutral clip" because it was expected to be emotionally neutral (neutral valence, low arousal[4]). It showed excerpts from an

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[4] Affectively "neutral" is the most common, everyday state that is felt most of the day, i.e. the answer to the question "How do you do?" would be "ok", but not good or bad. Because of the calibration of the valence/arousal space, this state is on neutral valence and slightly low arousal.

educational program about the characteristics and applications of materials. The clip was 10' 18'' long. For the second clip, participants were presented with one of the following four clips. Scenes of different sports (e.g., climbing, surfing, skiing, parachuting) with rock and pop music in the background were selected to induce the positive high-arousal emotional state (sport clip, 10' 02''). Takes from landscapes and animals with soft music score were used for the elicitation of positive low-arousal emotions (nature clip, 6' 19''). A scene adopted from the movie "The Deer Hunter" (Cimino, 1978), depicting captives in Vietnam being forced to play Russian roulette, was chosen to induce negative high-arousal feelings (torture clip, 10' 10''). Excerpts from the documentary "Les Enfants du Borinage - Lettre à Henri Storck" (Jean, 1999) about the Borinage, an old mining area and now a slum in Belgium, were meant to elicit negative low-arousal emotions (slum clip, 10' 52''). The nature clip had a shorter length than the others because in the selection phase, boredom was reported by some subjects when viewing a longer version. These four clips are referred to as emotional clips.

Table 4-1: Content of the film clips used in the experiment (PV = positive valence, HA = high arousal, NV = negative valence, LA = low arousal)

Mood	Content
Neutral	Educational movie about the characteristics of different materials
PV/HA	Clips of different sports with rock and pop music
PV/LA	Takes of landscapes and animals with classical music
NV/HA	Extract from Deer Hunter, depicting captives in Vietnam war
NV/LA	Documentary about an old mining area and now a slum

The five clips were selected from 23 clips based on evaluation in pretesting in our laboratory. They were chosen for their ability to induce different emotional states defined by the affective dimensions of valence and arousal. Their ability to evoke specific discrete emotions such as disgust, fear, or joy was not used as selection criterion.

The film clips were presented on a computer screen, embedded into the experimental environment. Sound intensity was set at a comfortable level. If desired, participants could regulate it.

4.2.4 Questionnaires

Affective state

Affective state was quantified with the rating scales of the graphical Self-Assessment-Manikin (SAM) (Lang, 1980). The SAM is a language-free instrument for rating valence and arousal, and consists of a graphic figure representing nine levels each of valence and arousal (see Figure 2-3). Subjects were asked to rate their momentary mood state on the nine point graphical scale. Valence and arousal ratings were completed electronically on the computer screen.

Personality

Because subjective responses and motor expression to affective stimuli may be influenced by personality traits (e.g. Gross, Sutton, & Ketelaar, 1998), participants completed at the end of the experiment the German version of the "NEO Five-Factor Inventory" (NEO-FFI) by (Costa & McCrae, 1992) on the five personality traits neuroticism, extraversion, openness, agreeableness, and conscientiousness.

4.2.5 Task

Subjects had to shop on an e-commerce website for office-supplies (see example in Figure 4-1). The task was selected because of its applied, real-world nature with little impact on the induced mood. Each task was divided into 8 subtasks telling the subject to buy one of the products from the website or – as a last task – to write a predefined message to the shop operator. For example: "Buy 6000 sheets of fanfold paper."

4.2.6 Technical environment

The technical environment consisted of a standard Windows PC with monitor (21" diagonal), mouse, keyboard and speakers. The experiment was fully automated and implemented as a web-based application, running on a local web-server with scripting support and a database for data collection. All materials (questionnaires, shop, film clips) were supplied from the local computer, all subject data and relevant behavioural data was stored locally. The materials were presented in a standard web-browser running in a kiosk-mode (a browser without menu controls, limiting interaction to the controls within the web-page).

The recording of mouse movements and mouse clicks was implemented with a custom-made JavaScript[5] application. Mouse recording data was transferred asynchronous via AJAX (Asynchronous JavaScript and XML) and saved in XML (Extensible Markup Language) format.

The following events were recorded:

- Mouse-down: mouse button pressed
- Mouse-up: mouse button released
- Mouse-click: mouse button click
- Double-click: mouse button clicked twice in short succession
- Mouse-move: movement of mouse
- Page-load: new page in web-browser window loaded
- Page-unload: page in web-browser window unloaded

For each recorded event, the following information was saved:

- X and y coordinates of the mouse pointer
- Timestamp in milliseconds (since start of recording)
- Code for event type
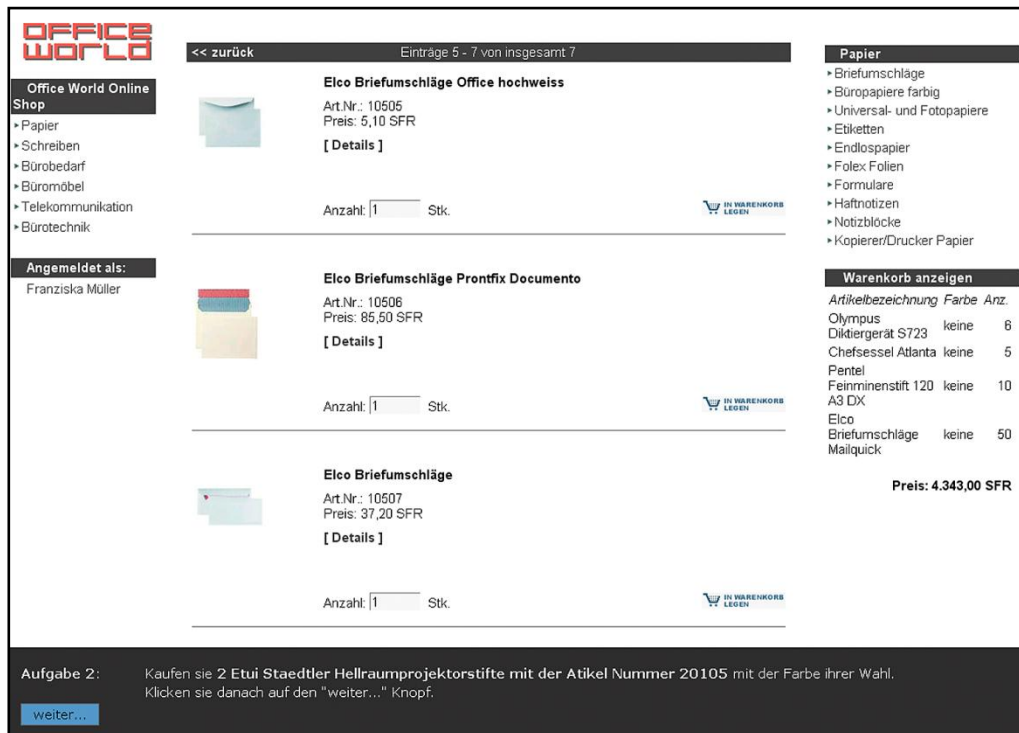- URL (Uniform Resource Locator) of the page that is displayed

Figure 4-1: Task window as presented to the subjects: online-shop on top, task on the bottom

[5] ECMA-Script 4: http://www.ecmascript-lang.org/

4.2.7 Procedure

The study consisted of a between groups design comprised of four experimental conditions. Participants were randomly assigned to view the positive high-arousal clip (sport film group), the positive low-arousal clip (nature film group), the negative high-arousal clip (torture film group), or the negative low-arousal clip (slum film group). Assignment was constrained so that approximately equal numbers of men and women were assigned to each condition. The four groups were composed as follows: sport film group: 20 (10f/10m); nature film group: 18 (9f/9m); torture film group: 19 (9f/10m); slum film group: 19 (9f/10m). The experimental procedure was identical for all groups except for the second film clip.
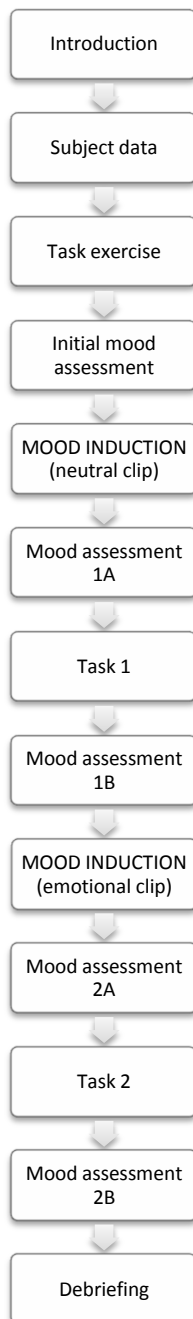
Students were invited to participate in an experiment announced to investigate physiological responses during two activities, i.e., while watching film clips and while completing a computer task. The two activities were presented as unrelated, and subjects were not informed about the recording of their mouse activities prior to the experiment.

Participants were tested individually in one experimental session. The experiment took place in a noiseless, air-conditioned room. Participants sat at a prepared table on a comfortable armchair which was placed in front of a computer monitor. First, they filled out an informed consent, and the experimenter provided them with an outline of the experimental procedure. Participants were told that they would complete three online-shopping tasks and would see two short film clips of about ten minutes in the order "task – film clip – task – film clip – task". They were further told that after each task and each film clip they should answer some questions and that all instructions during the experiment would be given at the appropriate stage on the computer interface, so that they would go through the

Figure 4-2: Experimental procedure

The flow diagram contains the following steps:
Introduction → Subject data → Task exercise → Initial mood assessment → MOOD INDUCTION (neutral clip) → Mood assessment 1A → Task 1 → Mood assessment 1B → MOOD INDUCTION (emotional clip) → Mood assessment 2A → Task 2 → Mood assessment 2B → Debriefing

experiment without the intervention of the experimenter. Yet, the presence of the experimenter assured that they could ask at any time if something was unclear.

Following completion of biographical and health data questionnaires, bands and electrodes were attached. After this, the participant was left alone. The experimenter sat in another part of the room separated from the participant by a cabinet. He could observe the subject by means of a closed circuit video system.

After the first computer task that served to familiarize the participants with the website, the neutral clip was presented. Afterwards, the participants completed the computer task for a second time. Then, the emotional clip was shown, followed by the third task. After completing each of the three tasks and viewing the two film clips, participants rated their momentary feeling state. After the last rating, bands and sensors were removed.

The experiment ended after 1.5 to 2 hours with the completion of the questionnaires. Participants were then offered something to eat, and the experimenter revealed the aims of the study and made sure that participants were fine. All participants reported to feel good. Finally, participants were thanked and paid for their participation and asked not to reveal any of the details of the experiment to other potential participants.

4.2.8 Behavioural measurements

In an extensive literature review, possible parameters that describe movements were collected. The parameters can be grouped into the following categories (see also Annex A: Mouse movement parameters):

- General activation
- Response time
- Spatial expansion
- Temporal expansion
- Speed
- Efficiency/Targeting
- Variability
- Fluency/course
- Complexity
- Energy
- Expressivity
- Emphasis

In a theoretical evaluation and selection process, the following 25 parameters were selected for analysis (for a complete list of parameters see Annex A: Mouse movement parameters):

- Median velocity of movements (speed_median)
- Interquartile range of velocity of movements (speed_7525)
- Median acceleration of movements (accel_median)
- Interquartile range of acceleration of movements (accel_7525)
- Median expressivity of movements (expressivitaet_median)
- Interquartile range of expressivity of movements (expressivitaet_7525)
- Median distance of movements (mov_median_pixel)
- Average displacement from ideal movement (abstand_total_perMove)
- Interquartile range of movement distances (mov_7525_pixel)
- Interquartile range of displacement from ideal movement (abstand_7525)
- Maximum movement distance (mov_max_pixel)
- Maximum movement duration (mov_max_msec)
- Maximum displacement from ideal movement (abstand_max)
- Standard deviation of displacements from ideal movements (abstand_std)
- Average difference between ideal movement and actual movement (realIdeal_diff)
- Clicks per minute (clicks_time)
- Number of movements (bewegungen_anz)
- Total distance travelled with mouse (mov_total_pixel)
- Total duration of mouse in movement (mov_total_msec)
- Number of velocity changes per movement (accdec_anz)
- Maximum velocity in all movements (speed_max)
- Maximum acceleration in all movements (accel_max)
- Maximum deceleration in all movements (decel_max)
- Median duration between a mouse click and the start of the movement (clickMov_med)
- Median duration between the stop of a movement and the mouse click (movClick_med)

4.2.9 Data preparation

Background

During the course of the experiment, mouse actions were recorded continually into a log-file. For each action, type (e.g. click, movement), screen coordinates and a timestamp were recorded. With this data, basic parameters can be calculated with simple trigonometric functions, which reflect the changes in distance, time, speed and acceleration between log-file entries, as well as the length of an ideal line between two points in space. Subsequently, parameters of higher-order can be calculated from these parameters.

The recording was event-based (as opposed to time-based, in fixed intervals), meaning that an entry was written only when a change in activity happened, i.e. a

movement or a mouse click. Some implications and difficulties result for the processing of mouse actions, similar to the processing of physiological signals, which has lead to complex pre-processing of the data. Highlighted in the following are the segmentation of the data into meaningful parts (i.e. movements and pauses) and the smoothing and interpolation of event data.

Data preparation and calculation was done with the software Matlab (The MathWorks company).

Segmentation

Data segmentation was done gradually in two steps. In a first step, the whole log-file was divided into segments by mouse clicks, so each segment started right after a mouse click and ended before the next mouse click. As the task was goal directed, the assumption that most movements were started and ended by a mouse click could be made. But not all movements end with a mouse click, so a further segmentation was made when the mouse "paused". A pause was defined as no movement for longer than 250 milliseconds. No information was found in a literature research to determine this value, so it was approximated from visual analysis of movement data. The resulting distinct movements were then filtered, so that any movement below the threshold of 400 milliseconds was ruled out as a "real" movement to avoid micro-movements as artefacts of recording technique.

