Aalto University
School of Business

What makes a satisfying user experience in the context of human-computer interaction?

MSc program in Information and Service Management

Master's thesis

Karoliina Pärnänen

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Department of Information and Service Economy
Aalto University
School of Business

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School of Business

WHAT MAKES A SATISFYING USER EXPERIENCE IN THE CONTEXT OF HUMAN-COMPUTER INTERACTION?

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Karoliina Pärnänen
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Aalto University
School of Business

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

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Author Karoliina Pärnänen

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Abstract

The purpose of this research is to study the relations of user interface aesthetics, usability, and user experience in the context of human-computer interaction (HCI). This study aims to discover the key factors contributing to a satisfying user experience from the user's perspective.

We present a novel user experience model that connects perceived usability, and its subcharacteristics, into perceived user experience, and to the emotional responses it evokes. The ISO/IEC 205010:2011 standard of the International Standardization Organization will act as a framework for the constructed user experience model, combining characteristics from both Product Quality and Quality-in-Use.

An empirical study including 149 participants, consisting mostly of young, Finnish university students, will be conducted, in which the respondents evaluate three European festival websites by 28 different user experience aspects per each website. A partial least squares structural equation modeling (PLS-SEM) will be used as a statistical methodology in order to discover the structural relations between usability subcharacteristics (Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability) and Satisfying User Experience in HCI.

Keywords HCI, user experience, usability, user interface aesthetics, ISO, PLS-SEM

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Aalto University, P.O. BOX 11000, 00076 AALTO
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Tiivistelmä

Tämän tutkimuksen tarkoituksena on tutkia käyttöliittymän estetiikan, käytettävyyden ja käyttökokemuksen välisiä suhteita ihmisen ja tietokoneen välisessä vuorovaikutuksessa. Tämän tutkimuksen tavoitteena on löytää tärkeimmät tekijät, jotka osallistuvat tyydyttävän käyttökokemuksen luontiin käyttäjän näkökulmasta.

Tämän tutkimuksen puitteissa esitämme uudenlaisen käyttökokemusmallin, joka yhdistää havaitun käytettävyyden sekä sen alakonstruktiot havaittuun käyttökokemukseen, ja sen aiheuttamiin tunneperäisiin reaktioihin. Internatinal Standardization Organizationin (ISO:n) ISO/IEC 25010:2011 standardia käytetään viitekehyksenä rakennetussa käyttökokemusmallissa, joka yhdistää piirteitä liittyen sekä tuotteen laatuun että käyttötilanteen laatuun.

Empiirinen tutkimus, johon osallistui 149 henkilöä, joista suurin osa oli nuoria suomalaisia yliopisto-opiskelijoita, suoritettiin tämän tutkimuksen puitteissa. Empiirisessä osuudessa osallistujat arvioivat kolmen eurooppalaisen festivaalin verkkosivustoja 28:n eri käyttökokemuspiirteen avulla. Tilastollisena menetelmänä käytetään osittaisen pienimmän neliösumman (PLS) rakenneyhtälömallinnusta (SEM), jolla pyritään selvittämään käytettävyyden alakonstruktioiden (soveltuvuuden tunnistus, käyttöliittymän estetiikka, opittavuus ja hallinta) sekä tyydyttävän käyttökokemuksen välisiä suhteita ihmisen ja tietokoneen välisessä vuorovaikutuksessa.

Avainsanat HCI, käyttökokemus, käytettävyys, käyttöliittymän estetiikka, ISO, PLS-SEM

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LIST OF ABBREVIATIONS

AVE	average variance extracted
CB-SEM	covariance based structural equation modeling
HCI	human-computer interaction
IEC	International Electrotechnical Commission
IoT	internet of things
ISO	International Standardization Organization
PC	personal computer
PLS-SEM	partial least squares structural equation modeling
SEM	structural equation modeling
SQuaRE	Software Quality Requirements and Evaluation
VIF	variance inflation factor

1 INTRODUCTION

1.1 Emergence of experience in human-computer interaction

A lot has changed in the field of human-computer interaction (HCI) during the past decades. Much of this is due to the rapid development of information technology. Today, information technology is accessible for nearly everyone, everywhere. One could say that today's societies and individuals highly depend on information services and technology.

Most of us must regularly interact with different interfaces throughout the day in order to carry out our everyday tasks. In the end of 2015, 46.4% of the total world population (~7.3 billion people) were internet users, with percentages substantially above average especially in North-America (87.9%), Europe (73.5%) and Oceania/Australia (73.2%) (Miniwatts Marketing Group, 2015). What is even more striking, is the fact that internet usage has grown by 832.5% between the years 2000 and 2015 (Miniwatts Marketing Group, 2015).

The accessibility of internet is rapidly expanding from traditional personal computers (PCs) to smartphones, tablets and everyday objects that are connected to a network, also known as Internet of Things (IoT) (Xia, et al., 2012). The number of worldwide smartphone owners is expected to grow from today's 2.6 billion to 6.1 billion by 2020 (Lunden, 2015). The 2020 prediction accounts roughly for 70% of world's population. That added to the fact that people today value experience over matter in general (Hassenzahl, 2014), it is no wonder that the concept user experience has gained growing recognition both amongst researchers and practitioners. Businesses are starting to recognize the value of experience as an end product itself, rather than just a marketing strategy for selling tangible products (Hassenzahl, 2014).

As the concept of what we call an interface becomes ever more complex, designers have to be able to solve holistic problems related to experience design. This requires a much more profound understanding from the designer than just the ability to follow a list of guidelines and best practices. Today's designers must be able to not only look at the interface being designed, but to step inside the mind of the user and understand the multifaceted contexts of use.

The concept of user experience rather than usability, and user experience design rather than user interface design have slowly started to dominate on the HCI community. Still, there is a lot to be done in order to truly change the researchers' and practitioners' full focus from the system to the user in order to create truly satisfying and helpful systems for the users. Since the use of technical interfaces will continue to grow tremendously in the future, it is ever more important that we strive to uncover the essence of superior user experience, and that is where also this study is aiming to succeed in.

Since technology use has become a commodity in nearly all civilizations, information service providers need to be able to differentiate themselves and engage users in new ways. Evidence has been found that aesthetical design of information systems increases the pleasure and engagement that the user experiences (Thüring & Mahlke, 2007). Engaged and satisfied customers are far more likely to stay loyal and come back again and again to use the service (Hassenzahl, 2014). In an optimal situation, users can feel that the interaction with a system improves the quality of their life by satisfying their basic human needs and provoking pleasant emotions. The aesthetical aspects of interactive systems play a major role in bringing forth these emotions (Tractinsky, 2014).

As the meaning of experience grows in the design field, so does the role of aesthetical aspects. These include not only visual aesthetics, but also the aesthetics of touch, smell and taste – the overall aesthetical experience. Still in the early 1990s, the idea of aesthetics as a vital part of HCI studies sounded outrageous to many, but in a few decades the views have changed. Today, beauty and aesthetics are one of the most studied dimensions of information systems alongside with emotions and enjoyment (Bargas-Avila & Hornbaek, 2011).

Experiments with computational art generation date back to as far as the 1960s (Nake, 2005), but systematic research on the visual aesthetics of interactive information systems began only in the mid-1990s (Kurosu & Kashimura, 1995; Tractinsky, 1997). Since then, the trend has been steadily moving towards a focus on the hedonic aspects of information systems, in which aesthetics plays a major role (Hassenzahl & Tractinsky, 2006).

Today, the interactivity of information systems is emphasized even more than it was in the beginning of the commoditization of internet use. In the beginning of the internet era in the 1990s, web pages resembled books or newspaper pages. They focused merely on providing information through text-intensive pages, that maybe served their purpose in providing the wanted information, but could hardly be considered as intuitive, exciting, delightful or pleasurable.

The World Wide Web was highly directed for technical experts, which was apparent in both the navigation pattern design, the website structure and the use of technically-oriented language. Visual aesthetics were paid little to no attention in the early HCI community. In fact, some experts thought that aesthetically rich information systems could disturb the user and prevent him/her from completing the tasks efficiently and effectively (Norman, 1988; Nielsen, 1993). Focus on aesthetics was generally considered as totally irrelevant in the design process of effective information systems.

The rise of the computer era came from a highly mathematical and quantitatively oriented community, that couldn't realize the complexity of the human even if they very well understood the complexity of computers and information systems (Cockton, 2014). At the time, even the contemporary meaning of the term usability was rarely the focus of the information system development process (Butler, 1996). The highly intrinsic and technical outlook on usability was partly to blame on the programmers and other information technology experts, who had a highly mathematical and technical approach to information system design. They were not trained to understand the actual human in human-computer interaction (Cockton, 2014).

If and when usability was considered, it focused merely on the intrinsic system attributes like effectiveness and efficiency, that could be precisely measured and quantified (Butler, 1996). Usability measures focused on things like task completion time, amount of clicks and amount of system errors (Dickson, et al., 1977). Still, these early quantitative and system-oriented usability studies were very valuable for the evolution of usability and user experience in the field of HCI. These studies formed the basis for the recognition that the field needed to put users in the center of focus (Cockton, 2014).

The HCI community was the first to introduce the concept of usability to the classically only mathematical and technical computing industry (Card, et al., 1983). The emergence of HCI studies dates back to the late 80s. In early 90s, came the first leap towards trying to understand the complex relationship between humans and computers (Kuutti, 1995). Slowly but surely the field started to shift from system-oriented to human-oriented approaches. Researchers started to understand that the design of effective information systems required a profound understanding of how the human brain works, and how we process information that is received mainly in the form of visual stimuli. Users were started to be seen not merely as passive information-receivers or robotic task-completers, but as active and complex entities that had human needs, limitations and emotions, which significantly affect interaction between humans and computers.

Today, HCI research has moved onwards from the partly outdated and limited concept of usability. Currently both researchers and practitioners rather speak about user experience, of which usability is still a vital part of. User experience is broadly seen as an umbrella term that covers concepts from usability to emotional responses (Hassenzahl, 2014). The visual representation of information and cognitive processes triggered by visual aesthetics are an important part of creating the overall user experience (Tractinsky, 2014). On the other hand, visual aesthetics is always tightly intertwined to all the other aspects of the system. Visual aesthetics goes hand in hand with things such as efficiency (Quinn & Tran, 2010; Sonderegger & Sauer, 2010) and the transmission of information (Hekkert, 2006). Visual aids help us to process information more efficiently and meaningfully (Sonderegger & Sauer, 2010) and in the optimal situation they make the interaction more satisfying, fun and enjoyable (Tractinsky, 2014).

This is why contemporary visual design of information systems cannot operate in a void, but on the contrary must converse closely with fields such as user interface design and user experience design. Even programming, especially front-end information system development, must be understood by visual designers at least on the theoretical level. The holistic understanding helps us to create truly helpful and meaningful systems, that help us both in executing obnoxious tasks, and on the other hand, also in providing joyful and enjoyable experiences. These experiences fulfill our basic human needs, act as an extension of our personal identity and facilitate us on tasks that are important to us as human beings, such as connecting to other people through social media, texting, calling or entertaining ourselves by for example games, movies or music. Technology should not be an end in itself, but rather a medium for doing the things we need and want to do as easily and effortlessly as possible.

In our decade, information systems no longer have any excuse to be highly unusable, to crash, or to have serious errors. These things only stress and irritate the user, and prevent him/her from succeeding in the interaction with the system. Still, all of us encounter numerous situations, in which we encounter severe stress and frustration because the system simply will not operate in the way we would need it to. This alone is a sufficient reason for researchers and practitioners to really put the user in its righteous place in the center of the design process, and really start focusing on producing satisfying experiences, that incorporate both the user and the system, and the interaction between the two.

1.2 Research question and empirical approach

Researchers, practitioners and international organizations are working hard to increasingly understand user experience and to come up with findings that will be useful for future researchers and designers in the ever-changing industry of user experience design. This research will use these valuable findings and in its part continue on the quest of trying to find an answer to the question in many researchers' and designers':

What user experience is in its essence and what are the key factors contributing to a satisfying user experience from the user's perspective?

The existing literature will act as a basis for the foundation of the model used in this study, which will be used in the empirical study, carried out as a part of this research. This study will use the web environment of PCs as a context of the empirical study. PC web environment was chosen firstly because it still is one of the most prevalent environments where people spend their time online, and secondly because it is an environment where we were able to gather the most reliable data regarding the scope and resources for this study.

The example cases used in this study were chosen with the probable group of respondents in mind. We wanted to pick web services where the group of respondents would be a realistic target group of the website. We also wanted the websites to be services that consciously bring forth the experiential aspects of both the web service itself and the end product they are trying to promote. This is why international music/art/culture festival websites were chosen as the case study of this research. The festivals were chosen so that they were presumed to be unknown for the respondent beforehand in order to avoid problems with already-established attitudes and opinions towards the festival at hand.

Structural equation modeling, or more specifically partial least squares structural equation modeling (PLS-SEM) was used as a method for approaching the problem at hand. Structural equation modeling was chosen because of it is one of the most prominent statistical analysis techniques today (Hair, et al., 2013). PLS-SEM has lately become a key research method to the side of the traditionally more popular covariance based structural equation modeling (CB-SEM). Regarding this study, PLS-SEM has many methodological advantages that make it a more viable option compared to its more traditional counterpart. These advantages include aspects related to sample size, the distribution of data and the complexity of the model.

1.3 Scope of the study

On a broad level, the purpose of this study is to continue the research of the complex relation of humans and computers in interactive information systems. More specifically, we will examine which factors in particular contribute to a satisfying user experience, and what are the relational importances of these factors. Empirically, we will study how the subcharacteristics of Usability[1] contribute to the formation of a Satisfying User Experience[2], and the emotional responses it evokes in the user.

Certain terms, such Usability and Satisfying User Experience, will be written with capital letters in this study. The capital letters indicate the use of the specific term defined in the context of this particular study, with a certain defined scope and meaning. This style is used for the sake of clarity, since the used terms are abstract in their nature, and exact definitions can vary substantially between different scholars.

The empirically studied subcharacteristics of Usability will be User Interface Aesthetics[3], Appropriateness Recognizability[4], Learnability[5] and Operability[6]. Similarly, the studied emotional responses of Satisfying User Experience will be Trust[7], Pleasure[8], Comfort[9] and Usefulness[10]. The subcharacteristics of both Usability and Satisfaction have been derived from a standard made by the International Standardization Organization (ISO). More specifically, we are focusing on the ISO/International Electrotechnical Commission (IEC) 25010:2011 standard of Systems and Software Quality Requirements and Evaluation (SQuaRE). The final model is a reduced and combined model of the complete SQuaRE model, including aspects related to both Product Qualities and context-dependent Quality-in-Use factors.

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[1] Degree to which a product or system can be used by specified users to achieve specified goals with Effectiveness, Efficiency, and Satisfaction in specified context of use.

[2] Degree to which user needs are satisfied when a product or system is used in a specific context of use.

[3] Degree to which a user interface enables pleasing and satisfying interaction for the user.

[4] Degree to which users can recognize whether a product or system is appropriate for their needs.

[5] Degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with Effectiveness, Efficiency, Freedom from Risk and Satisfaction in a specified context of use.

[6] Degree to which a product or system has attributes that make it easy to operate and control.

[7] Degree to which a user or other stakeholder has confidence that a product or system will behave as intended.

[8] Degree to which a user obtains pleasure from fulfilling their personal needs.

[9] Degree to which the user is satisfied with physical comfort.

[10] Degree to which a user is satisfied with their perceived achievement of pragmatic goals, including the results of use and the consequences of use.

The Product Quality stands exclusively for "just a software product, or to a computer system that includes software" (ISO, 2011). Quality-in-Use stands for the "impact that the product (system or software product) has on stakeholders", that is being determined by "the quality of the software, hardware and operating environment, and the characteristics of the users, tasks and social environment" (ISO, 2011). As clarified in the ISO/IEC 25010:2011 standard: "The Product Quality model focuses on the target computer system that includes the target software product, and the Quality-in-Use model focuses on the whole human-computer system that includes the target computer system and target software product." The selections will be further discussed and justified in section 2.4 "ISO standards".

As mentioned above, this study will examine the relational importances of the different subcharacteristics, with a particular emphasis in the role of User Interface Aesthetics. User Interface Aesthetics was chosen a subcharacteristic of interest due to the historical negligence of the subject and the increasing acknowledgement of its importance in HCI. Recently, the importance of visual aesthetics on the formation of human emotional responses in HCI has been widely studied and accepted (Hassenzahl, 2014; Tractinsky, 2014).

1.4 Purpose of the study

This study will hopefully aid researchers and practitioners in shifting their focus closer to the user and the creation of meaningful experiences through HCI. This seemingly small shift in thinking makes a huge impact on how information systems are being designed and developed.

The nowadays common and almost self-evident design philosophy of user-centered design unfortunately rarely actualizes in practice. We still regularly have to interact with highly unusable systems that are far from being user-friendly. Sadly enough, we tend to encounter the severest usability and user experience problems in the vitally important industries like public health, transportation, governmental organizations and large-scale business management products. The shift towards user-centered thinking will also have a positive effect on the benefits we gain from utilizing technologies, with limitless positive implications.

The academic world can in its part enlighten the designers of our generation on how to make interactive experiences as satisfying as possible by providing up-to-date information on the best design theories. The academic findings of user experience become ever more important as technology becomes more and more prominent in our lives and the amount of interfaces around us increase.

In addition to striving to find out what makes a Satisfying User Experience, this study will also aim to further strengthen the position of User Interface Aesthetics in HCI. This study will aim to proof that users value User Interface Aesthetics as a central information system characteristic and see it as an important contributor to the creation of a Satisfying User Experience. Paying attention to the visual design of information systems is much more than just making things look pretty, it is about improving the quality of everyday life.

I hope that the results of this study will both practically help designers in their work by providing information on the most important aspects in the design process and also providing fresh insights of user experience for all stakeholders in the information systems development industry. I also hope that this study will bring its share to the user-centered design evolution in HCI research and provide new insights for the other academic world as well.

1.5 Structure of the study

This study will be divided into five sections, including this one (section 1 “Introduction”). This study will first look into the theoretical background of usability, user experience and aesthetics, and on the international standards defining them (section 2 “Theoretical background”). All of the four concepts will be presented in their own chapters, and they will aim to explain the concepts on both on a deeply conceptual, even philosophical level and also in a more practical and applicable manner. The brief historical overviews will form a solid ground on understanding the role of these concepts in today’s vocabulary.

The next section will present the methodology used in the empirical part of this research. The empirical model used in this study to answer the original research question will also be presented and justified. In this section we will describe how the final questionnaire data was collected, who were the questionnaire participants and what were the case websites (section 3 “Methodology and the empirical study”).

The fourth section will present a thorough analysis of the collected data and the results derived from the constructed model using the SmartPLS software (section 4 “Data analysis and results”). Deficiencies of the model in the context of the PLS-SEM method will also be discussed, and possible remedies presented if a similar study would be conducted in the future.

The last section will draw together the whole study, reflecting on the empirical results and presenting final conclusions of the study (section 5 “Reflection and Conclusions”). In this section we will also give suggestions for future research and present possible implications of this study.

2 THEORETICAL BACKGROUND

The theoretical background section will be divided into four sections that present the main concepts used in this study. First we will introduce the existing research behind the concept of usability, how it has evolved over time and where it is heading (section 2.1 “Usability”).

The second section will introduce the concept of user experience, where it comes from, how it affects people (section 2.2 “User experience”). This section will also present views from leading researchers on how user experience should be designed for contemporary users.

The third section will look more closely to the long-neglected aspect of HCI, aesthetics. We will first look more deeply into the more classical and philosophical views of beauty and aesthetics, and gradually move on to explain its role in HCI (section 2.3 “Aesthetics”).