Smoothing and interpolation

The spatial and temporal intervals between data points could become as small as 5 milliseconds and 1 pixel and thus made the calculation of error-prone. To avoid artefacts and outliers, the data was smoothed with a zero-phase moving average filter with a window size of 5. This filter calculates each data point as an average of the neighbouring data points, the window size determines, how many neighbouring points will be included in the calculation.

Because the time intervals between data points (event-based recording) were not equal, an interpolation of the data was made. New data point were calculated with a fixed time interval of 20 milliseconds. The interval is large enough to assure accuracy of further calculations, and small enough so details of the movement are not lost.

Calculation of parameters

After the data preparation, the actual calculation of the base parameters distance, time, speed and acceleration between data points was completed. A detailed listing of calculations would go beyond the scope of this chapter, but to

exemplify some more complex parameter calculations are presented in the following.

Deviation of mouse movement from the shortest connection between beginning and end of a movement (ideal line):

$$\Delta distance_n = \frac{|(x_2 - x_1)(y_1 - y_0) - (x_1 - x_0)(y_2 - y_1)|}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$
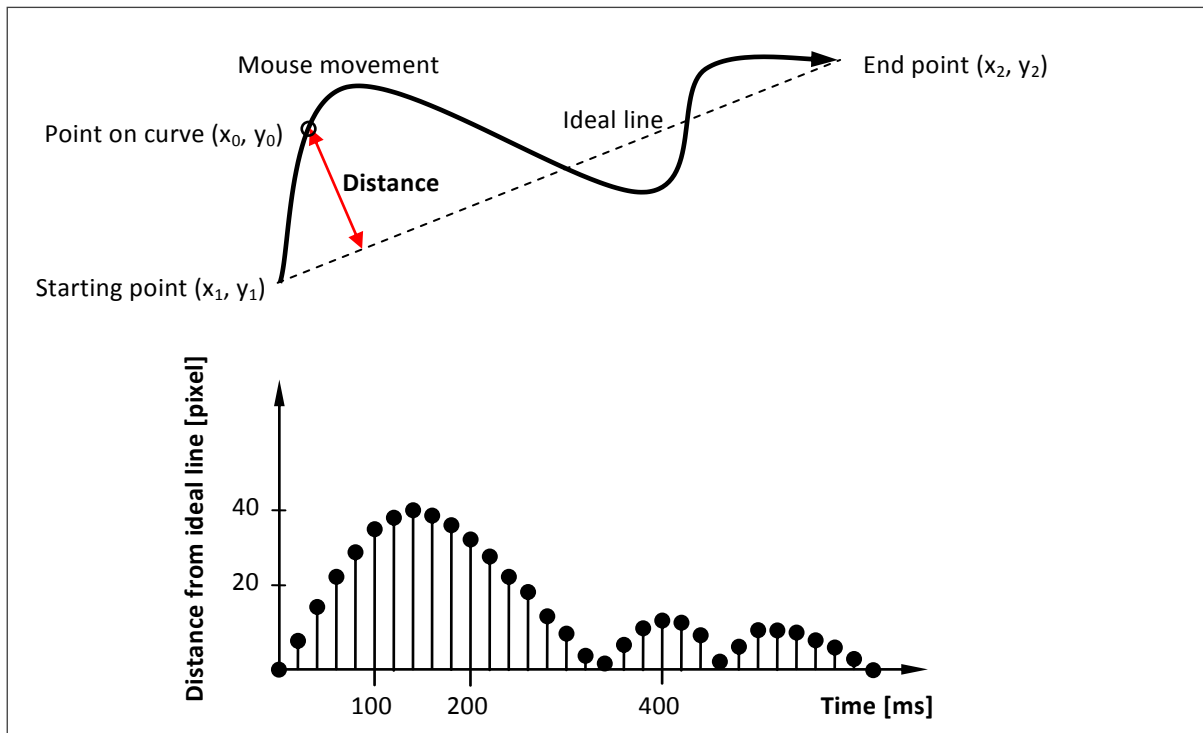

Figure 4-3: Example movement and calculation of deviation from ideal line

Number of crossings of the actual mouse movement with the ideal line:

$$crossIdealLine_{num} = \frac{\sum(\Delta distance_n = 0)}{number\ of\ movements}$$

Figure 4-4: Example movement with two crossing points with the ideal line

Calculation of complexity (number of changes in acceleration/deceleration), expressiveness (average slope velocity of speed peaks) and emphasis (average peak height):

$$complexity_{num} = \frac{\sum a^+ + \sum a^-}{number\ of\ movements}$$

$$expressiveness_{median} = median\left(\frac{max(v_n)}{slope\ duration_n}\right)$$

$$emphasis = \frac{\sum max(v_n)}{number\ of\ peaks}$$

Figure 4-5: Velocity and acceleration of an example movement

4.3 Results
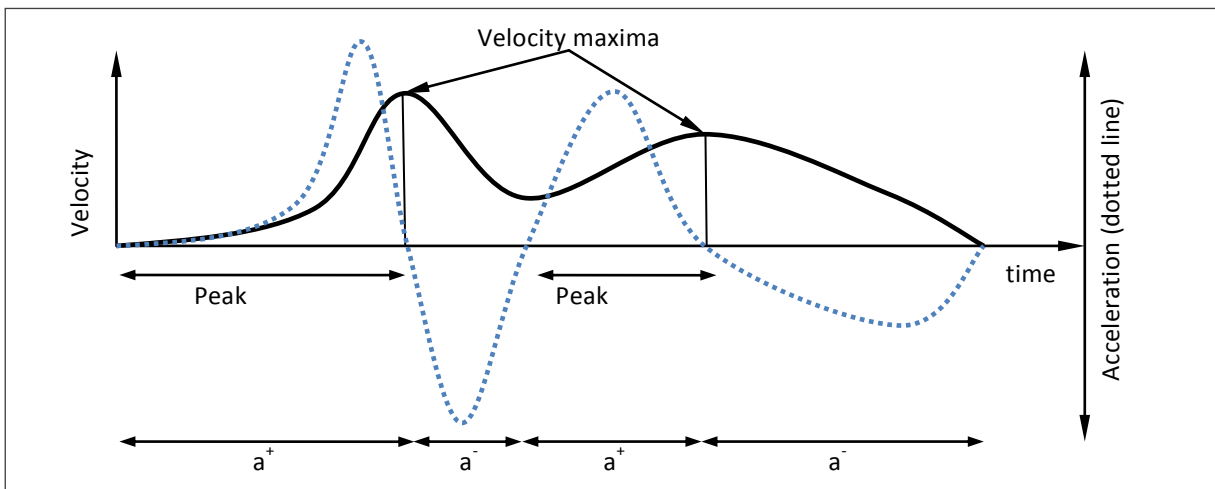
4.3.1 Participants

No differences in age, sex, education, computer use, weight, body size, and personality traits (NEO-FFI) between groups on a significance level of 0.05.

4.3.2 Valence and arousal ratings

Before the neutral clip

There were no significant differences between groups found at the start of the experiment. The results of two one-way ANOVAs were:

Valence: $F_{(3,70)} = .394$; $p = .76 > .05$;

Arousal: $F_{(3,70)} = .909$; $p = .44 > .05$;

After the neutral clip

The clip was rated by all groups as emotionally neutral. Means for valence and arousal were, respectively, as follows: sport film group: 5.4, 3.7; nature film group: 5.6, 3.7; torture film group: 5.2, 3.4; slum film group: 5.3, 3.7.

No significant differences were found between groups after the neutral clip, but the variance within groups has decreased compared to before the neutral clip. The results of two one-way ANOVAs were:

Valence: $F_{(3,70)} = .229$; $p = .87 > .05$;
Arousal: $F_{(3,70)} = .159$; $p = .92 > .05$;

After the emotional clip

Mean values of self-ratings after the emotional clip are as expected. The analysis (ANOVA) showed that for valence ratings, the valence effect was highly significant ($F_{(3,70)} = 19.35$; $p < .001$), for arousal, the arousal effect was highly significant ($F_{(3,70)} = 21.40$; $p < .001$). Mean values are reported in Table 4-2.

Additionally, pre-planned contrasts for the two factors valence (two levels: positive (+1), negative (-1)) and arousal (two levels: high (+1), low (-1)) was carried out on the affective ratings after the emotional clips. The results showed highly significant differences between the contrasts for valence ($T_{(53.8)} = 7.5$; $p < .001$) and arousal ($T_{(70)} = 7.66$; $p < .001$).

After the task, after emotional clip

To test the influence of the task on the induced mood and to control if mood persisted until the end of the task, affective ratings after the last task were analyzed.

Table 4-2: Mean values and standard deviations (in parentheses) of self-assessment ratings after the emotional clip and after the following task

	Means after emotional clip		Means after task	
	Valence	Arousal	Valence	Arousal
V↑A↑	6.2 (1.2)	6.6 (1.4)	6.0 (1.3)	5.0 (1.3)
V↑A↓	7.1 (1.1)	3.7 (1.5)	6.4 (1.0)	4.6 (1.3)
V↓A↑	4.2 (2.0)	6.9 (1.5)	6.1 (1.2)	5.1 (1.2)
V↓A↓	3.9 (1.1)	4.7 (1.4)	5.7 (0.9)	4.5 (1.6)

An ANOVA analysis with the pre-planned contrasts valence and arousal was carried out. No significant differences were found between groups and levels anymore after the task;

Valence:	$F_{(3,70)} = 1.01$; $p = .39 > .05$;
Valence contrast:	$T_{(70)} = .99$; $p = .32 > .05$;
Arousal:	$F_{(3,70)} = 1.08$; $p = .36 > .05$;
Arousal contrast:	$T_{(70)} = 1.72$; $p = .09 > .05$;

4.3.3 Mouse movement parameters

For the further analyses the four groups were rearranged into two contrasting factors: valence (two levels: positive (+1), negative (-1)) and arousal (two levels: high (+1), low (-1)). Furthermore, not the absolute parameter values were used for the analysis, but the logarithmic differences between the task parameters after the neutral film clip and task parameters after the emotional clip, to reduce individual differences in movement characteristics and error variance.

Individual parameters

For the independent variables valence and arousal separately, t-tests were run with each of the 25 individual movement parameters. The significance level was adjusted to 0.05 / 25 = 0.002 to account for multiple tests. For valence, no significant differences were found, for arousal, the parameters mov_total_msec ($T_{(55.5)} = 3.53$; $p = .001$) and accdec_anz ($T_{(55.9)} = 3.6$; $p = .001$) showed significant differences.

Principal components

It can be assumed that several of the parameters are correlated and measure a similar construct. To reduce from 25 individual parameters to fewer dimensions, and to be able to run tests with a higher significance level than 0.002, data reduction with a principal component analysis was conducted. The resulting principal components that were used in the further analysis are as follows (labels of the components by the author):

Component 1 – Movement speed

- Median velocity of movements (speed_median)
- Interquartile range of velocity of movements (speed_7525)
- Median acceleration of movements (accel_median)
- Interquartile range of acceleration of movements (accel_7525)
- Median expressivity of movements (expressivitaet_median)
- Interquartile range of expressivity of movements (expressivitaet_7525)

Component 2 – Spatial expansion

- Median distance of movements (mov_median_pixel)
- Average displacement from ideal movement (abstand_total_perMove)
- Interquartile range of movement distances (mov_7525_pixel)
- Interquartile range of displacement from ideal movement (abstand_7525)

Component 3 – Maximum expansion

- Maximum movement distance (mov_max_pixel)
- Maximum movement duration (mov_max_msec)
- Maximum displacement from ideal movement (abstand_max)
- Standard deviation of displacements from ideal movements (abstand_std)
- Average difference between ideal movement and actual movement (realIdeal_diff)

Component 4 – General activation

- Clicks per minute (clicks_time)
- Number of movements (bewegungen_anz)
- Total distance travelled with mouse (mov_total_pixel)
- Total duration of mouse in movement (mov_total_msec)
- Number of velocity changes per movement (accdec_anz)

Component 5 – Maximum speed

- Maximum velocity in all movements (speed_max)
- Maximum acceleration in all movements (accel_max)
- Maximum deceleration in all movements (decel_max)

Component 6 – Response time

- Median duration between a mouse click and the start of the movement (clickMov_med)
- Median duration between the stop of a movement and the mouse click (movClick_med)

With the six resulting components, a MANOVA with valence and arousal as independent variables was run. There is a significant effect for arousal, no significant effect for valence and the interaction.

Valence effect: $F(6,65) = .46$; $p = .836 > .05$;

Arousal effect: $F(6,65) = 2.42$; $p = .036 < .05$;

Valence x arousal: $F(6,65) = 1.6$; $p = .161 < .05$;

In the post hoc tests Component 4 (General activation) shows significant differences between high and low arousal groups ($F(1,70) = 11.75$; $p = .001 < .05$).

4.4 Method – Experiment 2

The second experiment was designed analogous to the first one. Its aim is to replicate findings of the first experiment and reduce error variance compared to the first experiment through the application of a repeated measures design. The differences to the first experiment are stated in the following chapters.

4.4.1 Design

The experiment applied a repeated measures within-group design as opposed to the between-group design of the first experiment.

The same four mood states PVHA, PVLA, NVHA, and NVLA (P=positive, N=negative, H=high, L=low, V=valence, A=arousal) serve as independent variables.

4.4.2 Subjects

Participants were 32 volunteers, all female. In the first study, the effect of mood induction on the different sexes has been suspected to differ. Although affective ratings showed no significant differences for sex, literature suggests that motor expression and effects of mood induction might be different.

Most participants were undergraduate students. Entry criteria for the study included good general health and German as mother tongue.

4.4.3 Mood induction

The same five movie clips (1 neutral, 4 emotional) have been used (see Chapter 4.2.3).

4.4.4 Questionnaires

The same Self-Assessment Manikin questionnaire was used as in the first study (see Chapter 4.2.4). Personality was not assessed anymore because it showed no correlation with affect ratings or motor expression.

4.4.5 Task

The same shopping task was used (see Chapter 4.2.5), but to avoid sequence effects, more sub-tasks were created. The sub-tasks were presented randomized on-screen.

4.4.6 Behavioural measurements

Behavioural measurements and data preparation techniques match the ones in the first experiment (see Chapter 4.2.8).

4.4.7 Procedure

The procedure differed from the first experiment (see Chapter 4.2.7) in two aspects. First, there were no physiological measurements anymore. The preparations for the physiological measurement needed a lot of time and effort and the measurement during the experiment took up a large amount of total experiment duration. Because the subjects needed to view five film clips and complete five tasks, the experiment would have been extended for too long.

Second, because of the repeated measures design, each participant was presented with the neutral clip to start, and then was randomly presented with the four emotional clips, questionnaires and tasks. The procedure was the same for every clip: mood questionnaire – film clip – task – mood questionnaire.

4.5 Results

4.5.1 Participants

No differences in age, sex, education or computer use were found on a significance level of 0.05.

4.5.2 Valence and arousal ratings

Valence and arousal ratings were analyzed for the four emotional clips. The data was tested with two repeated measures ANOVAs with the pre-planned contrasts valence (two levels: positive (+1), negative (-1)) and arousal (two levels: high (+1), low (-1)).

Mean values of self-ratings (see also Table 4-3) after the emotional clips are as expected. The repeated measures ANOVA showed that for valence ratings, the valence effect was highly significant, for arousal, the arousal effect was highly significant

Valence ratings: $F(2.48, 71.97) = 86.61$; $p < .001$;
Arousal ratings: $F(3,87) = 34.62$; $p < .001$;

For the valence contrast, the valence rating were highly significant for the different clips, the arousal ratings were not significant as expected. For the arousal contrast, the arousal ratings were highly significant, the valence ratings were not significant as expected:

Valence
Valence contrast: $F(1,29) = 180.20$; $p < .001$;
Arousal contrast: $F(1,29) = 1.44$; $p = .24 > .05$;

Arousal
Arousal contrast: $F(1,29) = 108.00$; $p < .001$;
Valence contrast. $F(1,29) = 0.42$; $p = .52 > .05$;

Table 4-3: Mean values and standard deviations (in parentheses) of self-assessment ratings after the emotional clips and the following tasks

	VALENZ			
	HH	HL	LH	LL
nach Film	6.2 (1.9)	7.1 (1.2)	2.9 (1.4)	2.5 (1.2)
nach Aufg.	5.7 (1.3)	5.9 (1.1)	4.5 (1.2)	4.5 (1.2)

	AROUSAL			
	HH	HL	LH	LL
nach Film	6.3 (1.6)	3.7 (1.8)	6.9 (1.6)	3.5 (1.4)
nach Aufg.	4.7 (1.4)	4.2 (1.2)	4.7 (1.8)	3.8 (1.2)

4.5.3 Mouse movement parameters

For the analysis of mouse movement parameters, the principal components of the first experiment were applied to the data of the second experiment. The fit of the principal components with the data of the second experiment was tested and confirmed: the correlations between variables within the individual components were high and the component analysis verified that variables within the components are stable.

Individual parameters

The data was tested with the independent variables valence and arousal with repeated measures ANOVAs with the pre-planned contrasts valence (two levels: positive (+1), negative (-1)) and arousal (two levels: high (+1), low (-1)). For the repeated measures ANOVAs, the significance level was adjusted to $0.05 / 25 = 0.002$, to account for multiple tests. For valence, no significant differences were found, for arousal, the parameter clicks_time $(F (1,29) = 20.56; p < .001)$ showed significant differences.

Principal components

The data was tested with a repeated measures MANOVA with the pre-planned contrasts valence and arousal. The dependent variables were the components, repeated measures factors were the mood states.

The overall test showed no significant result $(F (18,252) = .813; p = .68)$ and also the pre-planned contrasts showed no significant effect.

The findings from the first experiment could not be confirmed. No other significant results could be obtained.

4.6 Discussion

The aim of the study was to support the assumption that there are movement parameters that show a correlation with the affective dimensions valence and arousal. This implies that mood state is actually taking influence on how a computer user is manipulating his mouse.

4.6.1 Mood induction with film clips

A precondition for the analysis of the experiment at hand is a working mood induction. Although it is possible to use subjects in a natural mood state, and it is disputed if artificially induced mood has the same effects as natural mood, it is feasible to use a mood induction technique and to test its effectiveness. Only if

the effect of the mood induction is strong enough, differences in movement parameters can be expected. The mean values of the self-assessment and the according tests confirm that the film clips had the intended effect.

Interesting although is the result of the mood values after the task: there were no significant differences between the groups anymore. The induced mood wears off. It is difficult to determine if the task had a moderating effect or if the task was too long. In accordance to UX theory, the interaction itself should have an effect on mood state, even if the task was explicitly chosen for its neutrality. In addition, the cognitive load of the task (some of the subtasks were rather demanding cognitively) could influence mood state towards neutral valence and arousal. The task length averaged to 10 minutes and thus does not exceed the timeframe mood induction has proved to be effective found in literature. To account for this diminishing effect, the parameter log-files were cut to include the first 250 seconds of the task only.

In future studies, mood induction should be implemented differently. The one time mood induction at the beginning of the task is not suitable for this test setup. One possibility is to use music or scents that can continue their effect while the user is interacting with the computer. Music has the disadvantage that rhythm might lead to more repetitive, rhythmic movements and has thus been ruled out for the present study. Scents and odours are not a standard method to induce mood (yet), and could be promising. In line with UX theory, it would be obvious to use the interaction itself to induce mood. An appropriate stimulus would have to be found that induces a controlled mood state.

A stimulus from the product that the subjects interact with will face the problem to account for individual differences in the reaction to affective stimuli. A similar problem has the mood induction technique with films. Although the group averages might show the desired effect, the individual might react with a quite different affective reaction to a stimulus (a film). For other mood induction techniques, the proportion of subjects that do not or not in the desired way react affectively has been estimated. The Velten mood induction technique, for example, does not induce the desired mood in 30-50% of all subjects.

4.6.2 Movement parameters

The analysis uncovered a significant correlation of arousal with some movement parameters in the first experiment. This is in accordance with another study of Maehr (2005). However, the parameters that make up the dimension *general activation* (e.g. number of movements, clicks per minute, total distance travelled with mouse) do not describe the quality of movements in the narrower sense like speed, acceleration or movement length do. Thus, it is still not clear if

arousal actually influences movement per se or if subjects just are more or less activated (which is the definition of arousal: activation), which mirrors itself in the dimension of general activation. This would be in line with the missing correlations of valence with movement parameters.

Noticeable in the movement data were the great differences between individuals. The movement patterns differed much more between individuals than between the neutral and the emotional mood state within individuals. This had been acknowledged by researchers concerned with the authentication of users based on movement patterns (e.g. Ahmed & Traore, 2007). This research uses similar aspects of movements as this study, but the aim is to differentiate between individuals and to rule out variation from affective, physical or mental state of the moment. In this study, this issue has been addressed by using the neutral task as a baseline and subtracting the values of the neutral task from the emotional values.

Nevertheless, the basic assumption that every individual reacts with the same modulation of motor expression to affective stimuli (e.g. moves the mouse faster with increasing arousal) might not be correct. Significant characteristics of movements and their changes would have to be "uncovered" for every person specifically. A solution for this dilemma is not the search for general and universal patterns and movement characteristics, but the search and the development of adaptive systems, as for example Schuller (2006) has proposed. The development of adaptive systems is costly and needs a lot of technical expertise, but the research for individual movement patterns could be done in qualitative studies with only a few subjects. It would be interesting to see if there are individual patterns that are influenced by affective state.

Moods, as compared to emotions, are rather subtle affective states that often are subconscious (see Chapter 3.2.1). It is not clear if the effect mood has on motor expression is strong enough to be detected by such a measurement method as the present. Considering the great differences between individuals that were noted in this study, it is questionable if the sensitivity of the method is sufficient. Furthermore, the use of a computer mouse and the constricted space of movements it allows, the sitting position or the translation of motor expression from the hand to the mouse and to the computer screen, suggest that a lot of information about changing motor expression that would be present cannot be detected. It is possible and could be object of investigation in further research, that a direct observation of motor expression (e.g. with EMG sensors) would yield better and clearer results and could provide hints for possible parameters.

4.6.3 Parameter selection and analysis

The selection and calculation of the movement parameters posed a problem in this study. There are only a few relevant studies that deal with the selection of movement parameters, especially such studies concerned with parameters in the context of micro motor movements of the hand. There is a lot of research in clinical psychology on depression and movement of the body, but they are not applicable to the current context. The actual choice of parameters made for this study is somewhat arbitrary, although a lot of effort went into a wide selection, categorization and calculation of parameters. The assignment of parameters to higher-level categories, which were the basis for the actual selection process, is definitely not unambiguous.

The pre-processing of parameters with segmentation, smoothing and interpolation is problematic. Especially segmentation would have required concrete guidelines and thresholds. This has been acknowledged by Schuller (2006) and Maehr (2005) already, but they did not publish their respective values for thresholds. Apparently, there is an uncertainty concerning the calculation of parameters that leads to different definitions and applications among researchers. For the present study, thresholds had to be acquired by a visual analysis of movement data.

The analysis of the study based entirely on classical statistical test methodology that was developed for linear concepts and correlations. Alternatively, newer analysis methods could detect different interrelations between independent and dependent variables. For example, artificial neural networks have been used to approximate arbitrary functions, where the type of relation does not have to be known. Neural networks can model correlations that are non-linear and complex. Schuller (2006) has used a combination of newer analysis methods and had more success in detecting connections of affect and motor behaviour (but his study has some other downsides that make application problematic).

4.6.4 Conclusions

Although a final confirmation of a correlation between mood state and mouse movement parameters could not be brought forward, some evidence could be collected that some form of interrelation exists. The significant results for arousal in the first experiment can motivate additional research. The study had several methodological difficulties that should be addressed in future research.

5   Study 2: Perceived hedonic quality

Hedonic product qualities have been identified as important aspects and predictors of overall product quality and appeal. However, existing methods and instruments for the evaluation of hedonic qualities are rather simple and rudimentary, assessing product qualities with direct, verbal enquiries. This chapter describes a new method and the development of an associated measurement tool that addresses the shortcomings of existing methods. The tool has a modular, flexible, web-based layout, incorporates verbal and visual assessments and outputs, and applies a projective, playful approach. The tool accounts for the complexity of hedonic qualities in the assessment and the results. Method and measurement tool are still in development.

5.1 Introduction

Measuring hedonic qualities of products was identified as a central aspect of UX (see Chapter 3.3). It has been brought forward that hedonic quality is an important predictor for the evaluation of overall product appeal (Tractinsky, Katz, & Ikar, 2000; Zhang & Li, 2004; Hassenzahl, 2007). Especially within the first impression of a product, the sensory encounter, perceived hedonic aspects are important. Currently, only a few methods exist to measure these aspects and these are frequently rudimentary and overly simple. The aims of the present study are to address shortcomings of current methods, propose a new, improved measurement method and to put it into a comprehensive tool for practical use.

Sensory encounters last only for a short time. The perception of sensory qualities (i.e. visual aesthetics, tactile and auditory qualities) plays a predominant role. Cognitive and affective processing is limited to automatic judgements (e.g. good or bad) and stays subconscious. Processes on this level are biologically determined and relate to instinctive attraction to form, colour and the resulting bodily reactions (cf. Norman's (2004) visceral level of information processing).

A measurement method therefore needs to find a way to access this subconscious information without making it explicit. A possibility is to apply a projective method, where the perceived qualities can be projected onto a neutral agent. Projective techniques aim at measuring unconscious psychological states and attitudes. They are based on the assumption that they bypass conscious individual reflections of people's cognitive and affective processes. Classic projective methods are for example the Rorschach inkblot test (after Hermann Rorschach (1884-1922) or the Thematic Apperception Test (TAT), where a

picture - often of people with their emotional expressions ambiguous or hidden - is presented to a subject and is asked to describe the situation. A projective method uses a medium (e.g. drawings or essays) onto which people project aspects of their personality or their emotions during the measurement. Individual responses are then analysed in order to derive for example personality characteristics or emotions.

The method presented here uses virtual characters, called *manikins*, onto which the product character can be projected by the subject. The manikins are constructed by the subjects from a library of heads, torsos, legs, and shoes. The subsequent assessments in the course of the test refer to the manikin and not to the product directly anymore.

In sensory encounters, visual aesthetics play an important role (although not exclusive). Nevertheless, the most prominent method to assess hedonic quality, Hassenzahl's "AttrakDiff" (Hassenzahl, Burmester, & Koller, 2003), uses a purely verbal approach. Other techniques, such as creating mood boards, use a purely visual approach. Both approaches are able to capture certain qualities, others not. It would seem favourable to include some visual information side by side with verbal information to capture the whole product character. The present method uses different sub-tests or test-modules, which are displayed consecutively to the subject and apply a variety of different assessment forms: questionnaires, visual constructions, verbal differentials, multiple choice, slider indicators, or open question formats. Accordingly, the result is not a simple number, but a multifactorial construct that reproduces the complex product character on different dimensions. The results provide quantitative data as well as qualitative information about the product.

Although the tool makes various information about the product available, it does not necessarily have to be related to distinct product features. Some researchers have proposed the relation of product qualities to distinct product features a central aspect of their methods (e.g. Hassenzahl, 2003; Mahlke, 2008). While it is a possible long-term goal to provide information to designers, as of which features relate to which perceived qualities, it is difficult enough to capture the product character in its completeness for the moment. Nevertheless, the results can still provide valuable inspiration for designers, particularly through the visual results (e.g. the manikins).

The method proposed here tries to consider all the mentioned aspects. It has been implemented into a dynamic, modular, web-based tool for the evaluation of products. In the following, the different modules of the tool are presented.

5.2 Modules

5.2.1 Manikin library

The manikin library is the foundation of the method. The created figures are the projection surface for the subsequent tests. In chapter 3.3 it has been noted that people associate the physical appearance of products with personality attributes (Dion, Berscheid, & Walster, 1972). Desmet (2003) suggests that objects can be associated with user groups or institutions, which are the objects of social appraisal. The manikins are constructed by the subject from a library of graphical heads, torsos, legs, and shoes (see Figure 5-1). Considerable care has been taken in the selection and processing of the manikin elements.