The fourth section will open up the key framework used in this study. This section will show where the current understanding of usability, user experience and user interface aesthetics stems from in the context of international standards (section 2.4 “ISO standards”).

2.1 Usability

The usability section will begin from presenting different outlooks on usability and how they have evolved over time (section 2.1.1 “What is usability?”). After this we will present how the academic has slowly moved from usability to user experience, seeing usability only as one small part of the overall, context-dependent user experience (section 2.1.2 “From usability to user experience”).

2.1.1 What is usability?

”Put simply, usability evaluation assesses the extent to which an interactive system is easy and pleasant to use” (Cockton, 2014). The concept of usability has come a long way to incorporate a characteristic such as “pleasant” in its definition. Traditionally, usability has focused strongly on the harder, more technical side of efficiency and effectiveness (Butler, 1996).

In the 1980s, usability was generally seen as an inherent property of an interactive system that could be promptly measured and quantified (Dickson, et al., 1977; Butler, 1996). This partly due to the strong influence of mathematicians especially in the earlier ages of HCI studies

(Cockton, 2014). If the system matched to technical criteria and passed the quantifiable tests of usability, systems could be undeniably named usable without actually asking the users' opinion, even when the system hardly could be described with a word such as pleasant.

Usability guidelines

The practice of usability testing begun with creating technical guidelines that should be followed when designing an interactive information system. The early usability guidelines that were developed included recommendations for example regarding naming, ordering and grouping of menu options, prompting for input types, input formats and value ranges for data entry fields, error message structures, response times and undoing capabilities (Smith & Mosier, 1986).

One example of a comprehensive collection of design guidelines was Smith and Mosier's (1986) collection of over 300 pages made originally for the US Air Force containing 944 different usability guidelines. It probably never was, and never will be, cost-efficient for designers to develop systems by going through almost a thousand guidelines, but still, the emergence of these guidelines did bring the concept of usability to a broader awareness for the developers and designers of interactive information systems.

Another example of a similar collection of relatively early usability guides was written by a usability guru Ben Shneiderman (1987). Shneiderman's book, "Designing the User Interface: Strategies for Effective HCI", has been revised and updated four times since its 1st edition in 1987, with the latest and 5th edition published in 2010. The book has been widely used among researchers and practitioners and has been translated Japanese, Chinese, German, Portuguese and Greek. In his book, he for an example introduced the widely acknowledged "Eight golden rules of interface design" (Shneiderman, 1987), which still today is widely taught in universities and other institutions. The original eight rules are presented in Table 1.

Table 1: Shneiderman's (1987) Eight Golden Rules of Interface Design

The Eight Golden Rules of Interface Design
1. Strive for consistency. 2. Cater to universal usability. 3. Offer informative feedback. 4. Design dialogs to yield closure. 5. Prevent errors. 6. Permit easy reversal of actions. 7. Support internal locus of control. 8. Reduce short-term memory load.

Shneiderman was also a part of the early movement of incorporating human factors in computer software design. He is the author of the widely known book "Software Psychology: Human Factors in Computer and Information Systems" (Shneiderman, 1980), which has been a major influence to usability studies.

Another popular collection of design heuristics was written by another usability guru Jakob Nielsen (1994) in his book "Heuristic evaluation". These heuristics inspect software features for potential causes of poor usability, and are partly very similar to those written by Shneiderman in 1987. See Table 2 for Nielsen's (1994) 10 usability heuristics.

Table 2: Nielsen's (1994) 10 Usability Heuristics for User Interface Design

10 Usability Heuristics for User Interface Design
1. Visibility of system status. 2. Match between system and the real world. 3. User control and freedom. 4. Consistency and standards. 5. Error prevention. 6. Recognition rather than recall. 7. Flexibility and Efficiency of use. 8. Aesthetic and minimalist design. 9. Help users recognize, diagnose and recover from errors. 10. Help and documentation.

Nielsen is one of the most influential researchers on the field of usability and has introduced concepts such as "discount usability engineering", which was a movement for fast and cheap improvements in user interfaces (Nielsen, 1989). Discount usability's three main components were simplified user testing, narrowed-down prototypes and heuristic evaluation (Nielsen, 1989). Nielsen is also the researcher behind the five attributes named by him as "usability goals": learnability, efficiency, memorability, errors and satisfaction (Nielsen, 1993). Many of these concepts are still today regarded as vital for usability, and also user experience (e.g. ISO, 2011).

There is almost an endless amount of design guidelines and heuristics made for designers to help them in their work, but the heuristics of Shneiderman (1987) and Nielsen (1994) are probably the two most widely known and used. Compared to Smith and Mosier’s (1986) extensive 944-guideline collection, the heuristics developed by Shneiderman (1987) and Nielsen (1994) are far more easily approachable and usable, even if more abstract and not as practical as the very detailed instructions of Smith and Mosier (1986) that leave little room for contextual considerations. The shorter lists of 8-10 elements help designers focus on the core high-level concepts in usability evaluation, while following detailed instructions the user and the deeper purpose of the system easily get lost.

The International Standardization Organization (ISO) has also been a major authority in defining usability. The standards can be seen as guidelines of their own, and since they incorporate the work of a big group of key researchers in each field, they can be seen as highly trustworthy. ISO defines Usability in the context of HCI as the “degree to which a product or system can be used by specified users to achieve specified goals with Effectiveness, Efficiency, and Satisfaction in specified context of use” (ISO, 2011). The role of ISO and its contribution to usability definitions will be presented in more detail in section 2.4 “The ISO standards”, since it pulls together aspects related to not only usability, but also user experience, user interface aesthetics and their relations to one another.

Essentialist and contextual views of usability

Usability is often divided into two main scholars: essentialist and contextual views of usability. The essentialist scholar sees usability as an intrinsic feature of the product, whereas the contextual scholar sees usability as a result of the interaction between the user, the product and the context of use (Cockton, 2014).

In the world of software engineering and its standardizations, the essentialist view has always dominated the contextual view of usability (Cockton, 2014). Also in the HCI community, the contextual view has been dominant for decades (Cockton, 2014). Even if the importance and meaning of context is these days widely acknowledged and understood in usability studies, the software still usually always gets all the blame for poor usability (Cockton, 2014).

It is still thought, that only the hardware of software should be changed in order to improve usability. This mindset might also overly emphasizes the software engineers' position in for an example the international standard ISO/IEC 25010:2011 (Cockton, 2014). The intrinsically focused view somewhat contradicts with the well-known fact that usability depends both on the software and on the context, and that the design and evaluation process also need the expertise of human factor specialists in addition to pure engineers.

The focus in only software, when either user, context or product-related problems arise, may be explained by the fact, that software attributes are by default easier to fix than the complex, contextual and multidimensional problems, that are related to the user or the context-of-use. Even if user-related or context-related problems are recognized and fixed, it may feel frustrating for the developers, since the same solutions are hardly ever replicable with different users and different contexts. Thus similar, but still unique, problems must be overcome again and again with the same amount of effort, since problems related to the user and the context of use are always unique and complex. This in no way decreases the value of this work, since we are moving towards a world of accurately targeted and highly personalized use of technologies, where there are, and never will be, no one-size-fits-all solutions.

It is hard, in fact nearly impossible, to change the users of the software, the tasks they must accomplish or the contexts in which they use the software – nor should they be changed. Software products exist to help people accomplish their tasks and go on about their lives as easily and pleasantly as possible. The software should not be the one telling the user what he/she should do with it, but rather it should only act as a medium to ease the user's life or bring the user pleasure as such.

The dilemma between the engineering world and "real" world was already notified in Nielsen's (1994) 2nd design heuristic "the match between the system and the real world". The heuristic was further explained: "The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order" (Nielsen, 1994). Unfortunately, we still encounter numerous systems that do not meet this criterion, which shows that there is still a lot of work to do to improve today's design practices.

Cost-benefit thinking

One way of understanding good and/or bad usability is to think about it as a sum of costs and benefits incurred to the user. In this view, usability is seen as the combination of the benefits that users are able to achieve with the technology, and the costs that occur when realizing these benefits (Cockton, 2014). As Cockton (2014) aptly phrased: "The extent of usability, and its causes such as settings, is a matter of interpretation based on judgements of the value achieved and the costs incurred."

Usability should always be evaluated by both the intrinsic system attributes and the context-dependent attributes in order to gain a holistic view of the experienced usability of a system. Usability should thus be seen only as a part of the total user experience; a concept that is these days a much more often used term compared to usability in the HCI studies.

Seeing usability as a matter of perception allows researchers to approach it as a part of evaluating user experience. Perceptions will always be subjective to some extent, which will surely make the problems more complex and difficult, but which on the other hand is a far less of a problem compared to the traditional, and in many ways problematic, view that we have a "generic universal objective criteria for the existence or extent of usability in any interactive system" (Cockton, 2014).

The technical usability errors and deficiencies in early information systems' were the things that first drew the attention of the HCI community to usability. Now, the problem is that the point of focus has been merely on the poor aspects of usability, and other aspects that make the system bad. Unfortunately, it seems that good usability on the contrary rarely donates any additional value beyond the original intentions of the system designers (Cockton, 2014). Good usability usually remains unnoticed for the user, but bad usability on the contrary causes noticeable distress on the user. On the other hand, this is in no way a bad thing since good usability does not exist in order to get praised by the users; when usability is unnoticed, it has already delivered its value since users can then focus only on the core purpose of the system.

Still, if the focus of information system designers is only on bad usability, it will only be the defects that get fixed, nothing more. Like Cockton (2014) said, "usability evaluation methods are focused on finding problems, not on finding successes". Today's usability experts should broaden their vision beyond the defects, and open their eyes to the aspects that make usability good. That is where the incurred costs and achieved benefits become a vitally important tool for the overall evaluation of a system. After the interaction experience, users weigh whether the achieved resulting benefits justify the expended costs (Cockton, 2014). In other words, they ask themselves was the interaction worthwhile (Cockton, 2014). Worth weighs both the positives and the negatives of interaction instead of focusing merely on the poor aspects of usability, contrary to what the classical studies have done.

Cockton (2014) described usability in the context of cost-benefit thinking as the following: "Usability is the extent of impact of negative user experiences and negative outcomes on the achievable worth of an interactive system. A usable system does not degrade or destroy achievable worth through excessive or unbearable usage costs". This again combines usability as a part of user experience. Here usability is seen as a thing that can reduce gained value through adverse usage costs, but can only add to achieved worth through the iterative removal of usability problems.

The important notion is that usability improvements reduce usage costs, but they cannot increase the value of usage experiences or outcomes (Cockton, 2014). This is a similar approach to psychologist Frederick Herzberg's two-factor theory and concepts of *hygiene* and *motivator factors* (Herzberg, 1966). Like usability, the negative hygiene factors could significantly decrease motivation, but do not really motivate for example employees to do their work better, whereas the positive motivator factors, like positive interaction experiences, result in a greater satisfaction and thus better results in work (Herzberg, 1966).

2.1.2 From usability to user experience

It is well known that emotion is vital to the interpretation of an experience (Cyr, 2014). Still, only recently research has shifted its focus from usability to user experience, and from pragmatic[11] to the more hedonic[12] aspects (e.g. color, images, shapes, and use of photographs) of interaction design. These days it is not enough that the system is easy to use and has good usability. These days, users seek to experience emotions like enjoyment, involvement, trust and satisfaction more than ever before (Cyr, 2014).

Studies regarding users' emotional reactions to technology have become common only in the last decade, even though the importance of emotional reactions in human psyche have been long known in the field of psychology (e.g. Carver, et al., 1989; Russell, 2003). Like Hassenzahl (2006) said, usability as the mere definition of software quality is very limited, since it neglects additional hedonic human needs and related phenomena, such as emotion, affect and experience.

Emotion, usability and user experience

After the turn of the century, many studies have been conducted considering the emotional outcomes in the web environment. Some examples of hedonic outcomes that have been studied are flow (Huang, 2006), cognitive absorption (Wakefield & Whitten, 2006), involvement (Fortin & Dholakia, 2005), playfulness, (Wakefield & Whitten, 2006), enjoyment (Venkatesh, 2000), hedonic outcomes (Venkatesh & Brown, 2001), happiness (Beaudry & Pinsonneault, 2010), fun (Dabholkar & Bagozzi, 2002) and stimulation (Fiore, et al., 2005).

People react to situations with emotions if they are relevant to one's needs, goals and/or concerns (Cyr, 2014). Once emotions are evoked, they generate subjective reactions such as anger or joy, generate motivational states with action tendencies, arouse the body with energy-mobilizing responses that prepare it for adapting to whatever situation one faces, and express the quality and intensity of emotionality outwardly and socially to others (Damasio, 2001). Emotional responses are triggered by an ability to engage the user in an online environment

[11] Related to users' need to achieve behavioral goals effectively and efficiently.
[12] Related to users' own self, more specifically stimulation (i.e. novelty and challenge) and identification (i.e. personal values).

which is aesthetically pleasing, which ties it closely to the fields of visual design and interaction design (Cyr, 2014).

Emotional states have both negative (e.g. anger, guilt, sadness, fear/anxiety, disgust, and shame) and positive (e.g. joy, happiness, satisfaction, trust) valence (Cyr, 2014). In addition to valence, emotional responses includes the feeling of arousal. Arousal refers to the intensity of the emotional response, whereas valence refers to the direct positive or negative response (Deng & Poole, 2010).

Users respond emotionally to specific web design elements (Cyr, 2014). An example of this is when the user gets the feeling of satisfaction from appealing colors or an enjoyable and exciting graphical design. It is also important that the website matches the needs and special sensibilities of the user (i.e. taste), which is manifested as different website designs directed for different groups of users. Tastes can differ for an example by gender (Moss, et al., 2006), nationality (Cyr, et al., 2009) and culture (Cyr, et al., 2010).

If the website matches one’s sensibilities and needs, this increases the user’s loyalty and the probability of him/her returning to the site (Jiang & Benbasat, 2007; Cyr, 2014). Design aesthetics have found to affect online customer loyalty and result in feelings of enjoyment also in the mobile environment (Cyr, et al., 2006). It has been argued, that emotions may even more important in the web environment since people are drawn out from other emotional human interaction (Lam & Lim, 2004).

Emotional responses have been measured by for example responses to design elements such as shapes, texture and color (Kim, et al., 2003) or the visual characteristics of web pages (Lindgraad, et al., 2006). Other studied topics include for an example hedonic quality, aesthetic performance (atmospheric ques, media richness and social presence), presentation richness (e.g. symbol variety), interaction richness, human images, color and vividness (Cyr, 2014). Social elements such as pictures of people or emotive text effects users’ feelings of enjoyment (Cyr, et al., 2006).

Different contextual settings have an effect on how users evaluate websites. Deng and Poole (2010) found that the extent to which users seek stimulation from the website influences user’s impressions. Stimulation also refers to the hedonic system attributes introduced by Hassenzahl (2004). Also the preceding level of focus/relaxation has been found to an effect on whether the website is perceived as pleasant or not (Schenkman & Jönsson, 2000).

Enjoyment has been one of the most measured hedonic aspect of webpages (Cyr, 2014). Enjoyment has been argued to include subcharacteristics such as engagement, positive affect, fulfillment, flow and play (Cyr, 2014). In the environment of web commerce, enjoyment has been revealed to be a strong predictor of the customers' attitude (Cyr, et al., 2006). Characteristics such as website vividness and interaction of consumer product displays have resulted in loyalty and enjoyment (Jiang & Benbasat, 2007).

2.2 User experience

Now that we have formed an idea of what usability is, how it has transformed over time and how it has evolved to be a subcharacteristic of user experience, we will look deeper into the more high-level understanding of an experience, what it means to us as users, and how we process experiences as human beings (section 2.2.1 “What is user experience?”). In the second section of this chapter we will present several key aspects that should be kept in mind when designing user experience for today’s users (section 2.2.2 “Designing the user experience”).

2.2.1 What is user experience?

“User experience is not about technology, industrial design, or interfaces. It is about creating a meaningful experience through a device” (Hassenzahl, 2014). An experience is an overwhelmingly complex and multi-faceted concept that is very hard to define exhaustively. In the context of interactive information systems, it is of our interest to study meaningful, personally encountered experiences that are memorized stories of use and consumption, and that are distinct from the moment-by-moment experience (Forlizzi & Battarbee, 2004), since these are the ones that will be remembered and transformed in time in the users’ minds. This is why in HCI we are more interested in the memorized experiences rather than immediate reactions, since we use most of our time on memorizing things that have happened in the past or on anticipating what is to come (Hassenzahl, 2014).

Memorizing experiences

The creation of a memory (i.e. an experience) from the moment-by-moment perceptions is a complex process. A memory is never ready since our memories evolve all the time. Like van Boven (2005) said: “As one forgets the incidental annoyances and distractions that detract from the online, momentary enjoyment of an experience, one’s memory of an experience can be sharpened, leveled, and ‘spun’ so that the experience seems better in retrospect than it actually was.”

The phenomenon of altering memories is common for us all: life events from the past usually become better in our memories and the human psychology tenderly lets us forget the more unpleasant but irrelevant details of an otherwise great event. People both consciously and unconsciously control unwanted memories in their brains by stopping memory retrieval, which is partly related to identity-development and self-acceptance (Anderson & Levy, 2009).

If we experience something predominantly negative, it tends to have a greater effect on our psychological state compared to a positive event of equal intensity (Baumeister, et al., 2001). It has been found out that negative experiences have a greater impact on us than the positive ones, and negative impressions and negative stereotypes form quicker, and stick to our minds stronger than positive ones (Baumeister, et al., 2001). If, for an example, we have encounter a very negative experience with an interactive system, we are very likely to form a bad impression of the service that is harder to change afterwards compared to a positive impact of same intensity that could be more easily damaged with a negative experience.

Psychological understanding of an experience

Psychologically, an experience emerges from the integration of perception, action, motivation, and cognition into an inseparable, meaningful whole (Hassenzahl, 2014). Actions and emotions are closely linked together, as found out also in the so-called action theories (Carver, et al., 1989). Emotions are strongly linked to the need of fulfilling universal psychological needs, such as pleasure or satisfaction (Maslow, 1954). People are also for an example more willing to buy items worn by their favorite celebrities, possibly unintentionally fulfilling their psychological need for acceptance, relatedness and belonging to a personally valued reference group (Hassenzahl, 2003).

Although complex, emotions can be roughly divided on a pleasure-pain axis that provides a “yardstick on which qualitatively different possibilities can be compared” (Russell, 2003). Positive experiences make us happy and satisfy our psychological needs in many levels (Maslow, 1954). The feelings of autonomy, competence and relatedness are one of the key needs that result in forming a psychologically satisfying event (Sheldon, et al., 2001). Similarly, Hassenzahl and colleagues (2010) found out that positive experiences with technology are related to the feelings of relatedness, competence, stimulation and popularity (Hassenzahl, 2010).

The role of technology and hardware in experience

The important thing to grasp in the formation of great user experiences is usually the mediating nature of technology in forming a pleasurable and satisfying experience (Hassenzahl, 2014). Technology is usually there for us to aid us in fulfilling our universal psychological needs or to accomplish necessary tasks. For an example, an affectionate text message or a phone call from our loved one is definitely a positive experience, but probably not because the phone line was working so well or because the texting app was so great that it made us feel pleasure and satisfaction. In this case, the technology itself acts more as a hygiene factor (Herzberg, 1966), than the source of pleasure itself. On the other hand, a broken network in the midst of a passionate phone call or a texting session could make us very upset.

Even when looking for a purely experiential event, people need materialistic possessions like a phone or a computer to create those experiences (Hassenzahl, 2014). The constant development of new technologies will always continue to be important, but for experience designers, technologies are only the raw materials for experience design, just like paints, brushes and canvases act as raw materials for an artist. For an experience designer, it is far more important to understand the underlying human needs than understanding the technologies that aid us in satisfying those needs.