The requirements for the manikin library were:

- cover a wide variety of clothing styles
- represent the whole range of personalities as they appear in everyday life
- allow compilations of manikins with subtle differences but strong links to the design of the product
- still be small enough so subjects can keep an overview of the different clothing items

Figure 5-1: Example screen of the manikin module: on the left the product, on the right the menu with the faces and clothing selection, in the middle the assembled manikin.

Starting point for the selection of clothing types was the Outfit-5 study (Spiegel Verlag, 2002). The representative study includes the responses of 10'000 Germans answering questions concerning clothing, fashion and brands and their attitudes towards clothing, shoes and accessories. The study classifies men and women separately into seven clothing style types each, e.g. the conformist, the fashionable, the intellectual, etc. Each type is described by its attitudes and preferences towards clothing style, fashion, shopping behaviour, or body image and is depicted with a prototypical image of a person wearing the according clothing.

Figure 5-2: Example output of the manikin module

These 14 clothing types build the core of the manikin library. We added more clothing and faces to account for regional differences, changing fashion preferences and necessary additions in the context of product emotions (e.g. "ugly faces" to account for negative affective reactions). During the PEC-Test subjects compile one manikin out of the heads and clothing selections presented, representing the ideal user or the preferred buyer of the product. The images of

heads, clothing and shoes are shown fully randomised in order to avoid a sequencing bias.

The manikins not only serve as a projection for the following test modules, but are also part of the (visual) results of the evaluation (see Figure 5-2). The manikins give a first overview of fundamental aspects of product quality, transferred to style, colour or personality of the figures. Their visual impact can serve as an inspiration to designers. The manikins can give an unsorted, subjective impression of the product quality or they can be categorized either by visual aspects of the figures themselves or by characteristics of the subjects (i.e. demographic information) and their statements (i.e. mapping of manikins to answer categories).

5.2.2 Semantic differential

Charles Osgood originally introduced semantic differentials as measurement instruments in 1950-ies to measure people's reactions to stimulus words and concepts. They are applied either as ratings on bipolar scales defined with contrasting adjectives at each end like "good-bad", "soft-hard" or "valuable-worthless" or as "likert" single scales, psychometric response scales where respondents specify their level of agreement to a statement or term (Likert, 1932).

Table 5-1: The adjective pairs used in the semantic differential. The two pairs in each box belong to the same semantic category and have an equivalent emotional meaning (adapted from Küthe, Thun & Schriefers, 1995).

German	English
Sachlich – Romantisch Rational – Sensitiv	Factual – Romantic Rational – Sensitive
Konventionell – Originell Seriös – Ungewöhnlich	Conventional – Fancy Serious – Unorthodox
Klassisch – Modisch Zurückhaltend – Aufdringlich	Conservative – Trendy Demure – Pushy
Traditionell – Avantgardistisch Alt – Jung	Traditional – Avant-garde Old – Young
Herb – Süss Hart – Weich	Bitter – Sweet Hard – Soft
Natürlich – Künstlich Verspielt – Streng	Natural – Artificial Playful – Strict
Sparsam – Verschwenderisch Billig – Nobel	Frugal – Lavish Cheap - Classy
Sympathisch - Unsympathisch	Likeable – Not likeable

Mehrabian and Russell (1974) adapted the method to construct a set of 18 bipolar adjective pairs that generate scores on the affective valence, arousal and dominance scales. There have been many adaptations of this method using diverse sets of terms. We used a selection of adjective pairs from "Marketing mit Bildern" [marketing with images] (Küthe, Thun, & Schriefers, 1995), measuring seven characteristics of products with two adjective pairs each (see Table 5-1).

This test module is related to the technique used in the "AttrakDiff" questionnaire (Hassenzahl, Burmester, & Koller, 2003), that assesses pragmatic quality, hedonic qualities (identification, stimulation) and overall attractiveness. The semantic differential used here addresses classic and expressive aesthetic qualities, the hedonic quality stimulation and overall attractiveness. In respect to content, the different dimensions resemble the dimensions "classical aesthetics" and "expressive aesthetics", which Lavie and Tractinsky (2004) found in a study on website layout. The classical dimension concerns aesthetic notions that emphasize orderly and clear design and are closely related to many of the design rules advocated by usability experts. The expressive aesthetics dimension manifests itself by the designers' creativity and originality and by the ability to break design conventions.
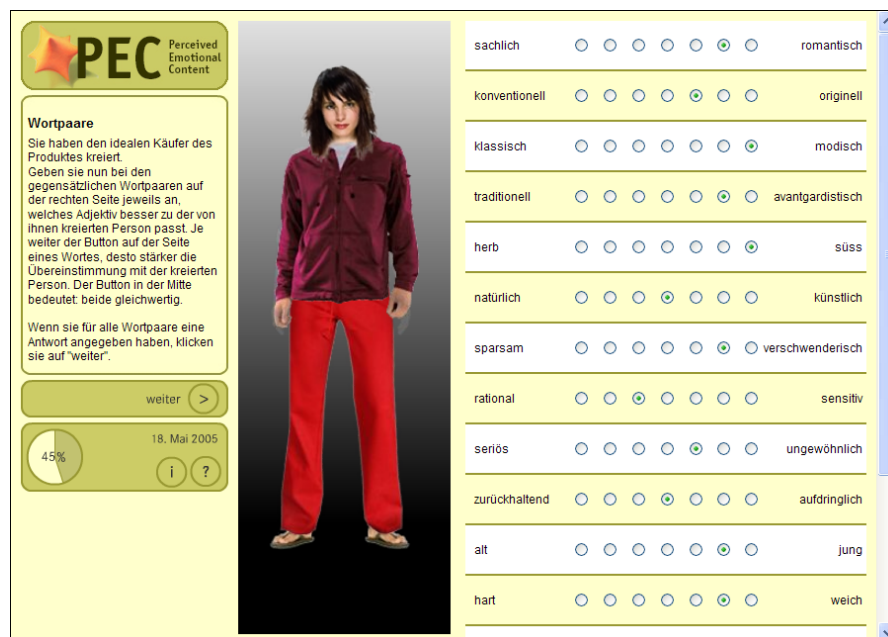

Figure 5-3: Screenshot of the semantic differential module.

In course of the test, subjects indicate agreement or disagreement with the adjectives on a 7 point scale (see Figure 5-3). The results include mean and median values of bipolar word pair ratings and higher-level dimensions, as well

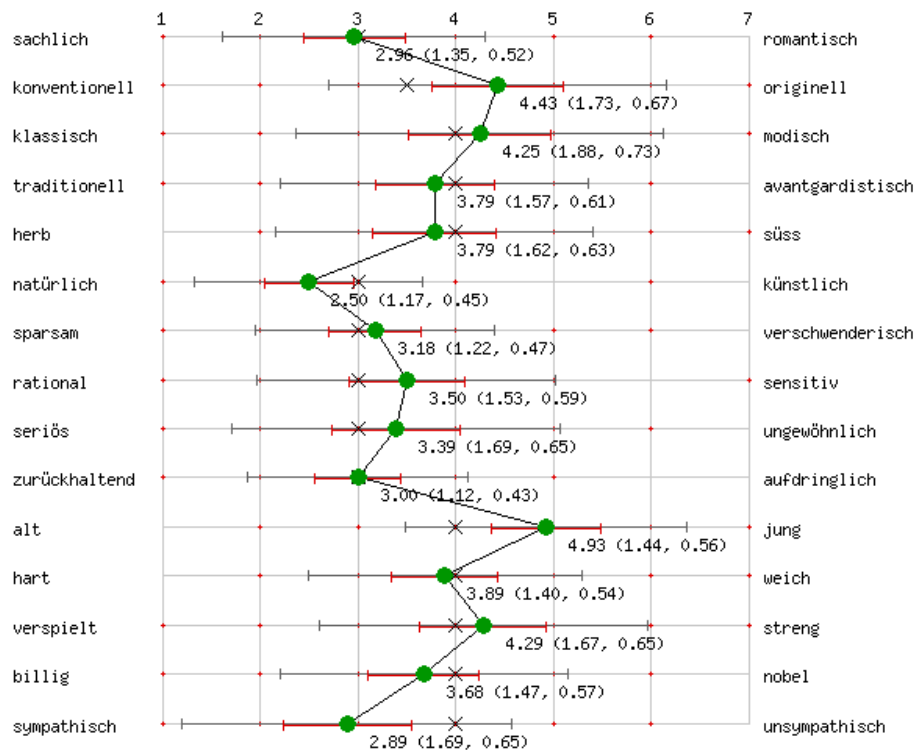as graphical profiles of the word pairs, which also allow comparisons between products (see Figure 5-4).

Figure 5-4: Profile of a product rated with the semantic differential (words in German). Mean values (large green dots, number below dot), median values (black crosses), confidence intervals (red lines, second number in parenthesis), standard deviations (grey lines, first number in parenthesis) of the population ratings.

5.2.3 Self-Assessment Manikin

The Self-Assessment-Manikin (SAM), devised by Bradley and Lang (1994), is used to assess the affective dimensions valence and arousal directly by means of two sets of graphical manikins (see also Chapter 2.3.2). An Assessment of affective qualities of products has been made by several authors. For ecample Zhang and Li (2004) have made the construct perceived affective quality operational on the two dimensions aroused-sleepy and pleasant-unpleasant. Desmet (2002) has used a more differentiated approach by assessing seven negative product emotions (disgust, indignation, contempt, unpleasant surprise, dissatisfaction, disappointment, boredom) and seven positive emotions (inspired, desire, pleasant surprise, amusement, admiration, satisfaction, fascination).

These assessments of "product emotions" seem problematic though, because products do not really have emotions, but might be able to elicit affect in humans. It seems more appropriate to assess product emotions in the context of a projective method, where the assumed affect can be projected onto a figure (or manikin; see Figure 5-5). The results of this module are straight forward as depicted in Figure 5-6.
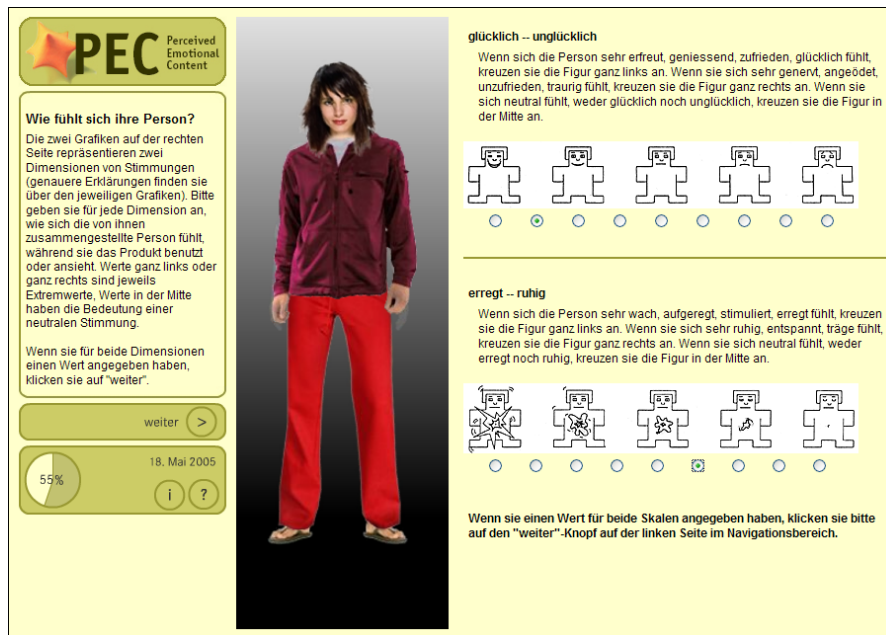

Figure 5-5: The module with the Self Assessment Manikin - valence scale (top) and arousal scale (bottom).
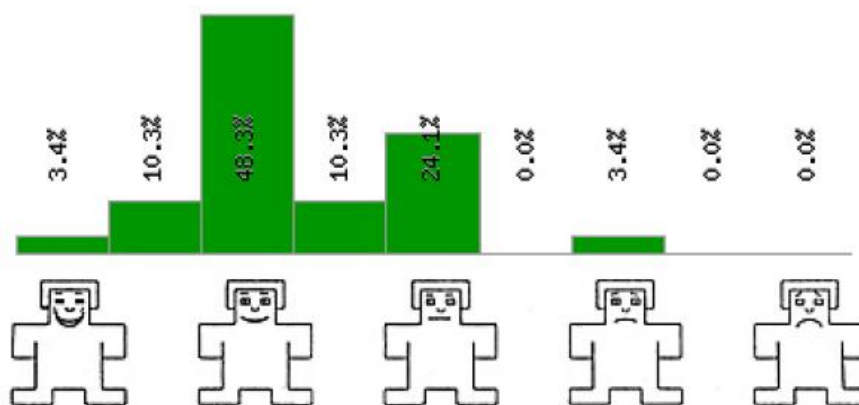

Figure 5-6: Rating of a manikin on the valence dimension. Values on the left indicate that the manikin was rated as happy, content, pleased, values on the right indicate that the manikin was appraised as sad, discontent or unhappy.

5.2.4 Personality

Personality types are based upon Carl Jung's notions of psychological types, basic patterns and traits of human behaviour. There are a manifold of personality inventories, tests to assess the personality type of a person. Common to all of them is the idea that human behaviour is not coincidental, but that there are behavioural patterns. Human behaviour is predictable and it can be classified up to a certain degree.

One of the most widely used personality inventories is the Myers-Briggs Type Indicator (MBTI) (Briggs-Myers & Myers, 1980). It is an instrument to assess personality using four basic scales with opposite poles: (1) extraversion/introversion, (2) sensing/intuition, (3) thinking/feeling and (4) judging/perceiving, resulting in 16 possible personality types. The standardised MBTI questionnaire is a 90-item instrument that takes 10 to 20 minutes to complete. In the presented tool, a shortened version, assessing the four scales directly through a description of each type, was used.