Pragmatic and hedonic attributes

As already mentioned in the theoretical background of usability, user experience can be approached as a combination of *pragmatic* and *hedonic* attributes (Hassenzahl, 2004). In this view, products and systems are seen as a combination of their *attributes* and *characters*. Product attributes refer to the combination of features such as the presentation, content, functionality and interaction. The attributes of products, systems and services can be divided into hedonic and pragmatic attributes based on their nature and goals. Product characters are bundles of attributes, by which products can be described as for an example innovative, comprehensible, professional and enjoyable and so on. The hedonic and pragmatic attributes describe product characters. (Hassenzahl, 2004)

Pragmatic attributes are connected to users' need to achieve behavioral goals effectively and efficiently. Goal achievement requires utility and usability from the product. Thus, products that are perceived as pragmatic are perceived to have high utility and usability attributes. Consequently, usability is a part of product's pragmatic attributes. (Hassenzahl, 2004)

Hedonic attributes, on the other hand, are related to the user's own self. Hedonic qualities can be further divided into stimulation and identification (Hassenzahl, 2004). Stimulation, novelty and challenge are the basis of human personal development, which is a basic human need (Berlyne & Praham, 1968). People identify themselves by possessing products and reflect the use of products on their own personal identity when assessing the hedonic values of them (Hassenzahl, 2004). Consequently, aesthetics and beauty are a part of product's hedonic attributes.

In short, a product is perceived as pragmatic if it provides effective and efficient ways to achieve behavioral goals and on the other hand, a product is perceived as hedonic if it provides stimulation (novelty and challenge) or identification (personal values). The use of products leads to certain consequences like emotions, evaluations and behavior, like approach or avoidance (Hassenzahl, 2004). Together the pragmatic and hedonic attributes form the overall user experience.

Is it possible – or is there a need – to define user experience?

Due to its complex nature, it is impossible to exhaustively define what user experience is, nor is there really a need for such an exhaustive definition. Experience is always somewhat subjective, since the perception is always true in the mind of the perceiver. If one hates beautiful sceneries, there is little one can do or say to argue that the perceiver is "wrong" or "right".

Similarly as people have different tastes in art, people have differing opinions on what are "good" or "bad" interaction experiences with information systems. The difference is, that visual art for an example exists purely to please our eyes or intrigue our minds, whereas forming a "taste" of good or bad user experience usually involves an interaction process, such as completing a task, finding information or accomplishing something else, that includes more complex ambitions than just pleasing our aesthetical perception.

As clarified before, the evaluation process of an experience is a highly contextually dependent event. A process, which the HCI community has just begun to understand in evaluating user experiences and the resulting consequences. The user-experienced worth that comes from an experience is highly contextual and subjective, and can differ greatly between people even when experiencing same events simultaneously.

Like Reiss (2014) said, "user experience has implications that go far beyond usability, visual design, and physical affordances". Hassenzahl (2014) saw user experience as the process of creating meaningful experiences through a device, whereas user experience practitioner, Eric Reiss described user experience as "the perception left in someone's mind following a series of interactions between people, devices, and events" (Reiss, 2014).

As we have witnessed, the word-to-word definitions of user experience vary greatly among one another, but the essence stays pretty much the same. What seems to be the most important learning from understanding user experience, is the fact that it is a unique, personal, contextually-dependent and emotionally-loaded event that evolves over time.

For practical reasons, we still must define and limit the concept user experience in the context of this study in order to be able to examine the phenomenon empirically. This study will define user experience based on the ISO/IEC 25010:2011 standard that incorporates qualities both from Product Quality and Quality-in-Use of the information system.

In this definition Usability is seen as a part of Product Quality, which in its turn affects Quality-in-Use. User experience is something that happens somewhere in between of Product Quality and Quality-in-Use, since user experience is the point where the product/system (Product Quality) and the human interaction (Quality-in-Use) join together.

2.2.2 Designing user experience

Designing for the post-materialistic user

The leading view on the field of user experience design sees today's users as more driven by experiential, rather than materialistic motivations (Hassenzahl, 2014). It has been shown, that especially in developed societies, that are in a continuous environment of material wealth, people become more interested in values such as self-improvement (Inglehart, 1997).

Studies have shown that people value experiential purchases more than materialistic purchases of the same value (Boven & Gilovich, 2003). Even materialistic purchases gain more value if they come with a good story, such as a history of how the product has been made and by whom, and what is the philosophy behind the design of that particular product (Boven & Gilovich, 2003).

The phenomenon of valuing experience over matter is also related to the famous "hierarchy of needs" (Maslow, 1954), that explains the 5-step hierarchical ladder of human needs from the physiological level to self-actualization, and where one level cannot be reached if the lower level has not been reached (see Figure 1).

In order to develop a post-materialistic society, the environment must provide enough food, clothing and shelter (Maslow, 1954; Inglehart, 1997). Societies, that have these basic physiological needs fulfilled, become so-called *experience societies* where the population sees happiness as an equality to having positive life experiences (Schulze, 2005).

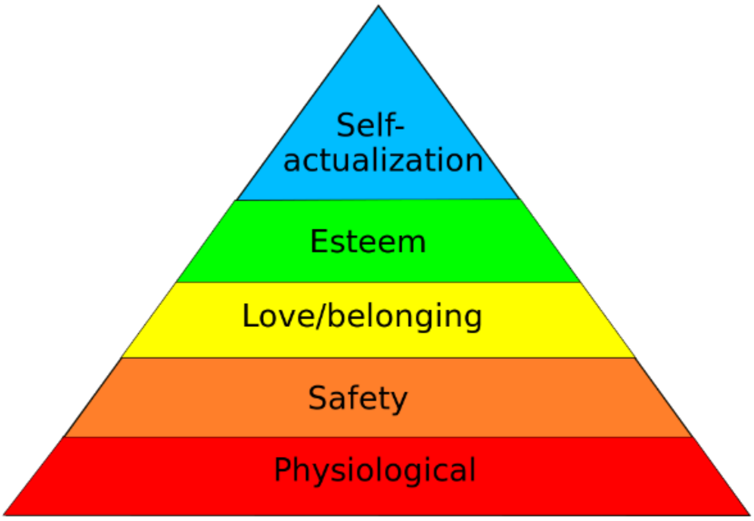

Figure 1. Maslow's (1954) hierarchy of needs.

These kinds of experience societies are also called *post-materialistic* (Hassenzahl, 2014). The earning of money is still valued, but people prefer having a personal engagement to their jobs and work for their passion rather than for money. These experience societies value declaration instead of acceleration, less instead of more, uniqueness instead of standardization, concentration instead of diversion, and making instead of consuming (Schulze, 2005).

The why, what and how of user experience

As explained before, the use of interactive products transfers into an experience in our memory. Already Krippendorff (1989) said, that “design is the creation of meaning”. These meanings are stored meaningful experiences in our brains, and these experiences, whether positive or negative, shape our actions in the future, affecting for an example our purchase decisions, attitudes and general mood (Hassenzahl, 2014). Similarly as usability is only subphenomenon of user experience, also user experience is just a subphenomenon of an experience. The word “user” only refers to an interaction with a system or a product, whereas the experience stands for the more psychological understanding of the concept that reaches far beyond HCI. As Hassenzahl (2014) said when talking about experience design in the HCI context, “experience design stands for technology, which suggests meaningful, engaging, valuable, and aesthetically pleasing experiences itself." Thus the technology once again acts only as the medium of designing experiences.

When designing the user experience, designers should always bear in mind the holistic understanding of what an experience is, beyond the event of interaction with a system. Designers must think about the universal psychological need of *why* the user is interacting with the system, and *what* he/she is trying to accomplish, and *how* this can be done as effortlessly and pleasurably as possible (Hassenzahl, 2014). Thus, almost every seasoned technology expert is in a way or another an experience designer, no matter whether the end product is physical hardware or an interactive information system.

Rarely the most successful products have superior technology behind their success. They rather excel in grasping a universal psychological need, and responding to that need through the technology, that only mediates the response to that psychological need (Hassenzahl, 2014). Take for an example the classical case of Apple. Apple offered hardly any groundbreaking technological advancements, but still gained overwhelming success by understanding the psychological needs for simplicity, aesthetical design and intuitivism. The creation of the first tablet computer is a good example of a realization of a previously unnoticed human need that didn't require any technical advancements, but drastically changed our understanding or when and how computers can be used. Apple clearly didn't start with the technology, the *how*, but rather with *why* people would need a new kind of a device of interaction.

Hassenzahl (2014) introduced practical steps of *why*, *what* and *how* for designing experiences. *Why* relates to the motivation for the use of a product or a system, that usually fulfills our emotional or practical needs. *What* describes what people can do with a product (e.g. make a phone call or buy tickets to a festival), and the *how* goes more into detail on how the user will interact with the product or system, including the details of for example user interface aesthetics, textual content and provided functionalities. The idea is that the use of these three trains of thought "leads to products which are sensitive to the particularities of human experience. It leads to products able to tell enjoyable stories through their use or consumption" (Hassenzahl, 2014).

2.3 Aesthetics

Aesthetics will be final key concept examined in detail in the theory section. Now that we have covered the essence of usability and showed how it has become to be understood as a subcharacteristic of user experience, we will look deeper into aesthetics, which is seen as a subcharacteristic of usability, and thus also a subcharacteristic of user experience.

The theory section of aesthetics will begin by presenting different views, definitions and philosophical stands on aesthetics and beauty (section 2.3.1 "What is beauty and aesthetics?"). The second section will look into aesthetics more specifically in the context of HCI (section 2.3.2 "Aesthetics in human-computer interaction").

2.3.1 What is beauty and aesthetics?

Aesthetical perception has always been a significant part of the psyche of human beings (Dutton, 2008). Throughout time, visual aesthetics has been expressed and appreciated in the form of art, architecture and the habit of trying to improve our own visual appearance. For as long as human beings have existed, they have had the intuitive need to surround themselves with things that brings aesthetical pleasure, be it decoration of our living spaces, carrying jewelry on our bodies, using beautiful fabrics to cover ourselves, decorating the everyday objects that we use or creating pure art for only aesthetical purposes.

Regardless of the state of development and education, regardless of war or peace and regardless of culture and geographical location, art and other forms of visual aesthetics always exist. People have always had the intuitive need of expressing themselves through visual aids and societies have always created different forms of art in their culture. People express their personalities and build their identities through visual aids (Venkatesh & Meamber, 2008), such as clothing, hairstyles, makeup or even by the items we possess and carry around. By visual aids we express our culture, the social circle we belong or want to belong in. This kind of behavior can largely be explained by our desire to express ourselves and to be seen in a specific way by others (Hassenzahl, 2003).

Aesthetics as a word is derived from the Greek word *aesthesis*, referring to sensory perception and understanding or sensuous knowledge (Hekkert, 2006). *Aesthesis* meant all perceptual experience, and it was used to discriminate between material things that could be seen and those that could only be imagined.

Already in the 1970s, aesthetics was most commonly defined beyond the specialized areas of art and literature. Williams (1976) defined aesthetics as “questions of visual appearance and effect”. One definition of aesthetics is that it is “the experience of all sensory pleasure and delight” (Goldman, 2001). This definition of aesthetics includes the all the sensuous delight from visual to haptic, auditory and gustatory signals. Aesthetics is most commonly associated with visual aesthetics, which is maybe the most dominant modality in our perception of the world (Hekkert, 2006).

Beauty in design

One of the first widely popular attempts of identifying core design principles came from architecture. The Vitruvian principles (Vitruvius, 1960), originally written around 15BC, were used as the three most important endeavors of architecture at the time. These three principles were *firmitas* (i.e. strength and durability), *utilitas* (i.e. utility, usefulness and suitability) and *venustas* (i.e. beauty). Architecture has naturally had a great impact on human life and the development of societies, similarly as today’s information architecture has had a significant impact on how we live and understand the world around us.

In information architecture, which is in the core of the design of information systems, the ancient architectural design principles of durability, utility and beauty should hold. From the beginning, especially *firmitas* has been a core value in information architecture design, since the need for functioning, reliable and robust software has always been acknowledged, and it can be seen as a precondition for any information system (Tractinsky, 2014).

Utilitas was introduced to the design community a lot later around the time when usability studies in HCI emerged around 1980s (e.g. Smith & Mosier, 1986, Shneiderman, 1987), with a focus on effectiveness and efficiency. The inclusion of usability as a key aspect in information system design slowly brought more attention to human-centered design in general (Tractinsky, 2014).

As the two first principles had been reached, interest raised among researchers to explore the third classical design principle: *venustas.* Even if first downplayed and depreciated, beauty and aesthetics gained a firm foothold in the industry when it was found be a key aspect in creating information systems that appeal to us as human beings (Tractinsky, 2014).

Visual attributes always coexist with other design elements, and thus should not be studied in isolation from other design aspects. *Venustas* should not be seen as a tradeoff with other software qualities (i.e. *firmitas, utilitas*), but rather as a dimension, that effects other design aspects and vice versa, resulting in the holistic user experience (Tractinsky, 2014). Classically, aesthetics was automatically seen as a tradeoff against usability (Norman, 1988; Nielsen, 1993). This attitude has gradually changed after findings of positive correlation between aesthetics and usability emerged (Tractinsky, et al., 2000; Lavie & Tractinsky, 2004; Sonderegger & Sauer, 2010).

Usability and aesthetics are tightly interrelated, especially when looking at only users' perceptions. For an example, Tractinsky (2014) used differently designed screens (see Figure 2) from a paper by Parush and colleagues (1998) to demonstrate the undeniable relationship between usability and visual aesthetics. The original study by Parush and colleagues (1998) asked the users to evaluate the interface quality in general, whereas Tractinsky (2014) questioned whether the students were referring to the interface design quality regarding usability or visual aesthetics. The answers were always nearly evenly distributed. This relates closely to Lavie and Tractinsky's (2004) findings of *classical* and *expressive* aesthetics. The classical subdimensions of aesthetics, standing for order and proportion, were highly correlated with usability, whereas the more creative subdimension of expressive aesthetics correlated only moderately with usability.

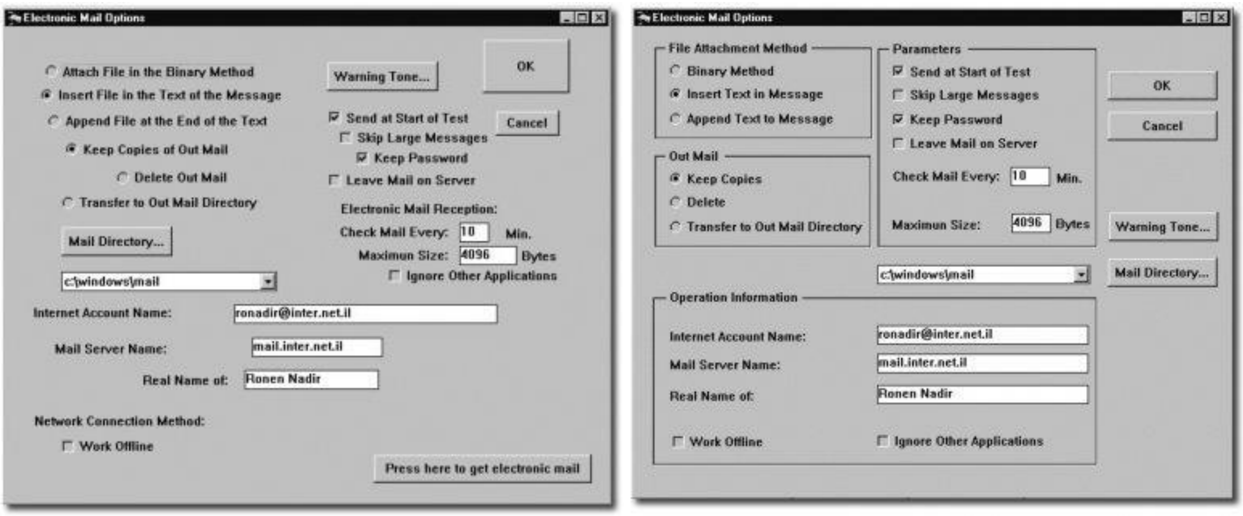

Figure 2. The two different interface designs from the Parush et al (1998) study.

Neurological aesthetics

All of our senses intend to inform us about the properties of the environment that are important for our survival (Goldstein, 2002). Visual (i.e. sight), haptic (i.e. touch), auditory (i.e. sound), olfactory (i.e. smell) and gustatory (i.e. taste) signals, that are all different forms of aesthetics, aid us in making sense of the world surrounding us.

The need for symmetry, and the judgements of beauty, has its roots in biology and evolutionary adaption (Rhodes, 2006), where things that were perceived beautiful or aesthetically pleasing were for an example usually better individuals for reproduction, and aesthetically pleasing items were more often edible than aesthetically displeasing items (Goldstein, 2002). In nature, what is aesthetically pleasing, is also most likely not dangerous, and might be useful and favorable for us (Hekkert, 2006). This is a key feature of human sensory perception, which has helped us to survive and as a race in this planet.

Vision is our most crucial sense in identifying objects around us. Perceiving the world through aesthetics is natural for humans, since it is the central human sense that occupies almost half of the brain (Ware, 2008). Visual stimuli is processed incredibly fast in the brain. Our brain forms an understanding of the visual stimuli in the brain in a matter of milliseconds (Lindgaard, et al., 2006).

Aesthetic evaluations and perceptions are formed in both cognitional and emotional processes in three levels: visceral, behavioral and reflective (Norman, 2004). The visceral reactions to the environment have been developed through evolutionary mechanisms and they happen quite automatically with only little or no cognitive processing, whereas the behavioral and reflective reactions use more developed and complex motivational, emotional and cognitive structures and processes.

People like to look at objects that support navigation and identification (Hekkert, 2006). Visual signals help us identify patterns in the environment, that facilitate perceptual organization, help us in understanding which items belong together and which are separated (Hekkert, 2006). All these visual cues help us to make sense of the surrounding world more efficiently. Visual patterns bring order to the constant flow of aesthetic signals. In many cases, also art aims to create some sort of visual patterns from otherwise random artefacts, and one, in my opinion apt, definition of art is “to preserve unity while almost allowing for chaos” (Boselie, 1996).

Similarly, well-designed information systems should strive to help us make sense of the world in context (the information or function the system is trying to deliver) as effortlessly and pleasantly as possible. By providing aesthetic stimulus that signals us of consistency, unity, ease of navigation and logic, information systems convey a message of usability and delight.

Some people are not as sensitive to aesthetic stimuli and may not see it as important as other people (Hoyer & Stokburger-Sauer, 2011), even if aesthetic experiences are proven to be associated with reflective thinking and affective responses (Leder, et al., 2004). This neurophysiological response has also been proven through functional magnetic resonance imaging (fMRI) in the context of product packaging (Reimann, et al., 2010).

Cultural aesthetics

The visual ques are always culturally and personally loaded. Each human being perceives visual stimuli slightly differently based on the different meanings we have created to different visual cues through our life (Hoyer & Stokburger-Sauer, 2011).

It has been shown that people differ significantly in their aesthetic taste and their sensitivity to aesthetic stimuli (Hoyer & Stokburger-Sauer, 2011). Jacobsen (2004) found that non-artist college students had a strong individual, consistent judgement of beauty and that there were great differences in their beauty judgements when compared to other participants. The average judgement of beauty in the group was found to misinterpret about half of the study participants. Norman (2004) also stressed the importance of considering contextual factors such as task-type and domain when designing the visual appearance. For an example, people tend to weight aesthetic factors less when performing utilitarian tasks than when performing more hedonic tasks (Ben-Bassat, et al., 2006) and change their attractiveness rating when provided a context for the evaluation (Van Schaik & Ling, 2011).