Figure 5-7: The MBTI module of the PEC-Test.

5.2.5 Lifestyle

Conventional market segmentation models utilize socio-demographic or socio-economic segmentation criteria like income, job or education. Often however, people with a similar income, identical professions and education may have different life contexts and therefore behave differently. Lifestyle-based

market segmentation models such as the Sinus Milieus (Sinus Sociovision[6]) group people with similar attitudes and lifestyles into categories. Basic values as well as attitudes to work, family, leisure, money and consumption are taken into account. Nevertheless, formal demographic criteria such as education, profession or income also influence the analysis. Sinus-Milieus turn the focus of attention to the individual and his / her whole life world and social environment.

The Sinus-Milieus in the tool allow on the one side to assess a classification of the manikin into one of the 10 milieus by the subject. On the other hand provides a mapping of the manikins to milieus with diverse verbal and visual background information, e.g. detailed descriptions including demographic information, values, consumer behaviour, leisure activities, etc.

Milieu-maps exist for Western Europe, the U.S., Russia and Japan. As an example, the 10 milieus of Switzerland are depicted in Figure 5-8.
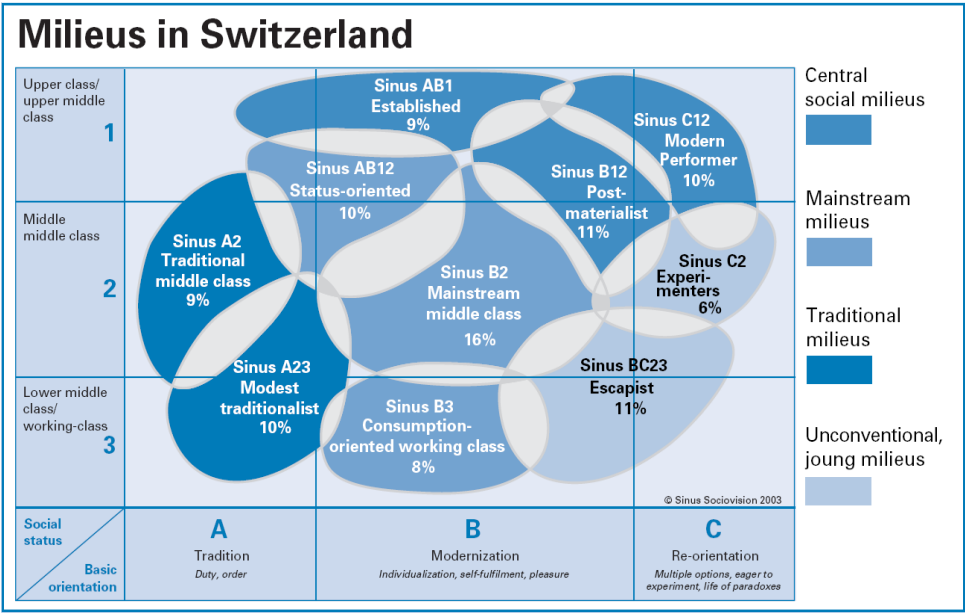

Figure 5-8: Lifestyle-based market segmentation - Milieus in Switzerland (Spectra, 2004).

The milieu module provides information about the target audience of the product. Although the present method is not a target-group analysis tool, the information about values, lifestyle, needs and social status provides information about the product character.
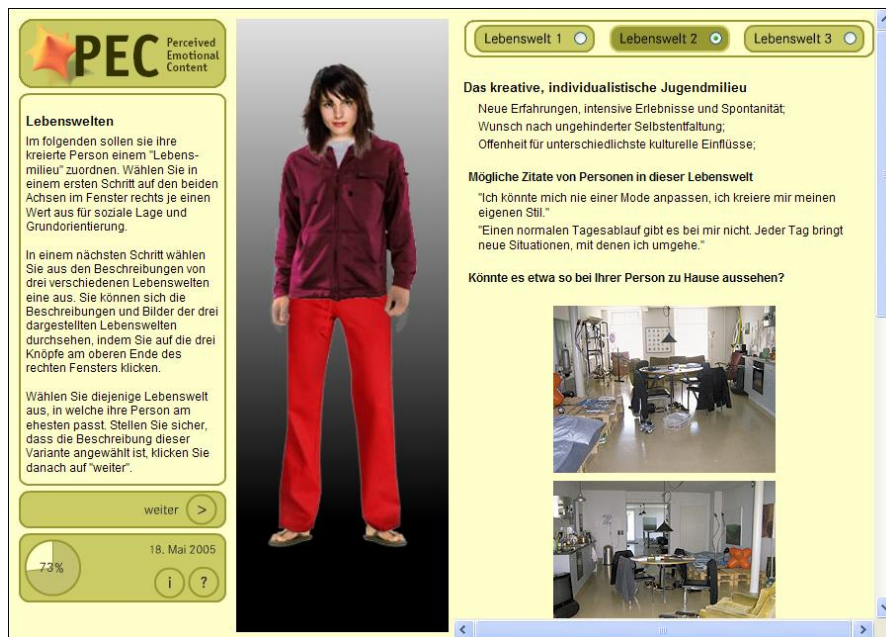
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[6] http://www.sociovision.de

Figure 5-9: Milieu module: after choosing a value on socio-demographic and lifestyle-based dimensions for their manikin, a selection of the 3 most plausible milieus are presented to the subject to choose from.

5.2.6 Direct inquiries about the product

This module assesses the opinions and attitude of the subject towards the product directly, without the manikin figure as a projection intermediate. The module resembles a questionnaire in a traditional marketing study.

In the first part of the module subjects are requested to state terms (adjectives, nouns, sentences) they associate with the product. It is an unstructured, open question. Previous experience has shown that this kind of question is a good source of information for emotion-laden terms, but that automatic analysis is difficult. Because questions in the other modules are in a closed format, it is the best way to account for limitations and product qualities not accounted for otherwise.

The following questions address overall appeal of the product and what value the subject is giving to the product:

- Would you buy the product yourself?
- Do you know of which brand the product is?
- Do you own a product with similar functionality?
- How does the product compare with other related products?
- How much would you pay for this product?
- Do you have further comments on the product?

Figure 5-10: The product module, assessing attitude towards the product without an intermediate manikin.

5.2.7 Demographics

Figure 5-11: Demographics data module.

The module assesses common demographic data of the subjects. The demographic information is used to analyse results in a more detailed manner in respect to differing demographics (e.g. sec, age, place of living, etc.).

The module contains questions about: age, sex, marital status, children, place of living (city, conurbation, village), way of living (family/couple/single household, flat share, other), type of ownership (own a flat/house, rent a flat/house), education, job, income and computer usage.

5.2.8 Analysis module

The analysis module aims at an automatic processing of the results, but is still in development. Simple statistics and a variety of graphical representations of the data from the different modules are provided. As of now, the modules are analysed separately for each test series. The idea is to build up a database with the results of all studies conducted with the tool to provide a basis for product comparison.
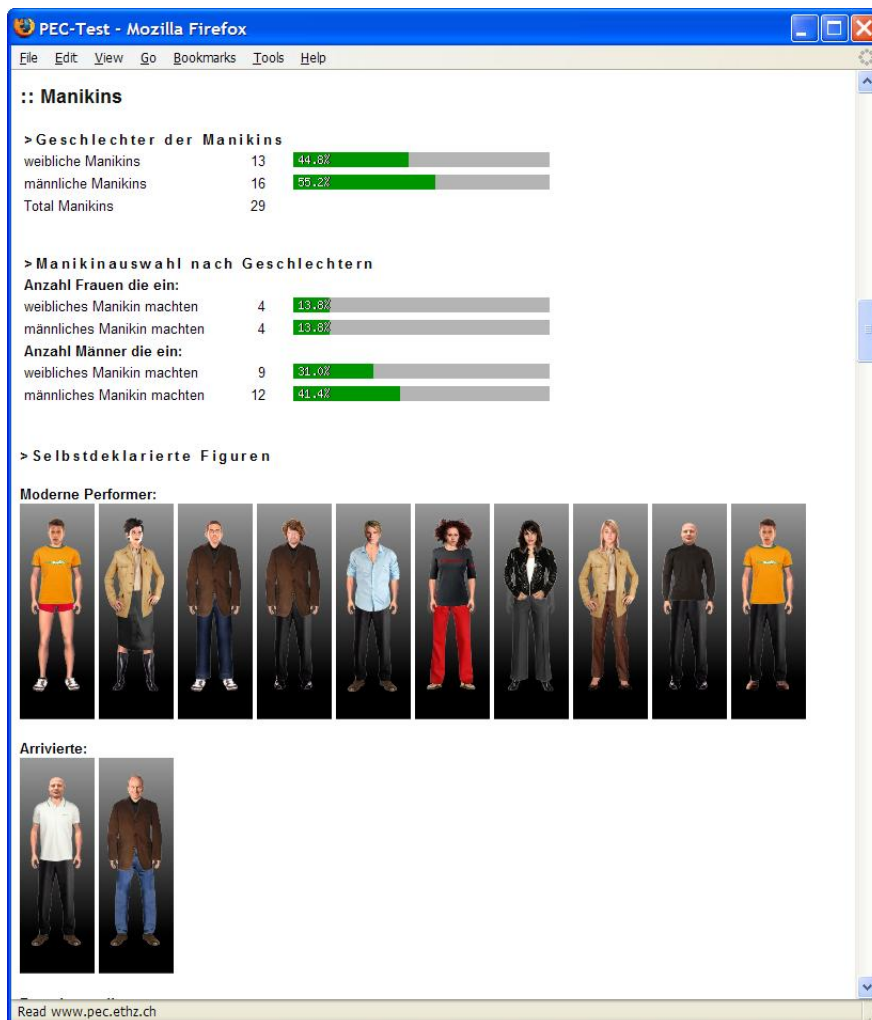

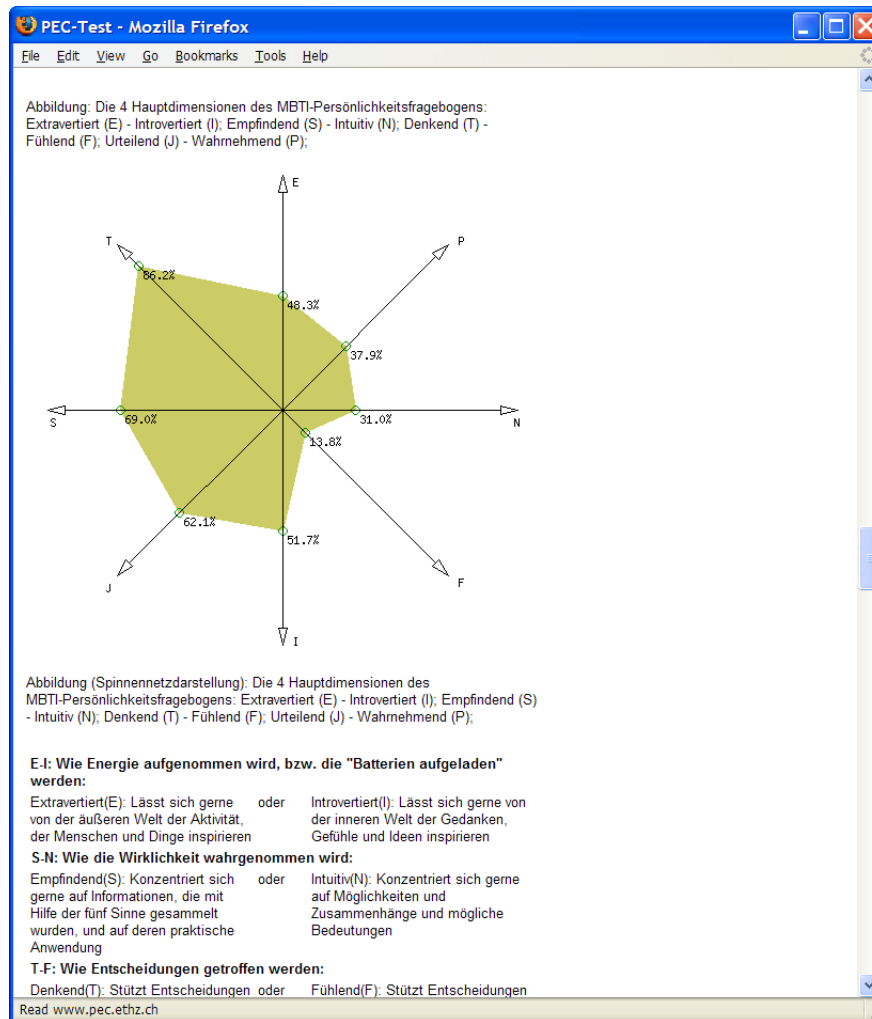*Figure 5-12: Example result output of the analysis module (manikins).*

Figure 5-13: Example result output of the analysis module (personality).

5.3 Discussion

The overall attractiveness is an important factor in product evaluations. Until recently, evaluation methods were confined to instrumental (pragmatic) aspects, as in traditional usability evaluation. It is common sense that pragmatic aspects alone do not determine the attractiveness of a product; hence, instruments for the evaluation of hedonic qualities of products are needed. Marketing and consumer oriented psychology have developed questionnaires and other methods (e.g. structured interviews, focus groups) for the assessment of hedonic qualities for quite a while, but these approaches have only a limited capability to assess modern interactive technology.

The UX model presented in chapter 3 shows the interplay of pragmatic and hedonic qualities and the resulting perceived product character. To evaluate products and their effects on the user/owner/customer requires a

multidimensional instrument, flexible enough to adapt to the differing requirements of product category, situation, and subjects. The presented tool for product evaluation has a modular composition and is therefore completely flexible. Test modules can be added on request and tests can be setup in any combination required. The web-based layout enables remote testing, e.g. with product images.

The underlying model of UX shows an approach to decompose user experiences into measurable elements. However, these elements might not be the conclusion to what shapes UX, as further research could prove. First preliminary tests with the tool have shown that it provides valuable results, but reliability of the tool and validity of the method need further exploration.