In the web environment the differences in taste are related to *aesthetic fidelity*, meaning the degree to which designers' design goals and users' impressions meet (Park, et al., 2004). Individuals weight the importance visual aesthetics of webpages differently (Hartmann, et al., 2008). Aesthetics affect users' system preferences and choices in ordinary situations, but when they have to perform e.g. competitive tasks this connection disappears (Ben-Bassat, et al., 2006).

Cultural differences have been shown to affect the variance in the feelings of trust. For an example, when an American sees a strong red color, he/she might think of "danger", "no", "forbidden" or other negative ques when again a Chinese person might think of something totally different (Hartmann, et al., 2007). Cyr (2008) also found that visual appeal raised trust in Chinese respondents but not in Canadian or German participants. Another study by Cyr and colleagues (2010) found that people from Japan, Germany and Canada had different reactions to color appeal on websites. The effect of user's background on aesthetic evaluations and on appreciation of aesthetics was also verified by Hartmann and colleagues (2010), showing that user's Western or Asian roots and design or technical background affected the responses.

Some general thoughts of clear cultural differences in aesthetical taste are of course partly stereotypes, since globalization and accessibility of visual stimuli through the internet have significantly brought cultures closer together regarding tastes and trends. Thus, our visual taste subconsciously converges through the spreading of information through internet and other global media. It has been shown that these days, design trends tend to appear concurrently in many places (Gladwell, 2000), which supports the notion of increasingly globalized aesthetical taste.

Psychological aesthetics

Psychological aesthetics refers to an individual's sense of aesthetics (Berlyne, 1974). Visual aesthetics fulfill our personal needs of self-expression (Hassenzahl, 2003), and in addition to that, we automatically associate beauty with other positive but unrelated personality traits in other people (Dion, et al., 1972). Like nature's own symmetrical formulas of geometry and patterns, we appreciate symmetry in human features, and naturally consider symmetric human beings beautiful (Dion, et al., 1972). For an example visual appearance and olfactory signals (i.e. pheromones) are key factors in partner selection, and thus reproduction (Thornhill & Gangestad, 1999).

An aesthetic experience is always related to the cognition and the emotion it evokes. An interactive experience between a human being and a product includes the degree to which all of our senses (i.e. aesthetics) are gratified, the meanings we attach (i.e. cognition) to the product and the emotions that are elicited through interaction (Hekkert, 2006).

Aesthetics has been found to have a positive effect on both cognitive and emotional processes (Leder, et al., 2004), and they can even have an effect on our physical well-being (Ulrich, 1984). For an example, people placed in a room with a window to a natural view in a hospital were found to recover faster, also needing less pain medication after a surgery compared to people that were placed in a room with a window facing a brick wall (Ulrich, 1984).

The famous psychological "halo-effect", which explains the phenomenon why people believe beautiful people also possess other positive qualities that are not related to physical attractiveness (Dion, et al., 1972). Attractive people are also treated better in school (Hamermesh & Parker, 2003) and the work environment (Hamermesh & Biddle, 1994).

When we talk about the aesthetics or the beauty of information systems, we need to reach much further than just the dictionary definition of beauty. In the context of information system design, we need to understand the whole visual perception process that results in various cognitional and emotional responses in the user. It can be said that beauty on its own is not important, but the reactions it provokes in us are the ones that guide our thoughts and actions, and thus matter the most.

Philosophy of beauty

There are two main scholars that think about beauty either as a subjective or an objective concept. The studies of beauty date back to the work of early philosophers, such as Plato, who thought of beauty as an objective matter (Plato, 2001). Immanuel Kant (1914) was also an important philosopher of beauty, who on the other hand saw it as a subjective matter. Another scholar argues that beauty is something universal that can be accurately described and even quantified (e.g. Aristotle, 1998). One other scholar, on the other hand, sees the perception of beauty as a highly subjective and culturally influenced matter (e.g. Hume, 1757), which is probably the most popular outlook on beauty today.

Most of the philosophers of beauty fall between the two extremes of subjectivity and objectivity, seeing beauty as something partly universal, partly subjective. Kant, who was an influential philosopher from the 18th century, argued that there is a distinction between the experienced pleasure, that results from an aesthetic experience, that may vary between people, and the aesthetic experience itself, which is the harmony of the cognitive faculties, and which is relatively invariant among individuals (Osborne, 1968).

Also in HCI, most researchers fall somewhere in between, seeing the perception of beauty as something that has universal qualities, but at the same time is always perceived subjectively, and being affected by our own personal matters such as culture, gender and education (Tractinsky, 2014).

Descriptive and normative aesthetics

There is another dual opinion of whether beauty should be seen as something *descriptive* or *normative* (e.g. Weitz, 1956). The descriptive scholar seeks to find out what *is* considered beautiful, without taking a stand on “good” or “bad” taste, but rather relying on the common opinion. The normative scholar, on the other hand, tries to define what *should* be considered beautiful (Hassenzahl, 2008), and thus taking a clear stand on what is good or bad aesthetical taste.

Many of the popular researchers of aesthetics, like Immanuel Kant (1724-1804), Georg Wilhelm Friedrich Hegel (1770-1831) and most of the current analytic aesthetics researchers, fall into the descriptive scholar. Still, there are some influential aestheticians, like Friedrich Nietzsche (1844-1900) and Theordor Adorno (1903-1969), who spoke for the behalf of normative aesthetics. Descriptive aesthetics theory seeks to decipher the structure and the implied values of existing aesthetic practices and discourses, whereas normative aesthetic theory may engage in a critique of the underlying values of these practices and discourses (Schroeder, 2005).

In this study we will focus on the descriptive approach of beauty based on a widely noted study by Lavie and Tractinsky (2004). They conducted four extensive factor analysis studies, using exploratory and confirmatory factor analyses in order to find out what are the most important constructs of user interface aesthetics in the HCI context. The study resulted in two distinctive aesthetic dimensions, classical and expressive aesthetics.

2.3.2 Aesthetics in human-computer interaction

The inclusion of aesthetics as one of the assessed features of usability and user experience is a surprisingly new trend in the field of HCI. The highly mathematical and technology-oriented software community was reluctant to consider the hedonic attributes of information systems as important factors in creating good software and aesthetics were thus long neglected in interactive user experience design (Butler, 1996).

In addition to being neglected as an important factor in generating a positive user experience and consequent user satisfaction, aesthetic features in interactive information systems have even been seen as potential dangers that may damage system usability (Norman, 1988;

Tractinsky, 1997) and HCI and usability experts were warned not to put too much emphasis on aesthetics (Nielsen, 1993).

Measures of usability, before the emergence of user experience, have classically been stressed by only task-related, pragmatic qualities such as effectiveness and efficiency (Butler, 1996). Instead of focusing on what makes the user experience good, the early usability experts focused only on removing detected inconveniencies in the way of the pragmatic goals of a system, such as reducing the amount of clicks during interaction (Dickson, et al., 1977) and improving task completion time (Hassenzahl, et al., 2000). Intuitive user interfaces and logical navigation paths were stressed over hedonic attributes such as user interface aesthetics (Hassenzahl & Tractinsky, 2006).

The field of HCI began to admit the importance of aesthetics only from the beginning of the 21st century (Tractinsky, 2014). The inclusion of aesthetics as a credible information system attribute arrived along with the new movement of “positive psychology”, that stressed the importance of focusing on human strengths and sources of happiness, and focusing on satisfaction instead of weaknesses, faults and their consequences (Seligman & Csikszentmihalyi, 2000).

The first usability studies that introduced aesthetics as an independent target of evaluation were conducted by Kurosu and Kashimura (1995), Tractinsky (1997), and Tractinsky and colleagues (2000). These extensively cited papers have spawned many studies discussing the importance of aesthetics in overall usability, and the formation of a positive user experience (Tuch, et al., 2012). Information system designers realized that in the quickly growing technology market, the role of aesthetics was a key factor in differentiating IT products (Postrel, 2002) and that the overall user experience, including the aesthetics of a system, should be taken into consideration right from the beginning of a system design process.

Gradually, in the early 2010s, aesthetics and other hedonic aspects had gained a permanent role amongst the academic and practical world, around the same time as user experience became more popular in the classical usability philosophy (Leder, et al., 2004; Hassenzahl & Tractinsky, 2006).

Visual aesthetics overtook space in the industry relatively quickly since its first studies, which reflects the general development in the technology industry. Classical usability problems were not as frequent nor severe as they used to be in the 80s, more software providers competed in the same markets, and users were seeking to satisfy their personal needs and experience more with the existing technologies. Design and style in general became more pervasive in the society (Postrel, 2002) and people demanded more aesthetical systems in general (Tractinsky, 2004).

Today, web pages are more aesthetic than ever. Images and photos take up to two thirds of screen space in the internet (Rabbat, 2010). Modern technology also makes the creation of aesthetic material easier than ever, and aids us in communicating by aesthetic means (Tractinsky, 2014). The increasing supply of visual material increases our aesthetic sensitivity, which in turn makes us seek aesthetics everywhere we look (Postrel, 2002).

Aesthetics and decision-making

Users evaluate information systems and services by similar attributes as any other consumer products, and it has always been an important factor in designing customer products (Tractinsky, 2014). It has been proven by several empirical studies, that product aesthetics has a major effect on user preferences, especially when comparing products with similar functionalities (Yamamoto & Lambert, 1994; McDonagh, et al., 2002; Tractinsky, 2004).

Aesthetics has also been found to be the most often mentioned characteristic in users' product choices (Creusen & Schoormans, 2005). People tend to choose aesthetically packaged products over their less expensive competitors with standard packaging, even if the cheaper alternative comes from a well-known brand (Reimann, et al., 2010).

Human emotions are important factors in the decision making process and it has been empirically tested that aesthetics also correlates positively with making purchase decisions (Creusen & Schoormans, 2005). The effect of aesthetics on purchase decisions is not limited to consumer products, but also IT services (Postrel, 2001). As interactive technologies have become a commodity, the potential of aesthetics as a means of differentiation has become ever more important (Tractinsky, 2014).

It has been proven in several studies that aesthetics play an important role in new product development, marketing strategies and the retail environment (Russell & Pratt, 1980; Kotler & Rath, 1984; Whitney, 1988). There is no doubt that the physical form or the design of a product is an unquestioned determinant of the product's marketplace success (Bloch, 1995). Regardless the extensive knowledge of the importance of aesthetics in satisfying basic human needs, making purchase decisions and making positive evaluations, the school of HCI seems to have for a surprisingly long time neglected the importance of aesthetic factors in system design (Darden & Babin, 1994; Jordan, 1998).

Psychological aesthetics in HCI

Researchers and practitioners begun to stress the values of emotions and psychological needs as an important information system design factor, since it was found that aesthetics makes us experience pleasure and improves our well-being (Tractinsky, 2014; Postrel, 2002), while also being recognized as a basic human need already in early psychological research (Maslow, 1954).

People are interested in for an example personalizing their technological hardware (e.g. phone covers) and software (e.g. screen savers, background images, operating system colors), even if it brings them no practical benefit (Tractinsky, 2014). This is a consequence related to our psychological need to express ourselves and to be seen in a certain way by other people, which is an integral part of our identity formation (Hassenzahl, 2003).

The cognitive and emotional processes affect people's evaluations and attitudes towards information systems (Hartmann, et al., 2008). Task-related attributes are usually related to extrinsic motivation (Tractinsky, 2014), whereas hedonic aspects, including aesthetics, are related to our intrinsic motivation, since aesthetically pleasing interactive systems enrich our experiences with them (Hassenzahl, 2007), and spark the feelings of engagement and pleasure (Mahlke & Thüring, 2007). Pleasurable interactions also make us overlook other design imperfections more easily (Norman, 2004).

Most of the researchers in the field of aesthetics in HCI have taken an *interactionist* approach on aesthetics, meaning that aesthetical experiences consist of the users' reactions to interactive systems, rather than seeing aesthetics as an inherent attribute of the system itself (Tractinsky, 2014). This way, HCI has adopted a *descriptive,* rather than a *normative,* approach to the analysis of beauty (Hassenzahl, 2008).

Aesthetical taste in HCI

What is interesting in the evaluation of aesthetics, is that the opinions between aesthetics professionals, such as designers and artists, differs greatly from the opinion of average, unprofessional users. Experts tend to agree on certain aesthetical judgements that are to some extent based on a set of criteria taught for an example in design schools, and are thought to be objectively determinable (Solomon et al, 1984).

Aesthetical taste in HCI is generally seen as something contextual, depending for an example on our cultural knowledge, personal experiences, personal taste and our views and opinions (Hoyer & Stokburger-Sauer, 2011). Taste depends highly on our senses, and could be described as “the natural capacity to take pleasure in certain artistic and natural objects by means of one’s own sensory experience” (Cohen, 1998), including all of our senses that produce aesthetical experiences. The descriptive and empirical approach to aesthetics in HCI somewhat differentiates it from the artistic and philosophical fields of aesthetics (Tractinsky, 2014), which may take a normative approach questioning the prevalent convictions of good taste and beauty.

Aesthetic judgements of web pages are being formed in less than 50 milliseconds in our brains (Lindgraad, et al., 2006; Tractinsky, et al., 2006). These perceptions are likely to form on a relatively subconscious level and thus be relatively uniform across people when comparing to more elaborated evaluations (Kumar & Garg, 2010).

Aesthetic judgements, as well as memories of experiences, may evolve in the course of time (Tractinsky, 2014). Many empirical studies have shown that the positive and negative emotions provoked by the visual experience before the interaction with a system, will be enhanced during and after the actual interaction when the memory of the experience evolves in our brains (Tractinsky, et al., 2000; Hassenzahl, 2004; Lee & Koubek, 2010). Both pragmatic (e.g. usability) and hedonic (e.g. aesthetics) qualities have a significant effect on user preferences after interaction (Lee & Koubek, 2010). Thus, the HCI community must thus reckon the whole timespan of aesthetic impressions and other emotional judgements.

Research on visual aesthetics in HCI

In the field of HCI, it is common that aesthetic evaluations are tested after only a short exposure to the aesthetic stimuli. The fast response evaluations are also known as low-level aesthetic research (Tractinsky, 2014). The higher level aesthetic research includes more elaborated mechanisms. For an example (Leder, et al., 2004) proposed a model of aesthetic appreciation and judgement, which includes both the automatic and deliberate stages, and both cognitive and emotional reactions.

Today's research has mostly focused on how aesthetics act as a mediator between visual stimuli and outcome variables, such as trust and user engagement (Hartmann, et al., 2008). Similarly, Mahlke and Thüring (2007) conducted a research, where perceived qualities were connected to appraisal and emotions. Long term studies of the possible changes in aesthetic evaluations over time are even scarcer in the field of HCI, but the direction is changing and the need for longer term evaluations has been recognized (Karapanos, 2013). At the moment, there are hardly any studies available that have examined the long term effects of aesthetics on the formation of attitudes, emotions and behavior.

Beauty has been found to be best single predictor of overall judgement of webpages (e.g. Schenkman & Jönsson, 2000). This may be since the visual impressions are the ones most readily available for the user when they interact with the system. Also visual complexity and order have been found to have an effect on user behavior and emotions (Deng & Poole, 2010). Order means the logical organization, coherence and clarity of the webpage, whereas complexity depends on the on the amount of text, graphics and links visible on the webpage (Deng & Poole, 2010).

Many studies have found that people form their first aesthetic judgement based on the *gestalt*, the whole, of the website. The gestalt theory suggests that visual impressions should be evaluated from unified whole that focus on general compositional elements instead of details (Koffka, 1935). Many relevant aesthetics studies in HCI study the perceptions of for an example web aesthetics as a whole, unified expression (Schenkman & Jönsson, 2000; Lavie & Tractinsky, 2004).

Some studies have suggested numerically measured algorithms that help designers in the composition of visual elements (Ngo, et al., 2003). The idea of formal and general aesthetic rules is not without foundation, since studies also suggest that people universally appreciate balance and symmetry in basic images (Bauerly & Liu, 2006). However, the same study also found out that the strong correlation with symmetry and aesthetic appreciation disappeared when the pictures were placed in realistic context on the web. The problem with automatic mathematical algorithms is that they suggest that aesthetic taste is universal, and not dependable on taste, culture or context of use, which has been shown to not to be the case (Hartmann, et al., 2007).

Attributes of aesthetics in HCI

Most of the aesthetics research in HCI has focused on trying to split the perception of overall beauty into different attributes that create the whole. Different researchers have got different results of what should be the most important dimensions of aesthetics and how detailed should this division be. Probably the most well-known study is Lavie and Tractinsky's study (2004) where they identified the classical (i.e. clean, clear, pleasant, symmetrical and aesthetic) and expressive (i.e. original, sophisticated, fascinating, creative and using special effects) dimensions and their subdimensions of aesthetics. These dimensions were also found to correlate with e.g. perceived usability, pleasure of interaction and perceived service quality (Lavie & Tractinsky, 2004).

Classical aesthetics is close to the notions of beauty from the antique era to the 18th century, which emphasizes orderly and clean design (Lavie & Tractinsky, 2004), and are often related to the valued constructs of classical usability experts in the HCI community. Expressive aesthetics on the other hand refer to the more creative and unconventional beauty (Lavie & Tractinsky, 2004), which also please human eye and affect our emotions.

Moshagen and Thielsch (2010) divided aesthetics into four dimensions (simplicity, diversity, colorfulness and craftsmanship) that were all found to affect aesthetic appeal. Simplicity was found to correlate highly with Lavie & Tractinsky's classical aesthetics and diversity with expressive aesthetics (Moshagen & Thielsch, 2010). In both studies the dimensions were positively but differentially correlated with resulting evaluations.

Park and colleagues (2004) identified 13 webpage aesthetics dimensions (bright, tense, strong, static, deluxe, popular, adorable, colorful, simple, classical, futuristic, mystic and hopeful).The studies conducted by Lavie and Tractinsky (2004), Moshagen and Thielsch (2010) and Park and colleagues (2004) are three examples of different divisions of aesthetical attributes. What seems to be a categorization that most researchers see relevant is the division between the pragmatic and hedonic attributes of design quality (Van Schaik & Ling, 2011). Also information system aesthetics on its own is usually seen to possess both classic, pragmatic attributes and more hedonic, expressive and creative attributes (Lavie & Tractinsky, 2004). People also appreciate products by a similar division, where the valuation of aesthetic appeal depends both on typicality and novelty (Hekkert, et al., 2003). Liu (2003) advised that high visual aesthetics is not always necessary and that the "selection of aesthetic levels of design" should be applied considering the needs and characteristics of intended use.

Aesthetics in relation to other design attributes

The most important question that intrigues both researchers and practitioners working with aesthetics in HCI is: what is the effect of aesthetics on HCI-related outcome variables, such us usability, satisfaction, engagement and trust? In HCI, visual aesthetics is usually not viewed as an end value itself, but rather as a potential attribute affecting users' perceptions and opinions about other system attributes, system characteristics and changes in the consequent behavior of the user.

Visual aesthetics has found to affect the users' perceptions of several outcome variables, such as ease of use e.g. (Kurosu & Kashimura, 1995; Tractinsky, 1997; Tractinsky, et al., 2000; Hassenzahl, 2004; Lindgraad, et al., 2006; Hartmann, et al., 2008), overall satisfaction (Tractinsky, et al., 2000; Lindgaard & Dudek, 2003; Cyr, 2008; Cyr, et al., 2010), preferences (Schmidt, et al., 2009; Lee & Koubek, 2010) and performance (Quinn & Tran, 2010; Sonderegger & Sauer, 2010). Visual aesthetics has also been identified to be one of the key factors in building trust (Cyr, et al., 2010; Lindgaard, et al., 2011) and reputation (Hartmann, et al., 2007) in the web environment.