6 Conclusions

User experience research is a still young discipline that incorporates researchers from diverse fields with their differing views. It comes as no surprise that UX theory and definitions are inconclusive. The research and practice in UX are maturing since it has popularized the HCI community. But are there well-defined policies where to position UX in a map of information technology evaluation? Is there enough common ground and any sound plans how to refine methodologies on designing and evaluating UX? There have been different advances in search of a common "UX manifesto" (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008), but as the theoretical part on research frameworks and measurement methods in this thesis illustrates, they are still far from reaching common ground.

So what is UX? UX is about technology that fulfils more than just instrumental needs, in a way that acknowledges its use as a subjective, situated, complex and dynamic encounter. UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.).

What are the challenges for future research? Above all, non-instrumental needs must be better understood, defined and made operational. Although not an immediate aim, it would be interesting to know which product attributes are linked to which needs. Based on a better understanding, their interplay and importance can be studied. An intriguing question is how the overall quality, or the "goodness" of a product is formed, given pragmatic and hedonic aspects and underlying needs (Hassenzahl, 2004a). Are instrumental and non-instrumental quality perceptions related to each other, as for example demonstrated for beauty and usability by Tractinsky et al. (2000)? What is the role and importance of usability measures within the field of UX? Can we create dynamic quality models, which are able to describe an adequate weighting of quality aspects for a given product in a given context? What is the impact of non-instrumental qualities when explicitly designed in terms of acceptance, valuation and choice?

However, not just in relation to non-instrumental and hedonic aspects remain a lot of questions. The role of affect in human-product interaction is unclear. Is affect an antecedent, a consequence or a mediator of product perception and use? It is for example debatable if technology should actually be a vehicle for

affect maintenance and regulation. Is it possible to design emotions or are they too fleeting? If emotions are the consequence of personal and situational aspects, how can designers have the control needed to evoke specific emotions? How is it possible to cope with the seeming complexity of experience?

In their effort to strive for a UX manifesto, Law et al. (2007) see the future of UX research lie on three pillars:

Principle

- Work on a unified view of UX
- Develop a generic UX model comprising the structure and process of UX
- Identify boundaries of UX

Policy

- Identify the relationship between UX and related fields
- Understand the role of UX in the means-end chains between product attributes, usage consequences and product values
- Develop standards for UX
- Identify teaching strategies

Plan

- Develop theoretically sound methodologies for analyzing, designing, engineering and evaluating UX
- Understand UX in practice through case studies

The theoretical considerations and the presentation of new measurement methods in this thesis aim at contributing to these three pillars.

Annex

Annex A: Mouse movement parameters

Below is the full list of parameters that were calculated from the movement data of the subjects in the two experiments "mood in interaction" (Chapter 4).

General activation

task_gesamtZeit	Total duration of task (before cutting to 250 sec, resp. 180 sec) [sec]
bewegungen_anz	Number of mouse movements in timeframe (experiment 1: 250 sec; experiment 2: 180 sec) [num]
pausen_anz	Number of pauses in mouse movements [num]
movpause_quot	Ratio of time in movement and time paused [num]
clicks_anz	Total number of mouse clicks [num]
clicks_time	Mouse clicks per minute [clicks/min]
speed_overall	Mouse speed (overall distance divided by overall time (incl. pauses)) [pixel/sec]

Response time

movClick_median	Median duration between mouse movement stop and a mouse click [ms]
movClick_mean	Mean duration between mouse movement stop and a mouse click [ms]
clickMov_median	Median duration between a mouse click and movement start [ms]
clickMov_mean	Median duration between a mouse click and movement start [ms]

Spatial expansion

mov_median_pixel	Median distance of all mouse movements [pixel]
mov_mean_pixel	Mean distance of all mouse movements [pixel]
mov_max_pixel	Maximum distance of all mouse movements [pixel]
mov_total_pixel	Total movement distances [pixel]
mov_std_pixel	Standard deviation of mouse movement distances

mov_7525_pixel	Interquartile range of movement distances
mov_9010_pixel	Range of 10th to 90th percentile of movement distances

Temporal expansion

mov_median_msec	Median duration of all mouse movements [ms]
mov_mean_ msec	Mean duration of all mouse movements [ms]
mov_max_ msec	Maximum duration of all mouse movements [ms]
mov_total_ sec	Total movement duration [sec]
mov_std_ msec	Standard deviation of mouse movement durations
mov_7525_ msec	Interquartile range of movement durations
mov_9010_ msec	Range of 10th to 90th percentile of movement durations

Pause duration

pausen_median_msec	Median duration of pauses between movements [ms]
pausen _mean_ msec	Mean duration of pauses between movements [ms]
pausen _max_ msec	Maximum duration of pauses between movements [ms]
pausen _total_ sec	Total pause duration [sec]
pausen _std_ msec	Standard deviation of pauses between movements
pausen _7525_ msec	Interquartile range of movement pauses
pausen _9010_ msec	Range of 10th to 90th percentile of movement pauses

Speed

speed _median	Median of velocity of all movements [pixel/sec]
speed _mean	Mean of velocity of all movements [pixel/sec]
speed _max	Maximum velocity of all movements [pixel/sec]
speed _std	Standard deviation of velocity of movements

speed _7525	Interquartile range of velocity of movements
speed _9010	Range of 10th to 90th percentile of velocity of movements
speed _avg_total	Average velocity (total distance of all movements divided by total time of all movements) [pixel/sec]

Efficiency/Targeting

abstand_total	Total displacement of movement from ideal movement (= straight line from starting to end point of single movement) [pixel]
abstand_total_perMove	Displacement from ideal movement per movement [pixel/move]
abstand_ perTime	Displacement from ideal movement per movement time segment [pixel/sec]
abstand_max	Maximum displacement from ideal movement [pixel]
abstand_std	Standard deviation of displacements from ideal movements
abstand_7525	Interquartile range of displacements from ideal movements
abstand_9010	Range of 10th to 90th percentile of displacements from ideal movements

Variability

realIdeal_diff	Average difference per movement between actually travelled distance and length of ideal movement [pixel/move]
crossIdealLine_anz	Number of intersects of actual mouse movement with the straight connection between starting and end point (ideal line) [num]

Fluency/course

accel_median	Median acceleration [pixel/sec^2]
accel_mean	Mean acceleration [pixel/sec^2]
accel_max	Maximum acceleration [pixel/sec^2]
accel_std	Standard deviation of acceleration
accel_7525	Interquartile range of acceleration
accel_9010	Range of 10th to 90th percentile of acceleration
decel_max	Maximum deceleration [pixel/sec^2]
speed _std	Standard deviation of velocity of movements

Complexity

accel_anz	Number of segments with accelerated movement or number of velocity maxima per movement [num/move]
decel_anz	Number of segments with decelerated movement or number of velocity minima per movement [num/move]
accdec_anz	Number of changes in velocity per movement [num/move]

Energy

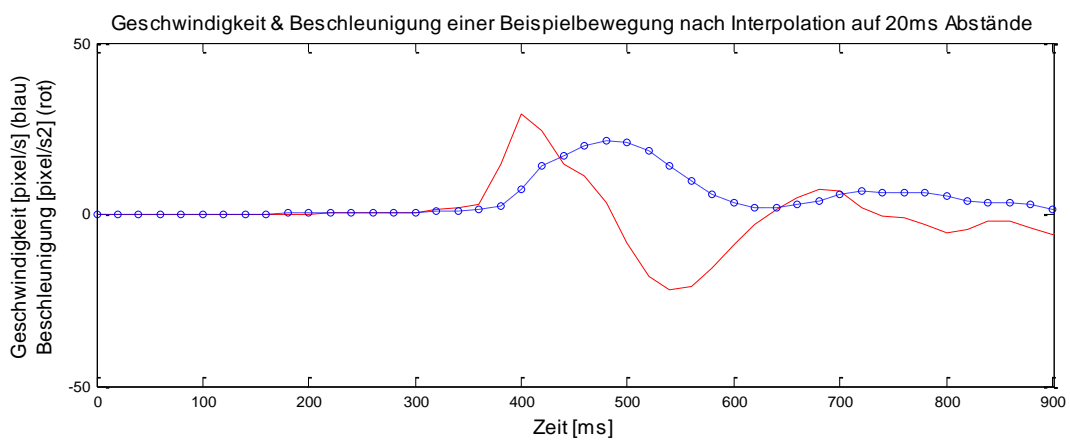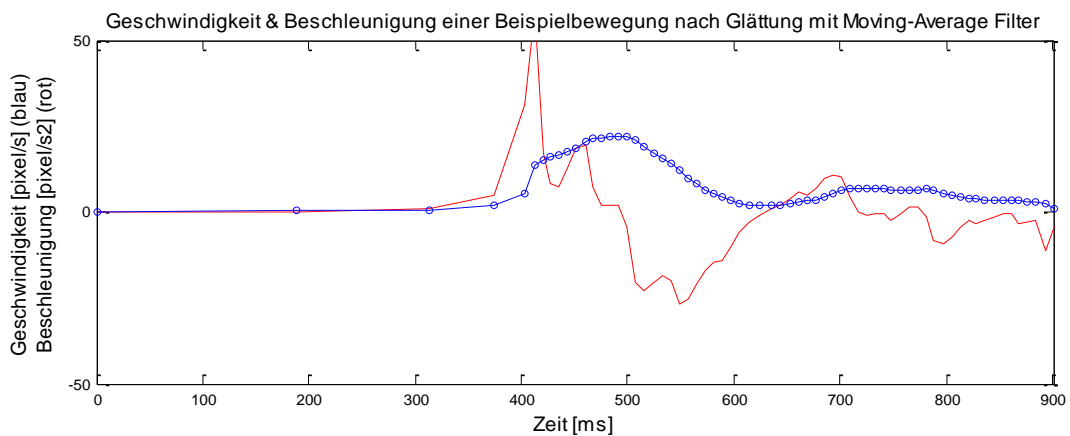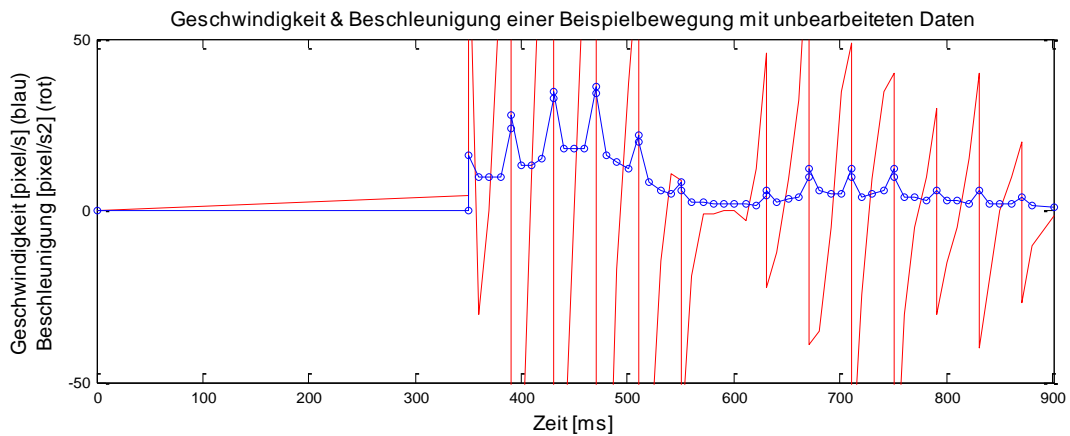|	
accel_time_avg	Average duration of acceleration segments [ms]
acceldecel_quot	Ratio of acceleration duration and deceleration duration

Expressivity

expressivitaet_median	Median of mean velocity increase per velocity peak (velocity maxima / duration; a measure for the speed of movement displacement)
expressivitaet_mean	Mean of mean velocity increase per velocity peak
expressivitaet_std	Standard deviation of mean velocity increase per velocity peak
expressivitaet_7525	Interquartile range of mean velocity increase per velocity peak
expressivitaet_9010	Range of 10th to 90th percentile of mean velocity increase per velocity peak

Emphasis

emphasis	Average height of velocity peaks (sum of peak velocity / number of peaks; closely related to expressivity)

Annex B: Smoothing and interpolation of data

Examples of speed and acceleration curves of a mouse movement with the original data before processing (top), after smoothing with a moving-average filter (middle) and after interpolation to 20ms intervals (bottom). [blue line: speed; blue dots: data points from log-file; red line: acceleration]

Geschwindigkeit & Beschleunigung einer Beispielbewegung mit unbearbeiteten Daten

Geschwindigkeit & Beschleunigung einer Beispielbewegung nach Glättung mit Moving-Average Filter

Geschwindigkeit & Beschleunigung einer Beispielbewegung nach Interpolation auf 20ms Abstände

References

Aboulafia, A., Bannon, L., & Fernstrom, M. (2001). Shifting perspectives from effect to affect: some framing questions. In M. Helander, H. M. Khalid, & P. O. Tham (Ed.), *Proceedings of the International Conference on Affective Human Factors Design* (pp. 508-514). ASEAN Academic Press.

Ahmed, A. A., & Traore, I. (2007). A New Biometric Technology Based on Mouse Dynamics. *IEEE Transactions on Dependable and Secure Computing , 4* (3), 165-179.

Alben, L. (1996). Quality of Experience. *Interactions , 3* (3), 11-15.

Ardito, C., Costabile, M. F., Lanzilotti, R., & Montinaro, F. (2007). Toward the evaluation of UX. In E. Law, A. Vermeeren, M. Hassenzahl, & M. Blythe (Eds.), *Towards a UX manifesto* (pp. 6-9). COST294-MAUSE.

Ark, W. S., Dryer, D. C., & Lu, D. J. (1999). The Emotion Mouse. *Proceedings of HCI International* (pp. 818-823). Mahwah, NJ: Lawrence Erlbaum Associates.

Batra, R., & Ahtola, O. T. (1990). Measuring the hedonic and utilitarian sources of consumer choice. *Marketing Letters , 2*, 159-170.

Battarbee, K. (2004). Co-Experience: Understanding User Experiences in Social Interaction (Doctoral dissertation). Helsinki: University of Art and Design.