A significant majority of the studies have found a statistically significant correlation between aesthetics and perceived usability (Hassenzahl & Monk, 2010). Since visual stimulation is the first one available for the users, the reactions to aesthetical aspects precede, and thus affect, the evaluations of variables that are later available for the user (Lindgraad, et al., 2006; Tractinsky, et al., 2006). Aesthetics has been found to correlate highly with usability before and after use (Lee & Koubek, 2010).

It has been found that high visual aesthetics can improve users' performance when the usability is poor, but doesn't affect performance under high usability (Moshagen & Thielsch, 2010). The effect of perceived aesthetics on perceived usability has been found to be stronger than the effect of objective performance on usability (Tractinsky, et al., 2000; Sauer & Sonderegger, 2009). For an example, van Shaik and Ling (2009) found no correlation between aesthetics and task performance.

Sonderegger and Sauer (2010) found that users gave higher evaluations of usability for visually appealing mobile phones compared to unappealing ones. The results are not undisputed, since there are also many studies that have found only weak or no correlation between aesthetics and usability (Lindgaard & Dudek, 2003; Hassenzahl, 2004; Mahlke &

Thüring, 2007; Hassenzahl & Monk, 2010). This suggests that the correlation between aesthetics and usability may not be universal and is probably dependent on the context of use.

The connection of visual looks to other design attributes and the subsequent outcomes in users' cognition and behavior should never be considered as universal or deterministic, even if backed up by research, philosophical arguments or common sense (Sutcliffe, 2009), since the usage situations always involve a complex combination of individual, social and technological parameters. There are many studies that witness relations between aesthetics and other attributes, but the generalization of these relations must always be approached with caution.

If the correlation between visual aesthetics, other system attributes and different user responses is varied and unstable, what are the factors that cause the variation and contradictory results? Researchers have suggested different answers for this question. Hassenzahl and Tractinsky (2006) suggested moderators such as the type of system used (e.g. consumer products vs. information systems, personal vs. public, pragmatic vs. hedonic etc.), the context of use (e.g. leisure vs. work) and different cultures (national, religious, sub-cultural, ideological, gender or age-related etc.).

Recently, researchers have placed interest also on how aesthetics mediate the emotions and affect (Tractinsky, 2014) and today, emotions, enjoyment and aesthetics are the most frequently assessed dimensions of user experience (Bargas-Avila & Hornbaek, 2011). Positive emotions and affect serve basic human well-being and are valuable on their own while the effect of aesthetics on subsequent cognitive processes, evaluation of other system attributes, formed attitudes and behavioral changes are usually of more interest (Tractinsky, 2014). Visual aesthetics has been found to be one of the key attributes contributing to the overall user experience (Hassenzahl & Tractinsky, 2006; Sutcliffe, 2009).

2.4 ISO standards

The International Organization for Standardization (ISO) is an independent, non-governmental membership organization founded in 1946, and the world's largest developer of voluntary international standards. ISO consists of 162 member countries who are the national standards bodies around the world. They make world-class specifications for products, services and systems in order to ensure quality, safety and efficiency, facilitating international trade. (ISO, 2015)

ISO covers almost every industry, from technology, to food safety, to agriculture and healthcare. All the standards are made by the experts from each sector all over the world, including the academia, consumer associations, non-governmental organizations and governments. The publication of an International Standard requires a minimum 75% approval of the national bodies casting a vote. (ISO, 2015).

The ISO standards section will begin by presenting how the understanding of usability has evolved in ISO standards (section 2.4.1 "The evolution of usability in ISO standards"). Then we will look more specifically how the ISO/IEC 9126-1:2001 evolved into the current standard ISO/IEC 25010:2011 that will be used as a framework in this study (section 2.4.2 "From ISO/IEC 9126-1:2001 into ISO/IEC 25010:2011"). Lastly, we will look deeper into the ISO/IEC 25010:2011 standard by presenting the two key concepts of the standard in their own sections (section 2.4.3 "ISO Quality-in-Use model" and section 2.4.4 "ISO Product Quality model").

2.4.1 The evolution of usability in ISO standards

ISO, alongside with individual usability experts, has been a notable authority on defining usability throughout its research history. In 1991, the ISO/IEC 9126 standard of "Software Engineering – Product Quality" defined usability as "a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by stated or implied set of users" with usability consisting of understandability, learnability, and operability (ISO, 1991).

ISO 9241-11 Human Factors standard (1998) on the other hand defined usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 1998). The important notion is that usability is not seen as an intrinsic quality or property, but as an *extent* to which the product can achieve its goals (i.e. effectiveness, efficiency and satisfaction), taking into consideration specified users and specified contexts of use. The context of use consists of the users, tasks, equipment (hardware, software and the materials), and the physical and social environments which may influence the usability of a product in a work system (ISO, 2011).

In contradiction to the engineering community, the human factors experts saw usability as something contextually dependable, and more complex than just being a mere intrinsic property of a product/system. The different point of views between the software engineering standard and the human factors standard is explained by the fact that this definition of usability was written by experts of humane issues in the field of ergonomics, psychology or similar. It took relatively long for the context-of-use thinking to spread from ergonomics to the engineering world.

The ISO/IEC 9126 (1991) standard of software engineering was further developed into ISO/IEC 9126-1 (2001) to combine the ISO/IEC 9126 software engineering and ISO 9241-11 human factor views of both product quality and quality-in-use. The ISO/IEC 9126-1 (2001) standard divided software product quality into internal and quality-in-use dimensions. Internal and external qualities included six characteristics: functionality, reliability, efficiency, usability, maintainability and portability (see Figure 3).

ISO/IEC 9126-1 defined usability as “the capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions” (ISO, 2001). The subcharacteristics of usability were understandability, learnability, operability and attractiveness (see Figure 3). In this standard, the thinking was still partly flawed, since usability was still considered to be an intrinsic product quality, not affected by extrinsic factors such as context-of-use.

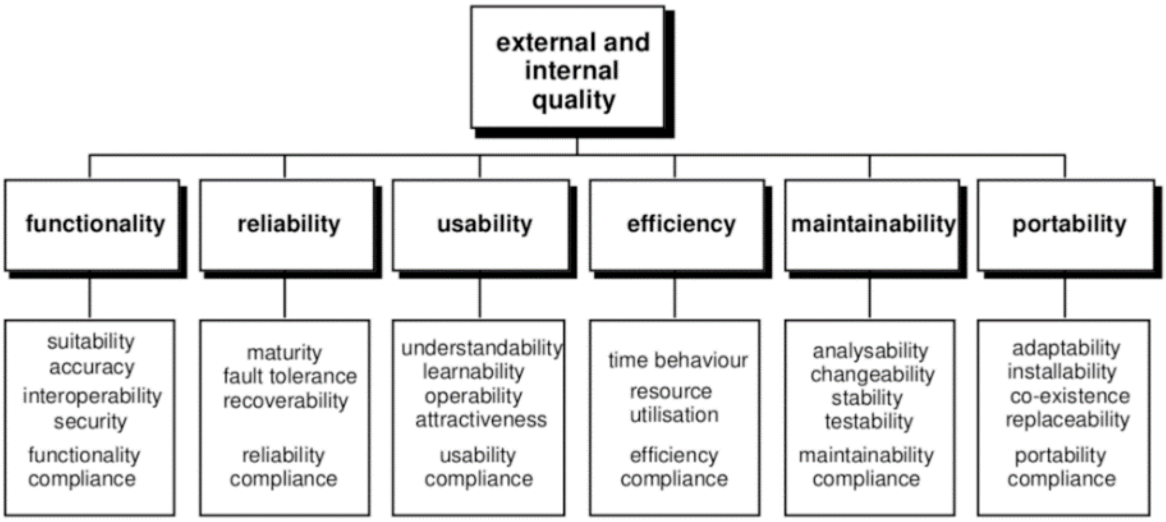

Figure 3. The ISO/IEC 9126-1 model for Internal and External Quality.

The quality-in-use characteristics of ISO 9126-1 (2001) were effectiveness, productivity, safety and satisfaction (see Figure 4). The ISO/IEC 9126-1 quality-in-use was defined as “the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction in specified contexts of use” (ISO, 2001).

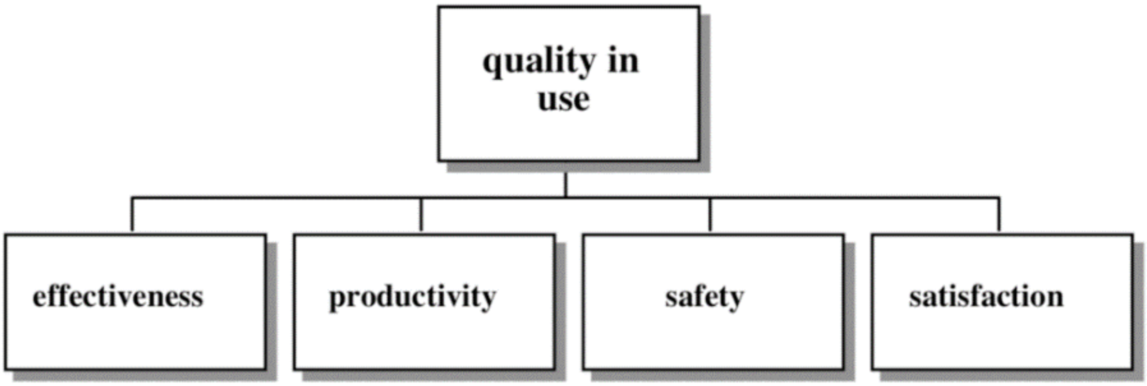

Figure 4. The ISO/IEC 9126-1 model for Quality-in-Use.

Quality-in-use is the umbrella term for the combined operation of the six external and internal software qualities (functionality, reliability, efficiency, usability, maintainability and portability). Thus, the overall objective is to reach quality-in-use with the help of the internal and external product quality attributes.

2.4.2 From ISO/IEC 9126-1:2001 to ISO/IEC 25010:2011

The ISO/IEC 25010:2011 Product/Software Quality model and the Quality-in-Use model will be used as a framework for this study's model of usability, user experience, user interface aesthetics and their relations. The ISO/IEC 205010:2011 cancels and replaces the ISO/IEC 9126-1:2001 (ISO, 2011).

The ISO/IEC 25010:2011 is a part of the technical sector "Information processing, graphics, photography and services" and in more detail, "Information Technology", with 34 participating countries and 59 observing countries (see Table 3). More specifically, it is a part of the Systems and Software Quality Requirements Evaluation (SQuaRE) series of international standards that consists of the following divisions:

- Quality Management Division (ISO/IEC 2500n),
- **Quality Model Division (ISO/IEC 2501n),**
- Quality Measurement Division (ISO/IEC 2502n),
- Quality Requirements Division (ISO/IEC 2503n),
- Quality Evaluation Division (ISO/IEC 2504n),
- SQuaRE Extension Division (ISO/IEC 25050 – ISO/IEC 25099).

The Quality Model Division (ISO/IEC 2501n) creates detailed quality models for computer systems and software products, Quality-in-Use and data, providing also practical guidance on the use of the quality models.

Table 3: The location of ISO/IEC 25010:2011 in the ISO

The structure of International Standardization Organization

International Standardization Organization
• Information processing, graphics, photography and services
    o Information technology (ISO/IEC JTC 1)
        ▪ Software and systems engineering (ISO/IEC JTC 1/SC 7)
            • Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models **(ISO/IEC 25010:2011)**

The ISO/IEC 25010:2011 in the context of this study

The ISO/IEC 25010:2011 standard was chosen for this study, because ISO as an organization incorporates the opinions of different experts and versatile stakeholders from different countries with different backgrounds (e.g. academia, users and practitioners). It is also an internationally acknowledged authority, and is thus not limited to the perception of a single researcher or a small group of advocates from a certain school of thought.

One of ISO's benefits is also the scope of standards, and the discourse between them, in versatile industries from ergonomics to software engineering, that is managed centrally by a single large organization. ISO/IEC 25010:2011 is also one of the few current definitions in the field of HCI that acknowledges User Interface Aesthetics as an equally important subcharacteristic under Usability besides characteristics such as Appropriateness Recognizability, Learnability, Operability, User Error Protection and Accessibility, without forgetting the classical usability subcharacteristics such as Efficiency, Effectiveness and Satisfaction through the Quality-in-Use model.

As noted in the ISO/IEC 25010:2011 standard's definition of Quality-in-Use, "usability us defined as a subset of Quality-in-Use consisting of effectiveness, efficiency and Satisfaction, for consistency with its established meaning" (ISO, 2011, p. 8) and on the other hand, as noted under the definition of Usability in the Product Quality model, "Usability can either be specified or measured as a Product Quality characteristic in terms of its subcharacteristics, or specified or measured directly by measures that are a subset of Quality-in-Use" (ISO, 2011, p. 12). The Product Quality model and the Quality-in-Use model can be seen in Figures 6 and 7, respectively.

In ISO/IEC 25010:2011, Usability is thus seen as a combination of the more classical, inherently interpreted product qualities, and the currently more popular user-centered perceptions of the externally interpreted Quality-in-Use characteristics, under which usability falls by the ISO definition, even if not separately listed in Quality-in-Use subcharacteristics. Product Quality and Quality-in-Use together form the user experience, which includes both the intrinsic product-centered, and extrinsic user-centered perspectives of information systems.

In this study, we are using both the Product Quality and the Quality-in-Use model. We will not use these models in their full form, since it would not serve the focus of this study and would extend the scope beyond being controllable. As also stated in the ISO/IEC 25010:2011 standard, "it is not practically possible to specify or measure all subcharacteristics for all parts of a large computer system or software product", and that the "relative importance of quality characteristics will depend on the high-level goals and objectives for the project", which in this case are to gain knowledge about the relationship of user-evaluated Product Quality Usability and resulting feelings Quality-in-Use Satisfaction through actual interaction with a system.

As advised in the standard, “the model should be tailored before use as part of the decomposition of requirements to identify those characteristics and subcharacteristics that are most important, and resources allocated between the different types of measure depending on the stakeholder goals and objectives for the product” (ISO, 2011). This is why we use a reduced model of the ISO/IEC 25010:2011 so that is tailored specifically for the needs and interests of this study.

The empirical setting of this study will include only primary users. Primary users are users who interact with the system to achieve primary goals (ISO, 2011). Other types of users, not used in this study, are secondary users (e.g. support providers such as content providers, maintainers, system administrators etc.) or indirect users (people who receive output from the system, but don’t personally interact with it) users (ISO, 2011). Product Quality Usability influences Quality-in-Use for primary users, but not for maintenance tasks and it does not affect the information system quality concerns of other stakeholders (ISO, 2011), such as system output receivers.

In this study we are especially interested in the relationship of Product Quality and Quality-in-Use. In Product Quality our characteristic of interest is Usability and its selected subcharacteristics, and their effect on user-experienced Quality-in-Use Satisfaction. Satisfaction was chosen as the Quality-in-Use subcharacteristic of interest since the HCI field has recently emphasized the meaning of emotions in HCI and in studying user experience (Hassenzahl, 2014). The chosen characteristics and subcharacteristics are highlighted in Figures 5 and 6.

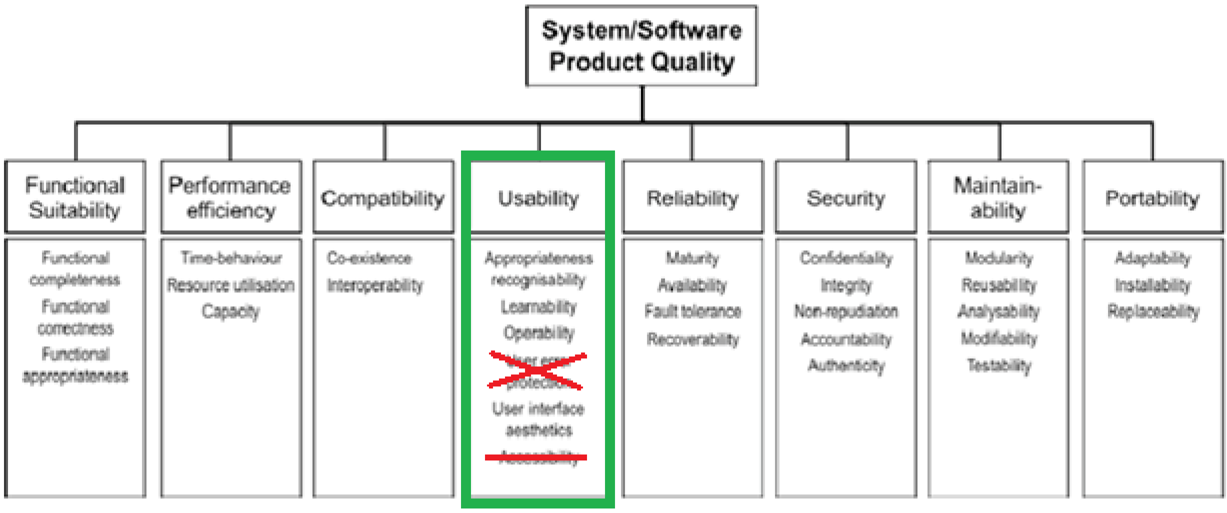

Figure 5. ISO/IEC 25010:2011 Product Quality model and its chosen characteristics.

All Product Quality Usability subcharacteristics, except User Error Protection and Accessibility, will be used in this model. There are several reasons for leaving the two subcharacteristics out of the scope of this study. Firstly, Accessibility is usually assessed by specialized experts with guidelines, conformance reviews and user testing, where the group is formed of people with different disabilities and skill levels that might affect Accessibility (Shneiderman, 1987).

The degree of User Error Protection would also be unreasonably difficult to evaluate for the questionnaire respondents, since users are only able to evaluate User Error Protection when making errors, and the core idea of User Error Protection is to prevent users from making their own mistakes (ISO, 2011). Thus, it is very likely that in a test setting like the one in this study, the users will not even encounter any significant errors.

The dilemma in User Error Protection is the balance between making the necessary actions in the interface simple and easy to accomplish but at the same time to prevent the user from making wrong actions by mistake. Especially when handling sensitive data, the protection of making mistakes may detriment the user experience and frustrate users by for example continuous security verifications and passwords.

All subcharacteristics of Quality-in-Use Satisfaction (see Figure 6) will be studied, since Satisfaction something that users can subjectively evaluate through a Likert-type scale questionnaire. In HCI studies, satisfaction is most often measured by using a questionnaire (Hornbaek, 2006). Psychometrically designed (i.e. concerned with theory and objectivity) questionnaires will give more reliable results than ad hoc (i.e. designed only for one specific purpose, may be unplanned beforehand) questionnaires (Hornbaek, 2006), since psychometrically designed questionnaires apply for wider use than ad hoc questionnaires designed only for the particular case.

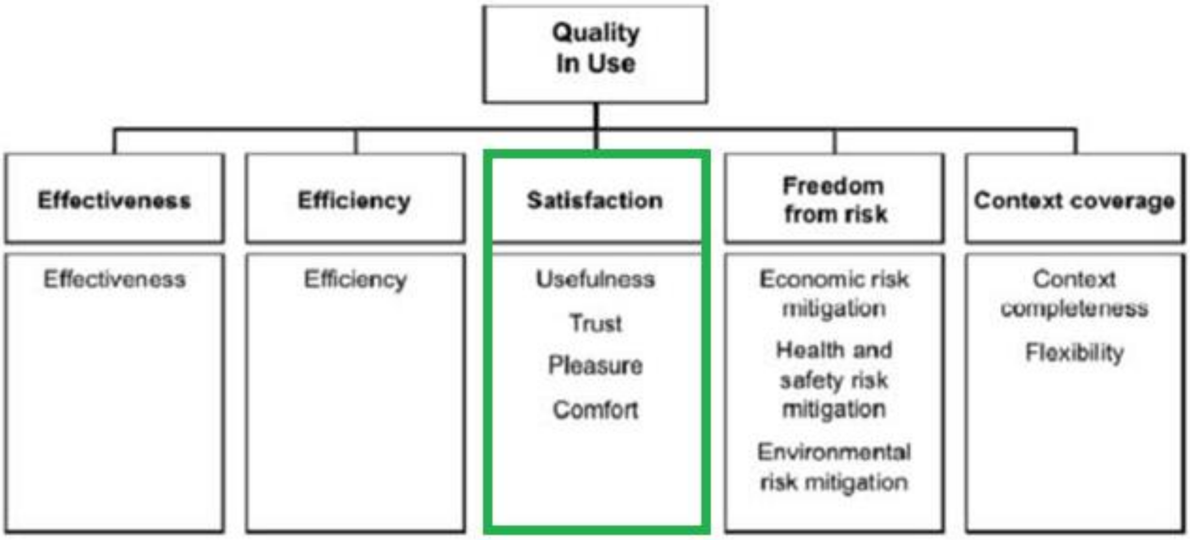

Figure 6. ISO/IEC 25010:2011 Quality-in-Use model and its chosen characteristic.

The ISO/IEC 25010:2011 also provides instructions on how to use the quality model for measurement. Quality properties are measured by applying a measurement method (in this case a questionnaire), the result of which is a quality measure element (ISO, 2011). The quality characteristics and subcharacteristics can be quantified by applying measurement functions (in this case PLS-SEM) (ISO, 2011). The result of applying a measurement function is called a software quality measure (ISO, 2011). In this way, software quality measures become quantifications of the quality characteristics and their subcharacteristics. The process is shown in Figure 7.

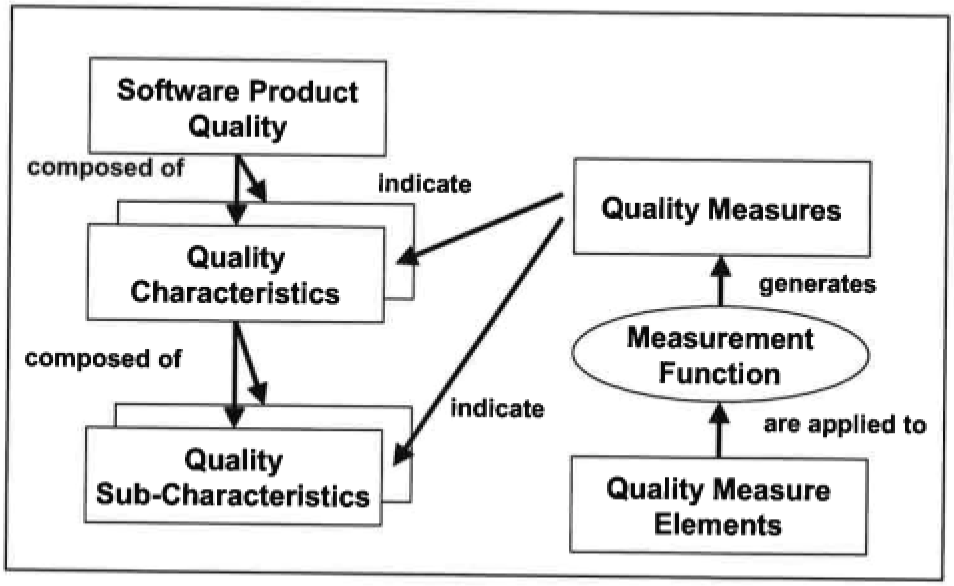

Figure 7. The ISO/IEC 25010:2011 Software Product Quality measurement model.

The Product Quality model includes the internal and external software Product Qualities that are also measured internally and externally, respectively. As ISO (2011) defines: “User needs for quality include requirements for system Quality-in-Use in specific context of use. These identified needs can be used when specifying external and internal measures of quality using software Product Quality characteristics and subcharacteristics.”

Measuring quality by internal properties

Software Product Quality can be measured through internal properties, typically measured by static measures (i.e. measures that do not require any knowledge of the task and are independent of the functioning of the application) (ISO, 2011). Dynamic measures on the contrary require the designer to be able to identify the functions of screen objects (e.g. when measuring layout appropriateness) (ISO, 2011).

Internal measure is the “measure of the degree to which a set of static attributes of a software product satisfies stated and implied needs for the software product to be used under specified conditions” (ISO, 2011). Internal measures of software quality can be used to predict external measures of software quality. Requirements for internal measures include requirements derived from external quality requirements. System is defined as a “combination of interacting elements organized to achieve one or more stated purposes”, whereas a software product is a “set of computer programs, procedures, and possibly associated documentation and data”. System thus includes the software product.

Measuring quality by external properties

Software Product Quality can also be measured by external properties that are usually measured by measuring the behavior of code when executed, or by Quality-in-Use properties, when the product is in real or simulated use (ISO, 2011).

External measure is the "measure of the degree to which a software product enables the behavior of a system to satisfy stated and implied needs for the system, including the software, to be used under specified conditions" (ISO, 2011). External quality evaluation can be used to predict system Quality-in-Use. Requirements for external measures include requirements derived from Quality-in-Use requirements. (ISO, 2011)

Influences of quality improvement

Improving process quality improves the software's internal and external properties (i.e. software Product Quality), which again contributes to improving the system's Quality-in-Use (ISO, 2011). The process is demonstrated in Figure 8. Therefore, "assessing and improving process is a means to improve Product Quality, and evaluating and improving Product Quality is one means of improving the system Quality-in-Use" (ISO, 2011).

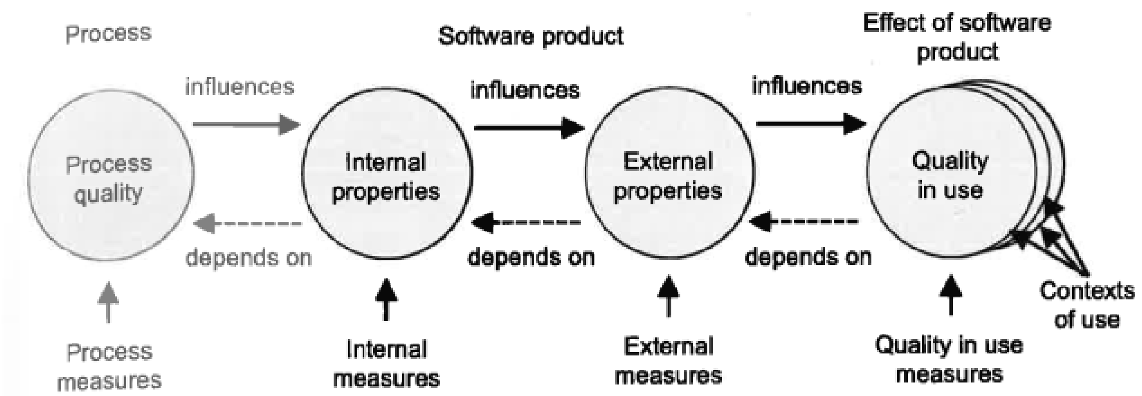

Figure 8. ISO/IEC 25010:2011 quality in the lifecycle.

The system quality has various influences depending on the contexts of use. The context of use can be defined by a set of users, a task, and the environment (ISO, 2011). The process is demonstrated in Figure 9. Quality-in-Use measures relate to the impact of the system on stakeholders. The system can include software, hardware, communications and users, and system dependent properties of a software-intensive computer system or of a software product (ISO, 2011).

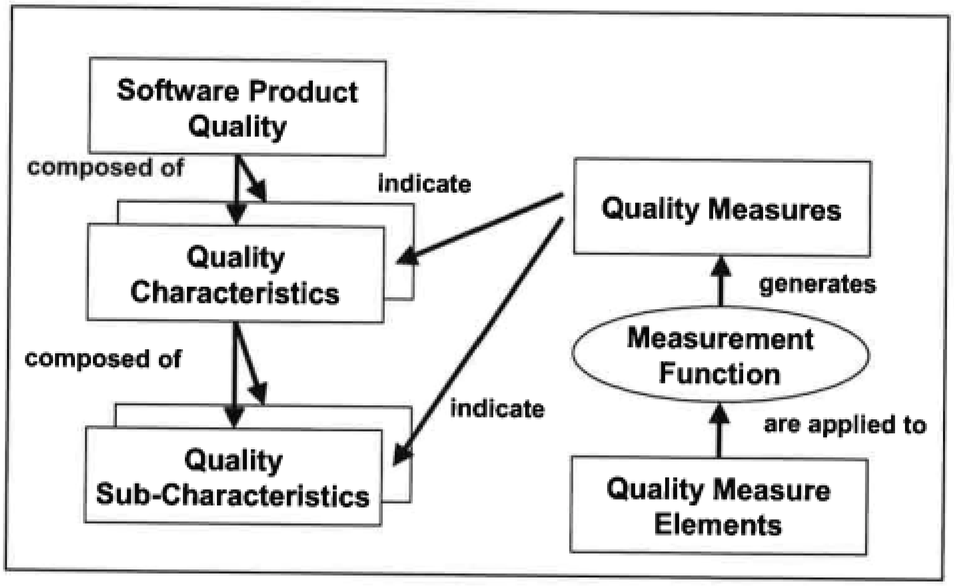

Figure 9. ISO/IEC 25010:2011 target entities of quality model and their relationship.

Measuring quality in this study

In this study, we are only concerned with external measures that do not require any previous knowledge of the task at hand. We will measure the Product Quality characteristic Usability through Quality-in-Use, since the product, in this case a website, is in real use. Quality-in-Use Satisfaction will also be measured by external measures in an actual use situation. Product Quality and Quality-in-Use of the system will be measured by a Likert-type questionnaire and analyzed by PLS-SEM.

The relationship between Product Quality and Quality-in-Use, and thus the relationship between Usability and Satisfaction, can be reasonably justified through the theory behind the ISO/IEC 25010:2011 standard. In this study we are interested in the users' perceptions of Product Quality, where the user subjectively evaluates the Usability aspects and the consequent Quality-in-Use characteristic Satisfaction.

2.4.3 ISO/IEC 25010:2011 Quality-in-Use model

The ISO/IEC 9126-1 (2001) standard was replaced by ISO/IEC 25010:2011, where Usability was placed as an intrinsic Product Quality, but at the same time as a subset of Quality-in-Use. The Quality-in-Use model defines five characteristics related to the outcomes of interaction with a system: Effectiveness, Efficiency, Satisfaction, Freedom from Risk and Context Coverage (see Figure 6 in previous section). Full descriptions of all the constructs and their definitions can be found from Appendix 3.

The standard notes that "Usability is defined as a subset of Quality-in-Use consisting of Effectiveness, Efficiency and Satisfaction" (ISO, 2011). Here, the former ISO 9241-11 human factors standard's usability factors Effectiveness, Efficiency and Satisfaction have become the Quality-in-Use attributes in ISO/IEC 25010:2011 with two additional attributes, Freedom from Risk and Context Coverage.

Context Coverage relates to Nielsen's (1994) "match between system and real world", but can be seen as an even more comprehensive term since it is "determined by the quality of the software, hardware and operating environment, and the characteristics of the users, tasks and social environment" (ISO, 2011). Satisfaction was also featured as a characteristic of Quality-in-Use in the ISO/IEC 9126-1 standard alongside with Effectiveness and Productivity.

Satisfaction will be the ISO/IEC 25010:2011 Quality-in-Use characteristic studied further in this research, and is defined in the standard as:

- **"Satisfaction.** Degree to which user needs are satisfied when a product or system is used in a specific context of use.
    - NOTE 1: For a user who does not directly interact with the product or system, only purpose accomplishment and Trust are relevant.
    - NOTE 2: Satisfaction is the user's response to interaction with the product or system, and includes attitudes towards use of the product." (ISO, 2011)

In ISO/IEC 25010:2011, the Quality-in-Use characteristic Satisfaction is further divided into Usefulness, Trust, Pleasure and Comfort (see Figure 6), which are defined in the standard as:

- **"Usefulness.** Degree to which a user is satisfied with their perceived achievement of pragmatic goals, including the results of use and the consequences of use.

- **Trust.** Degree to which a user or other stakeholder has confidence that a product or system will behave as intended.
- **Pleasure.** Degree to which a user obtains Pleasure from fulfilling their personal needs. NOTE: Personal needs can include needs to acquire new knowledge and skills, to communicate personal identity and to provoke pleasant memories.
- **Comfort.** Degree to which the user is satisfied with physical Comfort." (ISO, 2011)

Issues in measuring satisfaction

Satisfaction is almost exclusively measured only by post-use Likert-scale questionnaires (93% of studies in an extensive review of 180 usability studies by Hornbaek in 2006), which we will also use in this study. The problem with questionnaires in general is that they are collected post-use and are shaped by users' interpretation of the questions, and may be hard to link back to specific parts of the interaction (Hornbaek, 2006). Satisfaction could also be measured objectively, by for an example by monitoring user preferences when navigating on the interface (Hornbaek, 2006), but this would be impossible in the scope of this study.

Only few studies studying satisfaction have used measures of reliability (e.g. Cronbach's alpha) to validate the results (Hornbaek, 2006). In addition to that, satisfaction studies vary greatly among each other in what the chosen objective performance measures are or how they are investigated when asking participants their attitudes and perceptions (Hornbaek, 2006). In this study, Satisfaction will be measured abased on the ISO/IEC 25010:2011 definition of Satisfaction and its subcharacteristics, described above.

2.4.4 ISO/IEC 25010:2011 Product Quality model

The ISO/IEC 25010:2011 Product Quality model recognizes eight characteristics of Product Quality: Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability and Portability (see Figure 5). Full descriptions and definitions of all the Product Quality constructs can be found from Appendix 3. Usability will be the characteristic studied further in this research, and is defined in the standard as:

- **"Usability.** Degree to which a product or system can be used by specified users to achieve specified goals with Effectiveness, Efficiency, and Satisfaction in specified context of use.

- NOTE 1: Adapted from ISO 9241-210.
- NOTE 2: Usability can either be specified or measured as a Product Quality characteristic in terms of its subcharacteristics, or specified or measured directly by measures that are a subset of Quality-in-Use." (ISO, 2011)

The ISO/IEC 25010:2011 Product Quality definition of Usability has been adapted from ISO 9241-210:2010 (ISO, 2011). As the ISO/IEC 25010:2011 standard notes: "Usability can either be specified or measured as a Product Quality characteristic in terms of its subcharacteristics, or specified or measured directly by measures that are a subset of Quality-in-Use". This duality makes the nature of Usability somehow flawed in the light of state-of-the-art research, since it says that Usability can be either a Product Quality or a subset of Quality-in-Use, when Usability should be thought as a comprehensive and somewhat inseparable combination of them both.

As a part of ISO/IEC 25010:2011 Product Quality, Usability is further divided into six subcharacteristics: Appropriateness Recognizability, Learnability, Operability, User Error Protection, User Interface Aesthetics and Accessibility (see Figure 5). The subcharacteristics of Usability are further described in the standard as:

- **"Appropriateness Recognizability.** Degree to which users can recognize whether a product or system is appropriate for their needs.
  - NOTE 1: Appropriateness Recognizability will depend on the ability to recognize the appropriateness of the product or system's functions from initial impressions of the product or system and/or any associated documentation.
  - NOTE 2: The information provided by the product or system can include demonstrations, tutorials, documentation or, for a web site, the information on the home page.
- **Learnability.** Degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with Effectiveness, Efficiency, Freedom from Risk and Satisfaction in a specified context of use.
  - NOTE: Can be specified or measured either as the extent to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with Effectiveness, Efficiency, Freedom from Risk and Satisfaction in a specified context of use, or by product properties corresponding to suitability for learning as defined in ISO 9241-110.

- **Operability.** Degree to which a product or system has attributes that make it easy to operate and control.
    - NOTE: Operability corresponds to controllability, (operator) error tolerance and conformity with user expectations as defined in ISO 9241-110.
- **User Error Protection.** Degree to which a system protects users against making errors.
- **User Interface Aesthetics.** Degree to which a user interface enables pleasing and satisfying interaction for the user.
    - NOTE: This refers to the properties of the product or system that increase the Pleasure and Satisfaction of the user, such as the use of color and the nature of the graphical design.
- **Accessibility.** Degree to which a product or system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use.
    - NOTE 1: The range of capabilities includes disabilities associated with age.
    - NOTE 2: Accessibility for people with disabilities can be specified or measured either as the extent to which a product or system can be used by users with specified disabilities to achieve specified goals with Effectiveness, Efficiency, Freedom from Risk and Satisfaction in a specified context of use, or by the presence of product properties that support Accessibility." (ISO, 2011)

Issues in measuring usability

When designing and assessing usability, there are several issues that should be kept in mind, especially when evaluating complex and contextual interactions between the user and the system Most of the textbook definitions of usability still focus on the technical guidelines, and the measurable and quantifiable features of usability, when actually usability in practice goes far beyond its quantitatively measurable features.

On the other hand, quantitative measures make the general and somewhat vague term of usability more concrete and manageable (Hornbaek, 2006). Quantifiable measures may give a good direction for the usability evaluation, but should always evaluated with keeping the theoretical knowledge in mind in addition to the numerical usability measures.

The definitions of usability have often followed the practices of measuring it (Hornbaek, 2006). This has in its way limited to conceptualization of the term. In practice, subjective perceptions of usability are in fact part of the Quality-in-Use of the user interface being studied (Hornbaek, 2006). Usability measures often forget to take into consideration the hedonic aspects that are quality dimensions with no obvious relation to the task the user wants to accomplish with the systems, such as originality, innovativeness and beauty (Hassenzahl, et al., 2000).

It is also not straightforward to define what the valid measures for measuring usability are, and to know whether those measures really indicate usability. The question of which measures of usability to select in which case, has always been, and probably will be, one of the key questions in the design and development of user interfaces (Hornbaek, 2006). There have also been questions whether the sucharacteristics of usability, such as appropriateness recognizability, learnability or operability can be measured by users' personal perceptions, or whether they should be only assessed by usability specialists (Hornbaek, 2006).

In this study, we are using only subjective measures of usability that rely on users' perception. This must be taken into notice when evaluating the results of this study. When studying both objective and subjective measures of usability, the results are often different (Hornbaek, 2006). This becomes visible for an example when time-to-complete tasks or performance efficiency are being measured objectively and subjectively (Hornbaek, 2006). Also, many studies also mix subjective and objective measures, which may distort the results when results are assessed together (Hornbaek, 2006).

Issues in measuring aesthetics

In the field of HCI, aesthetics is usually measured through different divisions to subdimensions of aesthetics (e.g. Kim, et al., 2003; Lavie & Tractinsky, 2004; Park, et al., 2004; Moshagen & Thielsch, 2010), and by single item scales (e.g. Kurosu & Kashimura, 1995; Tractinsky, 1997; Schenkman & Jönsson, 2000; Hassenzahl & Monk, 2010) or multiple-item scales (e.g. Schenkman & Jönsson, 2000; Moshagen, et al., 2009).

Multi-item scales are usually regarded as more reliable measures, whereas single item measures are may be more practical, since they keep the questionnaires short and simple (Tractinsky, 2014). Strenuous questionnaires may cause errors in the results, due to the fatigue and frustration of the respondent. In this study, we will use a multi-item measurement scale for measuring User Interface Aesthetics, measuring the clarity, pleasantness, creativity, attractiveness and fascination of the interface.