Beatty, J. (1982). Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin , 91* (2), 276-292.

Bloch, P. H. (1995). Seeking the ideal form: Product design and consumer response. *Journal of Marketing , 59* (3), 16-29.

Bloch, S., Lemeignan, M., & Aguilera, N. (1991). Specific respiratory patterns distinguish among human basic emotions. *International Journal of Psychophysiology , 11* (2), 141-154.

Blythe, M., Hassenzahl, M., Law, E., & Vermeeren, A. (2007). An Analysis Framework for User Experience (UX) Studies: A Green Paper. In E. Law, A. Vermeeren, M. Hassenzahl, & M. Blythe (Ed.), *COST294-MAUSE affiliated workshop*, (pp. 1-5). Lancaster, UK.

Blythe, M., Monk, A., & Park, J. (2002). Technology biogarphies: field study techinques for home use product development. *CHI '02 Extended Abstracts on Human Factors in Computing Systems* (pp. 658-659). New York: ACM.

Bradley, M. M., & Lang, P. J. (2000). Measuring emotion: Behavior, feeling, and physiology. In R. D. Lane, & L. Nadel (Eds.), *Cognitive neuroscience of emotion* (pp. 242-276). New York: Oxford University Press.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. *Journal of Behavior Therapy and Experimental Psychiatry , 25* (1), 49-59.

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and Motivation I: Defensive and Appetitive Reactions in Picture Processing. *Emotion , 1* (3), 276-298.

Brandtzæg, P. B., & Følstad, A. (2001). How to Understand Fun: Using Demands, decision latitude and social support to understand fun in Human Factors Design. In M. Helander, H. M. Khalid, & M. P. Tham (Ed.), *Proceedings of The International Conference on Aff ective Human Factors Design* (pp. 131-139). London: Asean Academic Press.

Brave, S., & Nass, C. (2003). Emotion in Human-Computer Interaction. In J. A. Jacko, & A. Sears (Eds.), *The Human-Computer Interaction Handbook* (pp. 81-96). London: Lawrence Erlbaum Associates.

Briggs-Myers, I., & Myers, P. (1980). *Gifts Differing: Understanding Personality Type.* Consulting Psychologists Press.

Buchenau, M., & Suri, J. F. (2000). Experience prototyping. In D. Boyarski, & W. A. Kellogg (Ed.), *Proceedings of the 3rd Conference on Designing interactive Systems DIS '00* (pp. 424-433). New York: ACM.

Burmester, M., Platz, A., Rudolph, U., & Wild, B. (1999). Aesthetic design - just an add on? In H. J. Bullinger, & J. Ziegler (Eds.), *Human Computer Interaction: Ergonomics and User Interfaces* (pp. 671-675). Mahwah, NJ: Lawrence Erlbaum.

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (1993). The Psychophysiology of Emotion. In J. M. Haviland-Jones (Ed.), *Handbook of Emotions* (pp. 119-142). New York: The Guilford Press.

Carroll, J. M., & Thomas, J. C. (1988). FUN. *SIGCHI Bulletin , 19* (3), 21-24.

Chen, H. (2006). Flow on the net - detecting Web users' positive affects and their flow states. *Computers in Human Behavior , 22*, 221-233.

Cohen, I., Sebe, N., Chen, L., Garg, A., & Huang, T. S. (2003). Facial Expression Recognition from Video Sequences: Temporal and Static Modeling. *Computer Vision and Image Understanding , 91* (1-2), 160-187.

Costa, P. T., & McCrae, R. R. (1992). Revised NEO Personality Inventory (NEO PI-R) and NEO Five Factor Inventory (Professional Manual). Assessment Resources: Psychological Assessment Resources.

Cowie, R., Douglas-Cowie, E., Tsapatsoulis, N., Votsis, G., Kollias, G., Fellenz, W., et al. (2001). Emotion recognition in human-computer interaction. *IEEE Signal Processing Magazine , 18* (1), 32-80.

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies , 25*, 547-577.

Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety.* San Francisco: Jossey-Bass.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience.* New York: Harper.

Csikszentmihalyi, M., & Larson, R. (1987). Validity and reliability of the Experience-Sampling Method. *Journal of Nervous and Mental Disease , 175* (9), 526-536.

Davis, F. D., Bagozzi, R. P., & Warschaw, P. R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology , 22*, 1111-1132.

de Meijer, M. (1989). The contribution of general features of body movement to the attribution of emotions. *Journal of Nonverbal Behavior , 13* (4), 247-268.

Derbaix, C., & Pecheux, C. (1999). Mood and children: Proposition of a measurement scale. *Journal of Economic Psychology , 20* (5), 571-591.

Desmet, P. (2003). A multilayered model of product emotions. *The design journal , 6* (2), 4-13.

Desmet, P. (2002). *Designing Emotions (Doctoral Dissertation).* Netherlands: Delft University of Technology.

Desmet, P., & Hekkert, P. (2002). The basis of product emotions. In W. Green, & P. Jordan (Eds.), *Pleasure with products: Beyond usability* (pp. 60-68). London: Taylor & Francis.

Diener, E., & Iran-Nejad, A. (1986). The relationship in experience between various types of affect. *Journal of Personality and Social Psychology , 50* (5), 1031-1038.

Dion, K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of Personality and Social Psychology , 24* (3), 285-290.

Djajadiningrat, J. P. (1998). Cubby: What you see is where you act. Interlacing the display and manipulation spaces (Doctoral dissertation). Delft, the Netherlands: Delft University of Technology.

Doerr, J., & Kerkow, D. (2006). Total control of user experience in software development - a software engineering dream? In E. Law, *User Experience - Towards a Unified View* (pp. 94-99).

Edwards, E. C., & Kasik, D. J. (1974). User Experience with the CYBER graphics terminal. *Proceedings of VIM-21*, (pp. 284-286).

Ekman, P., & Friesen, W. V. (1978). *Facial Action Coding System: A Technique for the Measurement of Facial Movement.* Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., Levenson, R. W., & Friesen, W. V. (1983). Autonomic nervous system activity distinguishes among emotions. *Science , 221* (4616), 1208-1210.

Fahrenberg, J. (2001). Physiologische Grundlagen und Messmethoden der Herz-Kreislaufaktivität [Physiological fundamentals and measurement methods of cardiovascular activity]. In F. Rösler (Ed.), *Grundlagen und Methoden der Psychophysiologie* (pp. 317-454). Göttingen: Hogrefe.

Fernandes, G., Lindgaard, G., Dillon, R., & Wood, J. (2003). Judgning the appeal of web sites. *Proceedings of the 4th World Congress on the Management of Electronic Commerce.* Hamilton: McMaster University.

Fisher, C., & Sanderson, P. (1996). Exploratory sequential data analysis: exploring continuous observational data. *Interactions , 3* (2), 25-34.

Forgas, J. P. (1995). Mood and Judgement: The Affect Infusion Model (AIM). *Psychological Bulletin , 117* (1), 39-66.

Forlizzi, J., & Battarbee, K. (2004). Understanding experience in interactive systems. *Proceedings of the 2004 conference on Designing Interactive Systems (DIS 04)* (p. 261). New York: ACM.

Forlizzi, J., & Ford, S. (2000). The building blocks of experience: An early framework for interaction designers. *Proceedings of Conference on Designing Interactive Systems*, (pp. 419-423).

Frijda, N. H. (1989). Aesthetic emotion and reality. *American Psychologist , 44* (12), 1546-1547.

Frijda, N. H. (1986). *The Emotions.* Cambridge: Cambridge University Press.

Garrett, J. J. (2002). *The elements of user experience – user-centered design for the web.* Berkeley, CA: New Riders/Pearson Education.

Gaver, B., Dunne, T., & Pacenti, E. (1999). Cultural Probes. *Interactions , 6* (1), 21-29.

Gaver, W. W., & Martin, H. (2000). Alternatives: Exploring information appliances through conceptual design proposals. *Proceedings of the CHI 2000 Conference on Human Factors in Computing* (pp. 209-216). New York: ACM Press.

Gladwell, M. (2005). *Blink. The power of thinking without thinking.* New York: Time Warner Book Group.

Goleman, D. (1995). *Emotional Intelligence.* New York: Bantam Books.

Gomez, P. (2005). Respiratory Responses to Visual and Acoustic Stimuli From a Dimensional Perspective of Emotion (Doctoral Dissertation). Aachen: Shaker Verlag.

Grammer, K., Honda, R., Schmitt, A., & Juette, A. (1999). Fuzziness Of Nonverbal Courtship Communication. Unblurred By Motion Energy Detection. *Journal of Personality and Social Psychology , 77* (3), 509-524.

Gross, J. J., & Levenson, R. W. (1995). Emotion elicitation using films. *Cognition and Emotion , 9* (1), 87-108.

Gross, J. J., Sutton, S. K., & Ketelaar, T. (1998). Relations between affect and personality: Support for the affect-level and affective-reactivity views. *Personality and Social Psychology Bulletin , 24* (3), 279-288.

Hartmann, B., Mancini, M., & Pelachaud, C. (2006). Implementing Expressive Gesture Synthesis for Embodied Conversational Agents. In *Gesture in Human-Computer Interaction and Simulation* (Vol. 3881, pp. 188-199). Berlin: Springer.

Hassenzahl, M. (2007). Aesthetics in interactive products: Correlates and consequences of beauty. In H. N. Schifferstein, & P. Hekkert (Eds.), *Product experience.* Amsterdam: Elsevier Science.

Hassenzahl, M. (2004b). Emotions Can Be Quite Ephemeral. We Cannot Design Them. *Interactions , 11* (5), 46-48.

Hassenzahl, M. (2006). Hedonic, Emotional, and Experiential Perspectives on Product Quality. In C. Ghaoui, *Encyclopedia of Human Computer Interaction* (pp. 266-272). London, Hershey: Idea Group.

Hassenzahl, M. (2001). The effect of perceived hedonic quality on product appealingness. *International Journal of Human-Computer Interaction , 13* (4), 481-499.

Hassenzahl, M. (2004a). The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human-Computer Interaction , 19* (4), 319-349.

Hassenzahl, M. (2003). The thing and I: Understanding the relationship between user and product. In M. Blythe, C. Overbeeke, A. F. Monk, & P. C. Wright, *Funology: From usability to enjoyment* (pp. 31-42). Dordrecht: Kluwer.

Hassenzahl, M., & Tractinsky, N. (2006). User Experience – a Research Agenda. *Behaviour and Information Technology , 25* (2), 91-97.

Hassenzahl, M., & Ullrich, D. (2007). To do or not to do: Differences in user experience and retrospective judgements depending on the presence or absence of instrumental goals. *Interacting with Computers , 19*, 429-437.

Hassenzahl, M., Beu, A., & Burmester, M. (2001). Engineering Joy. *IEEE Software , 18* (1), 70-76.

Hassenzahl, M., Burmester, M., & Koller, F. (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität [AttrakDiff: A questionnaire for the measurement of perceived hedonic and pragmatic qualities]. In J. Ziegler, & G. Szwillus (Eds.), *Mensch & Computer 2003.Interaktion in Bewegung* (pp. 187-196). Stuttgart, Leipzig: B.G. Teubner.

Hassenzahl, M., Law, E. L.-C., & Hvannberg, E. T. (2006). User Experience – Towards a unified view. *Proceedings of NorciCHI. The Fourth Nordic Conference on Human-Computer Interaction*, (pp. 1-3). Oslo.

Hassenzahl, M., Platz, A., Burmester, M., & Lehner, K. (2000). Hedonic and ergonomic quality aspects determine a software´s appeal. *CHI 2000 Conference Proceedings* (pp. 201-208). New York: ACM Press.

Hektner, J., Schmidt, J., & Csikszentmihalyi, M. (2007). *Experience Sampling Method: Measuring the Quality of Everyday Life.* London: Sage Publications.

Helander, M. G., & Tham, M. P. (2003). Hedonomics - affective human factors design. *Ergonomics , 46*, 1269-1272.

Hess, E. H., & Polt, J. M. (1960). Pupil Size in Relation to Interest Value of Visual Stimuli. *Science , 132* (3423), 349-350.

Huang, M. H. (2003). Designing Website attributes to induce experiential encounters. *Computers in Human Behavior , 19*, 425-442.

ISO. (1998). *ISO 9241: Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11: Guidance on usability.* Geneva: International Organization for Standardization.

Janlert, L. E., & Stolterman, E. (1997). The character of things. *Design Studies , 18* (3), 297-314.

Jordan, P. W. (2000). *Designing pleasurable products. An introduction to the new human factors.* London, New York: Taylor & Francis.

Jordan, P. W. (1997). Products as personalities. In S. A. Robertson (Ed.), *Contemporary Ergonomics* (pp. 73-78). London: Taylor & Francis.

Juette, A. (2001). Veränderungen der Bewegungsqualität mit zunehmender Despressivität [Changes of movement quality with increasing despression] (Doctoral dissertation). Vienna: University of Vienna.

Kempf, D. S. (1999). Attitude formation from product trial: Distinct roles of cognition and affect for hedonic and functional products. *Psychology & Marketing , 16*, 35-50.

Kleiss, J. A., & Enke, G. (1999). Assessing Automotive Audio System Visual Appearance Attributes Using Empirical Methods. In *Human Factors in Audio Interior Systems, Driving, and Vehicle Seating.* Warrendale: Society of Automotive Engineers.

Knemeyer, D., & Svoboda, E. (2006, 08 11). *User Experience - UX.* Retrieved 05 01, 2008, from http://interaction-design.org/encyclopedia/user_experience_or_ux.html

Konečni, V. J., & Sargent-Pollock, D. (1977). Arousal, positive and negative affect, and preference for Renaissance and 20th-century paintings. *Motivation and Emotion , 1* (1), 75-93.

Kramer, A. F. (1991). Physiological metrics of mental workload: a review of recent progress. In D. L. Damos (Ed.), *Multiple-Task-Performance* (pp. 329-360). London: Taylor & Francis.

Küthe, E., Thun, M., & Schriefers, T. (1995). *Marketing mit Bildern [marketing with images].* Köln: DuMont.