Single-item measures are especially handy when first impressions are studied (Lindgraad, et al., 2006; Tractinsky, et al., 2006; Lindgaard, et al., 2011). When measuring beauty on a single item scale, we come back to the problem of defining beauty and aesthetics. Can beauty be correctly evaluated and understood in one dimension, or should it be broken down into different distinctive features? Measuring visual aesthetics also becomes problematic when the context of use is not taken into consideration, as people have been shown to have differing aesthetic opinions and evaluations in different contexts (Ben-Bassat, et al., 2006).

Both correlational (Lindgraad, et al., 2006; Hassenzahl & Monk, 2010) and experimental (Bauerly & Liu, 2006) studies can be found in the studies of aesthetics in HCI. Experimental studies would probably provide the most solid evidence when studying the cause and effect of aesthetics, but the application of experimental designs becomes difficult when using realistic visual stimuli instead of simple design effects, such as the measurement of symmetry using basic patterns (Tractinsky, 2014).

In an ideal situation all of the design attributes would be independently manipulated in order to separate the perception of aesthetics from the perception of other design attributes in order to test causality (Tractinsky, 2014).

3 METHODOLOGY AND EMPIRICAL STUDY

The methodology and empirical study section will be divided into four sections that present the key aspects related to the chosen methodology, the constructed model and the collection of data. First, we will present structural equation modeling as a methodology in general, and justify it as the chosen methodology for examining the relations of User Interface Aesthetics, Usability, User Experience and Satisfaction (section 3.1 “About structural equation modeling”).

Next we will present how the final hypothesized model was constructed based on theoretical knowledge using the chosen methodology (section 3.2 “Constructing the PLS-SEM path model”). The last section will present how the data was collected, who were the questionnaire respondents and what were the case websites used in the study (section 3.3 “Data collection”).

3.1 About structural equation modeling

In this study well will take a quantitative approach in studying the relationship between Usability, its subcharacteristics and Satisfying User Experience. More specifically, we will use structural equation modeling as the methodology for studying these relations. Structural equation modeling is a statistical methodology that takes a confirmatory (i.e. hypothesis-testing) approach to the analysis of a structural theory bearing on some phenomenon (Byrne, 2010). Structural equation modeling represents the relationships between observed (i.e. measured directly in the model) and unobserved (i.e. measured indirectly in the model) variables using path diagrams. Typically, this theory represents “causal” processes that generate observation on multiple variables (Byrne, 2010).

The term structural equation modeling (SEM) conveys two important aspects of the procedure: 1. The studied causal processes are represented by a series of structural (i.e. regression) equations, and 2. These structural relations can be modeled pictorially to enable a clearer conceptualization of the theory under study. The hypothesized model can then be tested statistically in a simultaneous analysis of the entire system of variables to determine the extent to which it is content with the data. If the goodness-of-fit is adequate, the model argues for the plausibility of the assumed relations among variables. If it is inadequate, the tenability of such relations is rejected. In contradiction to e.g. factor analysis, it takes a confirmatory rather than an exploratory approach to the data analysis. (Byrne, 2010)

3.1.1 PLS-SEM versus CB-SEM

In this study, we will use partial least squares structural equation modeling (PLS-SEM) method to study the structural relations of the chosen model. PLS-SEM is a method commonly used for testing hypotheses and it has no presumptions of data distribution. PLS-SEM becomes a good alternative to another popular structural equation modeling method, covariance-based structural equation modeling (CB-SEM), especially when the following situations are encountered:

1. “Sample size is small.
2. Applications have little available theory.
3. Predictive accuracy is very important.
4. Correct model specification cannot be ensured.” (Wong, 2013)

PLS-SEM is useful in applied research projects especially when there is a limited amount of test participants, and when the data distribution is skewed (e.g. when surveying only Finnish students from a certain discipline). PLS-SEM has been deployed in many fields, such as behavioral sciences, marketing, organization, management information system, and business strategy. (Wong, 2013)

It is important to note, that PLS-SEM is not appropriate for all kinds of statistical analyses. Wong (2013) warned that researchers need to be aware of some weaknesses of PLS-SEM, including:

1. “High-valued structural path coefficients are needed if the sample size is small.
2. Problem of multicollinearity if not handled well.
3. Since arrows are always single headed, it cannot model undirected correlation.
4. A potential lack of complete consistency in scores on latent variables may result in biased component estimation, loadings and path coefficients.
5. It may create large mean square errors in the estimation of path coefficient loading.”

CB-SEM is another widely used method for hypotheses-testing, but unlike PLS-SEM, it requires large sample sizes (usually 200+ observations), normally distributed data and a correctly specified hypothesis model that leaves little room for uncertainties (Wong, 2013).

CB-SEM is thus more suitable for theory testing and confirmation whereas PLS-SEM serves better in prediction, theory development and exploratory research. (Wong, 2013)

In the case of studying as complex, subjective and contextual factors like Satisfying User Experience and its indicators Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability, the requirements of CB-SEM become highly problematic, since it is unrealistic to expect the researcher to be able to flawlessly define the relational models and the internal relations between the constructs. In studies, such as this one, that are even partly exploratory in their nature, nothing absolutely certain is usually known about the relationships between variables. This is when PLS-SEM is usually recommended due to its many practical advantages for these kinds of studies (Hair, et al., 2013). Thus, PLS-SEM is a much more reliable and suitable method for studying the relations of the chosen constructs. PLS-SEM also offers a more realistic minimum amount of observations and leaves some room for uncertainties when building the model.

Acceptance of some uncertainties in the model is important in this study, since the built model is a combined adaption of the existing complete frameworks. Even though the conclusions were based on an extensive literature review of existing theory related to the subject, the final chosen constructs were in the end the researcher's own choices as the most crucial constructs contributing to the studied phenomenon. The researcher also made the final decisions on the hypothesized relations between the constructs, even though strongly based on the ISO/IEC 25010:2011 standard and other findings from existing research. Thus, choosing a method allowing at least a partly exploratory outlook on the model is highly sensible.

3.1.2 PLS-SEM elements

The PLS-SEM path model consists of a structural (i.e. inner) model and a measurement (i.e. outer) models. The structural model consists of the latent variables and their relations to one another. Latent variables are represented as circles in the path model. Latent variables cannot be measured directly, so they are represented by observed variables, also called indicator variables. Indicator variables are represented as rectangles in the path model. A latent construct and its indicators together form a measurement model. (Wong, 2013)

Latent variables are further on divided into exogenous (independent) variables and endogenous (dependent) variables (Hair, et al., 2013). Exogenous variables are not being explained in the model, but the endogenous variables are being influenced by the exogenous variables. In our model Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability act as exogenous latent variables explaining the endogenous latent construct Satisfying User Experience.

The PLS-SEM path model in this study will consist of five measurement models and one structural model. The structural model defines the relations between Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability. The five measurement models consist of Appropriateness Recognizability, User Interface Aesthetics, Learnability, Operability, and their indicator variables, respectively.

The researcher chooses the indicator variables to represent the underlying construct (i.e. the latent variable) based on existing theoretical knowledge. This way the indirectly measured latent variable is linked to the directly measured observed variables, making the estimation of the model possible. Given the relation of the indicator variables and the latent constructs, the assessment measures must be very carefully selected in order to achieve credible study findings.

3.2 Constructing the PLS-SEM path model

The PLS-SEM path model presented in this study is based on the ISO/IEC 25010:2011 standard of Product Quality Usability and Quality-in-Use Satisfaction. Detailed justifications for these selections were made in section 2.5 “The ISO Standards”. In the next sections we will present how these constructs were built into the structural model (section 3.2.1 “Structural model”) and the measurement models (section 3.2.2 “Measurement models”) for the PLS-SEM path model.

3.2.1 Structural model

Our model seeks to prove that the chosen subcharacteristics of Usability (Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability) are significant predictors of a Satisfying User Experience in the web environment. Theory and logic determine the sequence of constructs in the structural model.

The existing literature strongly suggests that Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability are important predictors of Usability. Consequently, current literature also suggests that user experience is an event that takes place somewhere between Product Quality and Quality-in-Use, Usability being a subcharacteristic of Product Quality. Further on, the existing research supports the understanding of Usability as a subcharacteristic of user experience. User experience is a contextually dependent sum of all the variables affecting the event of interaction (ISO, 2011; Hassenzahl, 2014).

Current literature has placed notable emphasis on the hedonic aspects of user experience, such as the emotional consequences of interaction, such as Satisfaction (Hassenzahl, 2014). The subcharacteristics of Quality-in-Use Satisfaction (Usefulness, Trust, Pleasure and Comfort) are hypothesized to be strong predictors of a Satisfying User Experience. The subcharacteristics of Satisfaction will serve as indicator variables of Satisfying User Experience, not as individual latent constructs in the path model.

The suggested theoretical model combines the ISO/IEC 25010:2011 concepts of Product Quality Usability and Quality-in-Use Satisfaction (including its subcharacteristics) into a single endogenous construct of Satisfying User Experience, that is being explained by the Product Quality Usability subcharacteristics, which act as the exogenous constructs Appropriateness

Recognizability, User Interface Aesthetics, Learnability And Operability. The hypotheses that can be derived from the structural model can be seen in Table 4.

Table 4: Hypotheses of the structural model

Hypotheses	
H1	Appropriateness Recognizability is a predictor of a Satisfying User Experience.
H2	User Interface Aesthetics is a predictor of a Satisfying User Experience.
H3	Learnability is a predictor of a Satisfying User Experience.
H4	Operability is a predictor of a Satisfying User Experience.

3.2.2 Measurement models

The measurement models define the relationship between indicators and latent variables (Wong, 2013). The indicators for each construct were created based on existing theory and research, and especially the ISO/IEC 25010:2011 standard was an important framework in defining the content of each construct.

The indicators for Satisfying User Experience were built based on the ISO/IEC 25010:2011 definition of Satisfaction, and the definitions of its subcharacteristics Usefulness, Trust, Pleasure and Comfort, which were presented in the section 2.4.3 “The ISO Quality-in-Use model”. These constructs were unified into a single formative measurement model of Satisfying User Experience, since this study is mainly interested in the individual and relational effects of the reflective measurement models Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability in indicating a Satisfying User Experience.

See Figure 10 for the final PLS-SEM path model including the structural model (latent constructs, i.e. blue circles, and the arrows, i.e. paths, connecting them), the reflective measurement models (latent constructs, i.e. blue circles, and the indicator variables, i.e. yellow rectangles, with arrows pointing from the latent construct to the indicator variables), and the formative measurement model (latent constructs, i.e. blue circles, and the indicator variables, i.e. yellow rectangles, with arrows pointing from the indicator variables to the latent construct).

Reflective and formative measurement models

In a reflective measurement model, the indicator variables are highly correlated and interchangeable, and their reliability and validity should be thoroughly examined (Wong, 2013). A reflective measurement model indicates that the indicator variables are a result of the phenomenon in the latent construct.

In a formative measurement model, the indicators cause the latent variable, and are not interchangeable among themselves, meaning that the indicators are not necessarily dependent on one another (Wong, 2013). In this case, the indicators of Satisfying User Experience are formative, since the indicators related to Trust, Pleasure, Comfort and Usefulness cause a Satisfying User Experience, not the other way around. See Table 5 for the detailed descriptions of the indicator variables.

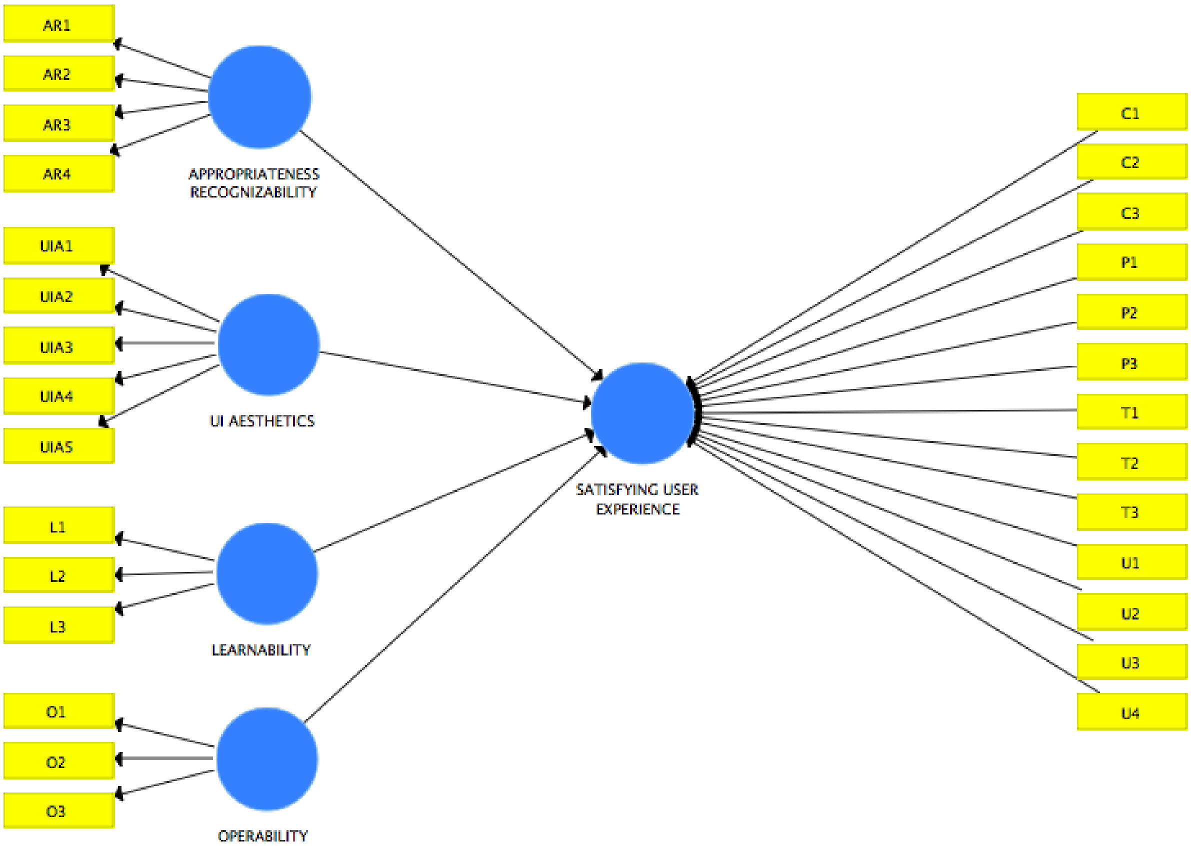

Figure 10. The final PLS-SEM path model.

Table 5: Descriptions of the indicator variables in the PLS-SEM path model

USABILITY		
User Interface Aesthetics		
	UIA1	The website was clear.
	UIA2	The website looked pleasant.
	UIA3	The website was creative.
	UIA4	The website was attractive/aesthetic.
	UIA5	The website was fascinating.
Appropriateness Recognizability		
	AR1	The elements in the website were self-explanatory.
	AR2	I easily understood what the website was meant for.
	AR3	The website was intuitive.
	AR4	I could easily tell whether I could accomplish the given tasks through this website.
Learnability		
	L1	I found it easy to start using this system.
	L2	It was easy to learn to use this system.
	L3	I was able to learn how to use all the functionalities in this website needed to complete the required tasks.
Operability		
	O1	It was easy to do the tasks with the system.
	O2	I found it easy to control the website while completing the tasks.
	O3	It was easy to recover from possible errors or navigation faults.
SATISFYING USER EXPERIENCE		
(Usefulness)		
	U1	I was able to easily achieve all the practical goals and tasks I had set for this website.
	U2	I found this website useful for completing the required tasks.
	U3	I felt successful after completing the required tasks.
	U4	I was satisfied with the results and consequences of use in this website.
(Trust)		
	T1	I could Trust that the website would behaved as intended.
	T2	The website was reliable.
	T3	The website built Trust towards the organization in question.
(Pleasure)		
	P1	It was a pleasure to use this website.
	P2	The website evoked pleasant mental images and/or memories.
	P3	I could see myself identifying personally with this website.
(Comfort)		
	C1	I felt comfortable using this website.
	C2	This website was Comfortable to look at (i.e. it didn't irritate my eyes).
	C3	It was NOT tiring to use this website.

3.3 Data collection

In this section we will discuss in detail the practical execution of the empirical study. First, we will describe how the questionnaire was constructed (section 3.3.1 “Questionnaire"). After this, we will round up the profile of the final respondent group that participated in the questionnaire (section 3.3.2 “Respondent group”) and finally present the websites that were chosen for the testing procedure (section 3.3.3 “Chosen case websites”).

3.3.1 Questionnaire

The final questionnaire consisted of 28 different questions with 3-5 indicators per each endogenous latent construct (see Table 5 in previous section). The questionnaire was executed completely in English. Indicators were created based on previous studies and the ISO/IEC 25010:2011 standard. The indicators of User Interface Aesthetics were derived from the comprehensive and widely known factor analysis study by Lavie and Tractinsky (2006). The other measures for Usability and Satisfaction subcharacteristics were constructed based on the ISO/IEC 25010:2011 standard’s definitions and a much-cited extensive study “Current practice in measuring usability: Challenges to usability studies and research” by Hornbaek (2006). The study critically evaluates all together 180 different usability studies, and categorizes and discusses different usability measures and their advantages and disadvantages.

The questionnaire followed the ISO/IEC 25010:2011 Product Quality model’s definition of Usability and its subcharacteristics, and the Quality-in-Use model’s definition of Satisfaction and its subcharacteristics. As defined by ISO (2011), Product Quality can also be measured through Quality-in-Use, which is what we are doing in this study.

The final set of claims in the questionnaire was approved by Dr. Sirpa Riihiaho from Aalto University School of Science, whose field of expertise is usability testing. The actual questionnaire was executed by using the Webropol 2.0 software. The questionnaire link was distributed on the researcher’s personal Facebook page, different Facebook groups, and in the Aalto University Information Systems Science research seminar group and for Information Technology Program minor students in Aalto University.

Before the link was distributed freely on the internet, a controlled test session was held by the researcher in an Aalto University computer class with four volunteer participants. The controlled test session was held in order to check the validity of the questionnaire and see if respondents could finish it independently without facing notable issues. Respondents had the possibility to ask for help in any phase of the questionnaire and give free feedback.

In the test session, the respondents didn't face any particular problems regarding the questionnaire, so it was published as a public link on the internet. The test session responses were joint with the final responses gathered through the public internet link. All the respondents were instructed to respond with a PC in order the get a similar user experience, and in order for the questionnaire results to be comparable with one another. The full questionnaire can be seen in Appendix I.

3.3.2 Respondent group

The questionnaire was publicly available on the internet for six days. The questionnaire gathered altogether 149 respondents (63.7% male, 36.3% female) from 12 different nationalities. The vast majority of the respondents were Finnish (85.9%), but also Swedish (2.7%), German (2.7%), Afghan (2.7%), Australian (0.7%), American (0.7%), Bosnian (0.7%), Chinese (0.7%), Danish (0.7%), French (0.7%), Israeli (0.7%) and Romanian (0.7%) people responded to the questionnaire. Most of the respondents were 24-29 years old (55.0%), but the group also included people aged 18-23 (33.6%), 30-35 (6.7%), 36-41 (4.0%) and 42-47 (0.7%).

The respondents were asked to evaluate their level of expertise in subjects related to design/art. Most of the respondents considered themselves as beginners (28.2%), while others considered themselves as intermediate (26.2%), no experience (19.5%) advanced (14.1%) or expert/professional (6.0%).

Respondents were also asked to evaluate their expertise in subjects related to information systems and their development. Most of the respondents considered themselves beginners (32.2%) also in this area, whereas people with intermediate (27.5%), advanced (16.8%), no experience (16.1%) and expert/professional (7.4%) skills were found as well.

When asked about their practical experience with software development and/or design, the majority had no experience (40.1%), while the rest considered themselves as beginner (30.2%), intermediate (14.8%), advanced (7.4%) or expert/professional (6.7%). As a conclusion, the respondents consisted mainly of young Finnish adults who did not have advanced or professional skills in design/art nor theoretical or practical information systems development.