Kurosu, M., & Kashimura, K. (1995). Apparent usability vs. inherent usability: experimental analysis on the determinants of the apparent usability. *Conference on Human Factors in Computing Systems* (pp. 292-293). New York: ACM.

Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, H. Johnson, & T. A. Williams (Eds.), *Technology in Mental Health Care Delivery Systems* (pp. 119-137). Norwood, NJ: Ablex.

Lang, P. J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist , 50* (5), 372-385.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology , 30*, 261-273.

Larsen, R. J., & Fredrickson, B. L. (1999). Measurement issues in emotion research. In D. Kahnemann, E. Diener, & N. Schwarz (Eds.), *Well-Being: the foundations of hedonic psychology.* New York: Russel Sage Foundation.

Laurel, B. (1991). *Computers as Theatre.* Boston, MA: Addison-Wesley.

Lavie, T., & Tractinsky, N. (2004). Assessing dimensions of perceived visual aesthetics of web sites. *International Journal of Human-Computer Studies , 60* (3), 269-298.

Law, E., Roto, V., Vermeeren, A., Kort, J., & Hassenzahl, M. (2008). Towards a Shared Definition of User Experience. *CHI 2008 Proceedings* (pp. 2395-2398). Florence, Italy: ACM.

Law, E., Vermeeren, A., Hassenzahl, M., & Blythe, M. (2007). *Towards a UX Manifesto.* Lancaster, UK: COST294-MAUSE.

Leder, H., Belke, B., Oeberst, A., & Augustin, D. (2004). A model of aesthetic appreciation and aesthetic judgments. *British Journal of Psychology , 95* (4), 489-508.

Lenderman, M. (2006). *Experience the Message: How Experiential Marketing Is Changing the Brand World.* New York: Carroll & Graf.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology , 140* (5), 1-55.

Lindgaard, G., & Whitfield, T. (2004). Integrating aesthetics within an evolutionary and psychological framework. *Theoretical Issues in Ergonomics Science , 5* (1), 73-90.

Logan, R. J. (1994). Behavioral and emotional usability: Thomson consumer electronics. In M. E. Wiklund, *Usability in practice: How companies develop user friendly products* (pp. 59-82). Boston: Academic Press.

MacDonald, A. S. (2001). Aesthetic intelligence: optimizing user-centred design. *Journal of Engineering Design , 12* (1), 37-45.

MacDonald, A. S. (2002). The Scenario of Sensory Encounter: Cultural Factors in Sensory-Aesthetic Experience. In W. S. Green, & P. W. Jordan (Eds.), *Pleasure with products: beyond usability* (pp. 113-123). London: Taylor & Francis.

Maehr, W. (2005). *eMotion - Estimation of the User's Emotional State by Mouse Motions.* Diplomarbeit. Dornbirn: Fachhochschule Vorarlberg.

Mahlke, S. (2008). User Experience of Interaction with Technical Systems (Doctoral dissertation). Berlin: Technische Universität.

Mäkelä, A., & Fulton Suri, J. (2001). Supporting Users' Creativity: Design to Induce Pleasurable Experiences. In M. Helander, & H. M. Khalid (Ed.), *Proceedings of the Conference on Affective Human Factors* (pp. 387-391). London: Asean Academic Press.

Malone, T. W. (1981). Toward a Theory of Intrinsically Motivating Instruction. *Cognitive Science: A Multidisciplinary Journal , 5* (4), 333-369.

Marcus, A. (2004). Six Degrees of Separation: Defining User Experience Spaces. *User Experience Magazin* , 16.

Margolin, V. (1997). Getting to know the user. *Design Studies , 18* (3), 227-236.

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review , 50* (4), 370-396.

Mayer, J. D., & Gaschke, Y. N. (1988). The Experience and Meta-Experience of Mood. *Journal of Personality and Social Psychology , 55* (1), 102-111.

McCarthy, J., & Wright, P. (2005). A Practitioner-Centred Assessment of a User-Experience Framework. *International Journal of Technology and Human Interaction , 1* (2), 1-23.

McCarthy, J., & Wright, P. (2004). *Technology as experience.* Cambridge: MIT Press.

Mehrabian, A. (1995). Framework for a Comprehensive Description and Measurement of Emotional States. *The Journal of Genetic Psychology , 121* (3), 339-361.

Mehrabian, A. (1996). Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in Temperament. *Current Psychology , 14* (4), 261-292.

Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology.* Cambridge, MA: The MIT Press.

Morris, W. N. (1989). *Mood: The Frame of Mind.* New York: Springer-Verlag.

Mulder, I., & van Vliet, H. (2008). In Search of The X-Factor to Develop Experience Measurement Tools. In J. Westerink, M. Ouwerkerk, T. Overbeek, W. Pasveer, & B. de Ruyter (Eds.), *Probing Experience: From Assessment of User Emotions and Behaviour to Development of Products* (Vol. 8, pp. 43-56). Springer Netherlands.

Nagamachi, M. (2001). Kansei Engineering – A Powerful Ergonomic Technology for Product Development. In M. Helander, H. M. Khalid, & M. P. Tham (Ed.), *Proceedings of the Conference on Affective Human Factors* (pp. 9–14). London: Asean Academic Press.

Newell, A. (2006). Theatre as an intermediary between users and CHI designers. *HI 2006*, (pp. 111-117). Montreal, Quebec, Canada.

Norman, D. A. (2004). *Emotional Design: Why we love (or hate) everyday things.* New York: Basic Books.

Norman, D. A., & Draper, S. (1986). *User Centered System Design: New Perspectives on Human-Computer Interaction.* Hillsdale: Lawrence Erlbaum.

Oppenheim, A. V., & Schafer, R. W. (1989). *Discrete-Time Signal Processing.* Englewood Cliffs, NJ: Prentice-Hall.

Ortony, A., Clore, G. L., & Collins, A. (1988). *The cognitive structure of emotions.* Cambridge, MA: Cambridge University Press.

Osgood, C. E., Suci, G., & Tannenbaum, P. (1957). *The Measurement of Meaning.* University of Illinois Press.

Overbeeke, C. J., Djajadiningrat, J. P., Hummels, C. M., & Wensveen, S. G. (2002). Beauty in Usability: Forget about ease of use! In W. S. Green, & P. W. Jordan, *Pleasure with products: Beyond usability* (pp. 9-18). London: Taylor & Francis.

Pagulayan, R. J., Keeker, K., Wixon, D., Romero, R. L., & Fuller, T. (2003). User-Centered Design in Games. In J. A. Jacko, & A. Sears, *The Human-Computer Interaction Handbook* (pp. 883-906). London: Lawrence Erlbaum Associates.

Park, S., Choi, D., & Kim, J. (2004). Critical factors for the aesthetic fidelity of web pages: empirical studies with professional web designers and users. *Interacting with Computers , 16* (2), 351-376.

Partala, T., & Surakka, V. (2004). The effects of affective interventions in human-computer interaction. *Interacting with Computers , 16* (2), 295-309.

Picard, R. W. (1997). *Affective Computing.* Cambridge, MA: MIT Press.

Picard, R. W., & Klein, J. (2002). Computers that recognize and respond to user emotion: theoretical and practival implications. *Interacting with Computers , 14*, 141-169.

Plutchik, R. (2001). The Nature of Emotions. *American Scientist , 89* (4), 344-349.

Prentice, D. A. (1987). Psychological correspondence of possessions, attitudes, and values. *Journal of Personality and Social Psychology , 53* (6), 993-1003.

Prentice, D. A. (1987). Psychological correspondence of possessions, attitudes, and values. *Journal of Personality and Social Psychology , 53* (6), 993-1003.

Rafaeli, A., & Vilnai-Yavetz, I. (2004). Instrumentality, aesthetics and symbolism of physical artifacts as triggers of emotion. *Theoretical Issues in Ergonomics Science , 5* (1), 91-112.

Rhea, D. K. (1992). A New Perspective on Design: Focusing on Customer Experience. *Design Management Journal* , 40-48.

Roto, V. (2006). Web Browsing on Mobile Phones - Characteristics of User Experience (Doctoral Dissertation). Helsinki: University of Technology.

Rubinoff, R. (2004, 04 21). *How To Quantify The User Experience*. Retrieved 05 10, 2008, from sitepoint.com: http://www.sitepoint.com/article/quantify-user-experience

Russel, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology , 39* (6), 1161-1178.

Russel, J. A. (1979). Affective space is bipolar. *Journal of Personality and Social Psychology , 37* (3), 345-356.

Russell, J. A. (2003). Core Affect and the Psychological Construction of Emotion. *Psychological Review , 110* (1), 145-172.

Russell, J. A., & Feldman Barrett, L. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology , 76* (5), 805-819.

Russell, J. A., Weiss, A., & Mendelssohn, G. A. (1989). The Affect Grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology , 57*, 493-502.

Schenkman, B. N., & Jönsson, F. U. (2000). Aesthetics and preferences of web pages. *Behaviour & Information Technology , 19* (5), 367-377.

Scherer, K. R. (2001). Appraisal considered as a process of multi-level sequential checking. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods, research* (pp. 92-120). New York: Oxford University Press.

Scherer, K. R. (1984). On the nature and function of emotion: A component process approach. In K. R. Scherer, & P. Ekman (Eds.), *Approaches to emotion* (pp. 293-317). Hillsdale, NJ: Erlbaum.

Schorr, A. (2001). Subjective measurement in appraisal research: present state and future perspectives. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.),

Appraisal Processes in Emotion: Theory, Methods, Research (pp. 331-349). New York: Oxford University Press.

Schuller, B. (2006). Automatische Emotionserkennung aus sprachlicher und manueller Interaktion [Automatic recognition of emotions from verbal and manual interaction] (Doctoral dissertation). München: Technische Universität München.

Schwartz, S. H., & Bilsky, W. (1987). Toward a universal psychological structure of human values. *Journal of Personality and Social Psychology , 53* (3), 550-562.

Shedroff, N. (2001). *Experience Design.* Berkeley, CA: New Riders /Pearson Education.

Spiegel Verlag, H. (2002). *Outfit-5 Typologie.* Hamburg: Spiegel Verlag.

Stern, R. M., Ray, W. J., & Quigley, K. S. (2001). *Psychophysiological Recording.* New York: Oxford University Press.

Summative assessment (Wikipedia). (2008, 05 18). Retrieved 06 01, 2008, from http://en.wikipedia.org/wiki/Summative_assessment

Tiger, L. (1992). The Pursuit of Pleasure. Boston: Little, Brown & Company.

Tractinsky, N. (1997). Aesthetics and apparent usability: empirically assessing cultural and methodological issues. *Conference on Human Factors in Computing Systems* (pp. 115-122). New York: ACM.

Tractinsky, N., & Zmiri, D. (2006). Exploring Attributes of Skins as Potential Antecedents of Emotion in HCI. In P. Fishwick (Ed.), *Aesthetic Computing* (pp. 405-422). Cambridge, MA: MIT Press.

Tractinsky, N., Cokhavi, A., & Kirschenbaum, M. (2004). Using Ratings and Response Latencies to Evaluate the Consistency of Immediate Aesthetic Perceptions of Web Pages. *Proceedings of the Third Annual Workshop on HCI Research in MIS.* Wahington, D.C.

Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers , 13*, 127-145.

User Experience (Nielsen-Norman Group). (2007, 01 05). Retrieved 05 10, 2008, from Nielsen-Norman Group: http://www.nngroup.com/about/userexperience.html

User Experience Design (Wikipedia). (2008, 05 03). Retrieved 05 10, 2008, from Wikipedia: http://en.wikipedia.org/wiki/User_experience_design

Wallbott, H. G. (1982). *Bewegungsstil und Bewegungsqualität. Untersuchungen zum Ausdruck und Eindruck gestischen Verhaltens.* Weinheim: Beltz Verlag.

Wallbott, H. G. (1998). Bodily expression of emotion. *European Journal of Social Psychology , 28*, 879-896.

Wallbott, H. G. (1985). Hand Movement Quality: A Neglected Aspect of Nonverbal Behavior in Clinical Judgement and Person Perception. *Journal of Clinical Psychology , 41* (3), 345-359.

Watson, D., & Tellegen, A. (1985). Tellegen. *Psychological Bulletin , 98* (2), 219-235.

Weisstein, E. W. (2003, Februar 1). *Point-Line Distance--2-Dimensional.* Retrieved Dezember 12, 2007, from MathWorld--A Wolfram Web Resource: http://mathworld.wolfram.com/Point-LineDistance2-Dimensional.html

Wensveen, S., Overbeeke, K., & Djajadiningrat, T. (2000). Touch me, hit me and I know how you feel: a design approach to emotionally rich interaction. *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques* (pp. 48-52). New York: ACM.

Whitfield, T. (2000). Beyond prototypicality: towards a Categorical-Motivation model of aesthetics. *Empirical Studies of the Arts , 18*, 1-11.

Wicklund, R. A., & Gollwitzer, P. M. (1982). *Symbolic self-completion.* Hilldsdale, NJ: Lawrence Erlbaum Associates.

Wright, P., & Blythe, M. (2007). User Experience Research as an Inter-discipline: Towards a UX Manifesto. In E. Law, A. Vermeeren, M. Hassenzahl, & M. Blythe, *Towards a UX Manifesto* (pp. 65-70). COST294-MAUSE workshop.

Yeung, C. M., & Wyer, R. J. (2004). Affect, appraisal and consumer judgment. *Journal of Consumer Research , 31* (2), 412-424.

Zacks, J. M. (2004). Using movement and intentions to understand simple events. *Cognitive Science , 28*, 979-1008.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist , 35* (2), 151-175.

Zajonc, R. B., & Markus, H. (1982). Affective and Cognitive Factors in Preferences. *Journal of Consumer Research , 9* (2), 123-131.

Zhang, P., & Li, N. (2004). Love at first sight or sustained effect? The role of perceived affective quality on user's cognitive reactions to information technology. *Proceedings of the Twenty-Fifth International Conference on Information Systems (ICIS)*, (pp. 283-295).

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