3.3.3 Chosen case websites

The websites were chosen by the researcher with several different aspects in mind. Firstly, we wanted the respondent group, likely to be urban, young adults studying in a university, to be a realistic target group of the websites. Secondly, we wanted the websites to present products/services/concepts that would naturally emphasize experiential factors. Thirdly, we wanted to choose websites that would probably not be familiar for the respondents beforehand. Lastly, we wanted to choose websites that the respondents would possibly find stimulating and motivating, in order to decrease the distress of responding to a long questionnaire.

This is why we ended up choosing music/art/culture festivals as the target websites in this study. Young and urban university students are a target group of such events and it is also naturally in the websites' interest to emphasize experiential factors. Because we wanted the websites to be unfamiliar for the respondents, we ruled out Finnish festivals and focused on European festivals that are not commonly known.

Since we wanted to keep up the motivation and interest of the respondent throughout the questionnaire, we chose three websites that were clearly different from one another and followed different styles of design. We also wanted the websites to be different from one another in order to avoid the situation where the user learns the common navigation paths from the first website and utilizes them in the following websites, thus affecting reliable evaluations of especially Learnability and Operability. Namely, the three chosen festivals were Dimensions Festival held in Croatia, Reworks Festival held in Greece and Reworks Festival in Netherlands. All festivals were held around the end of summer or beginning of fall.

The Dimensions Festival website was the most classically designed website of three, using clear navigation panes and clear design. The Reworks Festival website used a full screen promotion video on the entrance of the website, which has recently become a trendy web design element (Nagy, 2015). TodaysArt Festival website was the most experimental and artistic website of the three. It presented a full screen design on the opening website that moved according the mouse movements made by the user. There were no clearly clickable elements and the user kind of had to experiment his/her way through the interface in order to find the required information. All the websites were held in English and promoted themselves for international guests. Screenshots from the chosen festival websites at the time of the open internet link for the questionnaire can be seen at Appendix II.

4 DATA ANALYSIS AND RESULTS

The model estimation gives us information about the relationships between the constructs (structural model) and the relationships between the single constructs and their indicators (measurement models). The method lets us compare how well the theory fits the gathered data. The analysis of a PLS-SEM path model includes a separate assessment of the measurement models and the structural model.

In our study structural model consists of latent variables Appropriateness Recognizability, User Interface Aesthetics, Learnability, Operability and Satisfying User Experience. The path model consist of four reflective measurement models (Appropriateness Recognizability, User Interface Aesthetics, Learnability, Operability, and their respective indicators) and one formative measurement model (Satisfying User Experience and its indicators).

SmartPLS (v. 3.2.3) was the software used for the estimation of the path model in this study. The path-model was calculated using a path weighting scheme with a mean of 0 and a variance of 1. The maximum number of iterations was 300 and the stop criterion was 1.0E-5. The initial weights were marked as 1.0.

4.1 Analysis of the measurement models

The analysis of the measurement models evaluates the reliability and the validity of the construct measures that were chosen for the path model based on theoretical knowledge. Using several indicators for measuring each latent construct, i.e. using multivariate measurement, results in a more accurate and reliable measure, that is more likely to represent all the relevant aspects related to the construct compared to measurement with a single indicator (Hair, et al., 2013). In order for the measurement model to be valid, it must first be reliable (Hair, et al., 2013). Thus an unreliable measure can never be valid, but a reliable measure can be invalid. A good model reaches both measurement reliability and validity.

Reflective and formative measurement models require different assessment approaches since they are inherently different in nature. Reflective measurement models are assessed based on their internal consistency reliability and validity, whereas when measuring the formative measurement models, the most important step is ensuring content validity, and only after that the quantifiable measures (Hair, et al., 2013).

4.1.1 Reliability of the reflective measurement models

Reliability should always be checked before the validity of the measurement model, since reliability is a precondition for validity. In order to check the reliability of the reflective measurement models, it is recommended to check the indicator reliability, internal consistency reliability, convergent reliability and discriminant reliability (Wong, 2013).

Indicator reliability

The reflective indicator reliability can be checked from the outer loadings values in SmartPLS. In a research that is more confirmatory than exploratory in nature, the outer loading values should be 0.70 or higher, whereas in exploratory research a level of 0.40 or higher is acceptable (Hulland, 1999). In our reflective measurement models only two out of 15 indicators had outer loading below the recommended value 0.70 (see Table 6). These two indicators were both related to User Interface Aesthetics: UIA3 ("The website was creative.") with a value of 0.408, and UIA5 ("The website was fascinating.") with the value of 0.694.

Both indicators were decided to be kept in the model, since both meet the minimum acceptable outer loading value of 0.4, and UIA5 is even very close to the confirmatory research outer loading recommendation of 0.7. The line between confirmatory and exploratory research is not always that clear, and the path model in this study has characteristics from both confirmatory and exploratory research. Confirmatory research tests the hypotheses of existing theories, whereas exploratory research looks for patterns in the data when there is only little, or none, existing knowledge on how the variables are related with one another (Hair, et al., 2013).

Internal consistency reliability

The internal consistency reliability can be checked from the composite reliability values in SmartPLS. Traditionally, Cronbach's alpha was used to measure internal consistency reliability, but it tends to provide a conservative measurement in PLS-SEM (Wong, 2013).

The composite reliability values vary between 0 and 1, where higher values indicate better reliability (Hair, et al., 2013). In confirmatory research, the composite reliability should be 0.7 or more, whereas in an exploratory research, a value of 0.4 or higher is also acceptable (Bagozzi & Youjae, 1988). In this research all values were well above the recommended value 0.7, with the lowest composite reliability value in User Interface Aesthetics (0.871) and the highest value in Learnability (0.960) (See Table 6).

Table 6: Results summary for reflective outer models

Latent variable	Reflective indicator	Outer loading	Composite reliability	AVE
Appropriateness Recognizability	AR1	0.931	0.934	0.779
	AR2	0.886		
	AR3	0.802		
	AR4	0.906		
User Interface Aesthetics	UIA1	0.943	0.871	0.888
	UIA2	0.965		
	UIA3	0.918		
	UIA4	0.952		
	UIA5	0.960		
Learnability	L1	0.907	0.960	0.884
	L2	0.818		
	L3	0.918		
Operability	O1	0.408	0.958	0.590
	O2	0.890		
	O3	0.694		

4.1.2 Validity of the reflective measurement model

Validity shows whether the chosen indicators uniquely represent the construct they are measuring. The validity of the reflective measurement model can be checked by convergent validity and discriminant validity (Wong, 2013).

Convergent validity

Convergent validity means the extent to which the measure correlates positively with alternative measures with the same construct (Hair, et al., 2013). Convergent validity can be checked from the average variance extracted (AVE) numbers in SmartPLS.

AVE is the grand mean value of the squared loadings of the indicators associated with the construct (Hair, et al., 2013). The values should be 0.5 or higher in order to reach convergent validity (Bagozzi & Youjae, 1988). An AVE value above 0.5 indicates that on average the construct explains more than 50% of the variance of its indicators (Hair, et al., 2013).

In our model all the values are above the recommended level, with Learnability having the highest value (0.888) and User Interface Aesthetics having the lowest value (0.590) (See Table 6). Also individual indicator reliability is used for evaluating convergent validity, which in our case was fulfilled by outer loading values above 0.7 or above 0.4 in the case of indicators O1 and O3 (see Table 6).

Discriminant validity

Discriminant validity is the extent to which a construct is unique from other constructs (Hair, et al., 2013). Discriminant validity can be checked by assessing indicator cross-loadings (Henseler, et al., 2015). Each indicator loading should be greater than all of its cross-loadings in order to establish discriminant validity (Chin, 1998). If this requirement is not met, the measure in question is unable to discriminate as to whether it belongs to the construct it was intended to measure or to another (Chin, 1998).

In our cross-loading table all the other indicators have greater indicator loadings compared to its cross-loadings, with the exception of UIA1 (“The website was clear.”), which seems to be a better indicator of all the other constructs. UIA1 had an outer loading of 0.818, whereas its cross-loadings exceeded this level with Appropriateness Recognizability (0.871), Learnability (0.885) and Operability (0.887). This may suggest that users don’t perceive clarity primarily as a feature of User Interface Aesthetics, but rather they relate clarity to how easy it is to learn to use the system, to operate it and recognize what the website is meant for. See Table 7 for full list of cross-loading values.

Table 7: Indicator loadings and cross-loadings

	Appropriateness Recognizability	Learnability	Operability	User Interface Aesthetics	Satisfying User Experience
AR1	**0.931**	0.858	0.851	0.688	0.846
AR2	**0.886**	0.801	0.785	0.678	0.803
AR3	**0.802**	0.665	0.658	0.695	0.700
AR4	**0.906**	0.874	0.879	0.670	0.862
L1	0.892	**0.943**	0.903	0.706	0.875
L2	0.890	**0.965**	0.921	0.738	0.907
L3	0.790	**0.918**	0.845	0.679	0.848
O1	0.885	0.919	**0.952**	0.719	0.916
O2	0.883	0.914	**0.960**	0.696	0.898
O3	0.777	0.827	**0.907**	0.660	0.825
UIA1	0.871	0.885	0.887	**0.818**	0.905
UIA2	0.663	0.643	0.629	**0.918**	0.761
UIA3	0.065	0.038	-0.005	**0.408**	0.123
UIA4	0.581	0.539	0.527	**0.890**	0.670
UIA5	0.332	0.302	0.271	**0.694**	0.407

Even though all the other indicators had greater individual loadings than their cross-loadings, they are still highly loaded on other constructs as well (i.e. the cross-loading numbers are very close to the indicator's individual loading). This basically means that many of the indicators also measure the other constructs in addition to the one they were built to measure in the hypothesized path model. This is visible especially between the constructs of Appropriateness Recognizability, Learnability and Operability, and their indicators. All User Interface Aesthetics indicators except UIA1 have significantly better cross-loadings compared to the indicators of other constructs.

The high cross-loadings show that respondents were not able to distinctly discriminate between Appropriateness Recognizability, Learnability and Operability, whereas they clearly saw User Interface Aesthetics as a separate construct compared to other constructs in the model. The clearly better cross-loading values of User Interface Aesthetics, may suggest that users discriminate websites more easily based on User Interface Aesthetics alone, and that the discrimination between the other characteristics is not as easy for the user.

Users seem to evaluate the website and its constructs more as a whole, rather than as separate characteristics of the website. This would suggest that even if there were only problems with one construct that was strongly loaded on other constructs as well, the construct would easily be mixed with the constructs it loads highly to. The website would still be evaluated as a single entity where only User Interface Aesthetics is seen as the only clearly distinctive characteristic of the website that affects the evaluation.

This would suggest that for an example problems in Operability can easily effect the users' evaluations of Learnability and Appropriateness Recognizability negatively, while the website can still be perceived as aesthetically pleasing. On the other hand, well done User Interface Aesthetics that please the user may not be able to diminish the problems that lie within Learnability, Operability and Appropriateness Recognizability.

This for its part proofs wrong the claim, that aesthetically pleasing interfaces can be used for hiding usability issues under beautiful design (Tractinsky, 1997). The issues in discriminant validity may indicate that users are able to discriminate only between User Interface Aesthetics, and only as a whole the other constructs contributing to Satisfying User Experience. This indicates that other usability issues should not be able to be hidden under beautiful design.

Content validity

As stated in the reflective model reliability assessment, all the composite reliability values were above the recommended value 0.7, but this may also indicate that all the reflective indicator variables are measuring a similar phenomenon, especially if the values exceed 0.9 (Hair, et al., 2013). Excessively high reliability values may have a negative effect on the measures' content validity (Hair, et al., 2013). This problem can occur especially if the same phenomenon is measured with semantically redundant items by asking the respondents similar questions, only with a different phrasing (Hair, et al., 2013).

In our model, Learnability, Operability and Appropriateness Recognizability exceeded the composite reliability value of 0.9 (see Table 6), which indicates validity problems between these constructs. These kinds of problems can be expected since the questions were largely based on the ISO/IEC 25010:2011 standard, where the definitions of the constructs aim for accuracy and unambiguousness, rather than versatility and differentiation in the characteristics.

Thus it is understandable that a normal respondent is not able to differentiate with slight differences in meaning between terms that may sound very similar for a person not trained in the field-specific scientific terminology. This is the dilemma the research must battle with when designing the questionnaire, on the other hand trying to make it as simple and understandable as possible and on the other hand using accurate terms.

Testing remedies for validity problems

The path model was recalculated first by trying to move some of the most problematic indicators (e.g. AR2, AR3, AR4 and L2). This didn't improve the discriminant validity significantly, so we tried first removing the whole Appropriateness Recognizability constructs since it was a problematic construct alongside Learnability regarding discriminant validity, but it also had a smaller path coefficient (0.117) than Learnability (0.202). Unfortunately the problems with discriminant validity still remained after these operations.

The only solution that significantly diminished discriminant validity issues was removing both Appropriateness Recognizability and Learnability from the path model. Still, regardless the discriminant validity issues we decided to continue the model estimation with the original model, since minor modifications didn't affect the problem much and on the other hand removing two of the four constructs from the path model would drastically change the conceptual understanding of the core issue and be in flagrant contradiction with the theoretical findings.

Due to the validity issues, when looking at the results of this study, one should use them with certain precautions regarding the validity problems. When mirroring the results of the PLS-SEM model estimation to the existing theory, one must keep in mind the difference between theoretical discriminations between different constructs, and the concrete discriminations that normal, untrained users make while using a system for the first time, and for a relatively short period of time.

4.1.3 Assessment of the formative measurement model

The assessment methods of a formative measurement model are different to those of the reflective measurement model, since the formative indicators are not hypothesized to be highly correlated with each other (Wong, 2013). Formative indicators are assumed to cover all aspects relevant to the construct at hand, and to have low covariance with one another (Hair, et al., 2013).

Regardless of the challenging nature of constructing formative measurement models, if the amount of formative indicators is tried to be restricted based on correlation patters, it can have a negative effect on the construct's content validity, since the indicators are supposed to cover the construct as holistically as possible (Hair, et al., 2013).

Due to the nature of formative indicators, it is very important to make sure that the chosen formative indicators describe the construct comprehensively. From the researcher, constructing formative measurement models requires deep and wide understanding and knowledge of the studied phenomenon. When analyzing the formative measurement model, one should look into the model's content validity (Hair, et al., 2013), outer weight and significance, convergent validity and collinearity of indicators (Wong, 2013).

Content validity

In this case, we are using Satisfying User Experience and its indicator variables as a formative measurement model, since its indicators related to Usefulness, Trust, Pleasure and Comfort clearly result to a Satisfying User Experience, not the other way around. For example, the indicator U2 "I found this interface useful for completing the required tasks", could not be a reflective construct of Satisfying User Experience, where the Usefulness of the interface would be a result of a Satisfying User Experience. By the contrary, the notion that the user perceives the interface as useful, results in Satisfying User Experience. Same goes with the other indicators – the feelings of Pleasure, Trust and Comfort experienced by the user contribute to the creation of a Satisfying User Experience rather than being results of one.

An extensive literature review on the field of user experience and the use of a widely recognized international standard ISO/IEC 25010:2011 justify the selection of the chosen formative indicators contributing to a Satisfying User Experience. There is a deliberately chosen group of leading user experience and interaction design researchers working on the international standards produced by ISO (ISO, 2015).

However, the formative view on measuring Satisfying User Experience could also probably be criticized, since the absolute categorization of formative and reflective measures is not always completely straight-forward. The indicators were chosen to be formative, since for the large part, existing theories strongly indicate towards the formative conception of these kinds of emotions.

Outer model weights

In a formative measurement model, the indicators are assumed to explain the construct holistically, meaning that the indicators account for 100% of the variance in the latent construct ($R^2 = 1$). The outer weights of the formative indicators show the relative contribution of each indicator to the construct (Hair, et al., 2013).

Indicators with the highest outer weights show the most important aspects of the concept at hand. Weight is the partialized effect of the indicator on its intended construct, which in this case is Satisfying User Experience, controlling for the effects of all other indicators of that construct (Cenfetelli & Bassellier, 2009).

From our 13 formative indicators pointing to Satisfying User Experience, U2 ("I found this website useful for completing the required tasks."), U1 ("I was able to easily achieve all the practical goals and tasks I had set for this website."), C2 ("This website was comfortable to look at (i.e. it didn't irritate my eyes)."), C1 ("I felt comfortable using this website.") and T1 ("I could trust that the website would behaved as intended.") were the five indicators with the highest values ranging from 0.111 to 0.212 (see Table 8).

Table 8: Formative indicators with the highest outer weights

Formative indicator	Outer weight
U2	0.212
U1	0.134
C2	0.130
C1	0.124
T1	0.111

The other indicators fall under 0.1, ranging from 0.011-0.095, with T3 ("The website built Trust towards the organization in question."), P3 ("I could see myself identifying personally with this website."), U3 ("I felt successful after completing the required tasks."), T2 ("The website was reliable.") and P1 ("It was a Pleasure to use this website.") getting the lowest scores (see Table 9). Weights should be above 0.1 or better above 0.2 to achieve a significant relationship between the indicator and the construct (Hair, et al., 2013). See Figure 12 in the end of the data analysis section for all the outer weights.

Table 9. Formative indicators with the lowest outer weights

Formative indicator	Outer weight
T3	0.011
P3	0.013
U3	0.031
T2	0.053
P1	0.061

On the other hand, the maximum values of the outer weights depend on the amount of indicators pointing to a single construct. The maximum possible value for a single outer weight can be calculated by $1/\sqrt{n}$, where *n* is the number of formative indicators, that are assumed to be uncorrelated with one another (Hair, et al., 2013). In our model the maximum possible outer weight is $1/\sqrt{13} \approx 0.277$. U2 (“I found this website useful for completing the required tasks.”) is clearly the most significant formative indicator of Satisfying User Experience with an outer weight of 0.212.

Outer model significance

Bootstrapping can also be used to test the significance of formative indicators’ outer weight (Wong, 2013). In bootstrapping, the SmartPLS software generates *T*-statistics for significance testing of both the inner and outer model (Wong, 2013). A large number of subsamples are taken from the original sample with replacement to give bootstrap standard errors, which in turn gives approximate *T*-values for significance testing of the structural path (Wong, 2013).

Our data set had 447 valid observations, which acts as the minimum number of subsamples in the bootstrapping procedure. In our bootstrapping procedure we used the recommended number of subsamples (5000) with no sign changes, and completed the procedure as complete bootstrapping. The test-type was two-tailed with a significance level of 0.05 and a bias-corrected and accelerated (BCA) bootstrap as the confidence interval method.

If the *T*-statistics of the bootstrapping procedure give values under the significance level 1.96, the outer loading significance of that indicator must also be checked. If also the outer loading is below the recommended value of 0.7, or 0.4 for exploratory research, then the indicator should be removed (Hair, et al., 2013). Four of the formative indicators (P3, T3, U3 and U4) had T-statistics under the significance level 1.96 (see Table 10 for outer weights and

T-statistics). All the outer loadings were above the recommended minimum value of 0.7 (see Table 11), so all the indicators were decided to be kept in the model.

Table 10: Bootstrapping procedure T-statistics and outer loadings of formative indicators

	Original Sample (O), outer weight	Sample Mean (M), outer weight	Standard Deviation (STDEV)	*T*-statistics (|O/STDEV|)
C1	0.124	0.124	0.033	3.794
C2	0.130	0.129	0.025	5.280
C3	0.095	0.093	0.027	3.525
P1	0.061	0.061	0.031	1.961
P2	0.086	0.084	0.024	3.493
P3	0.013	0.013	0.021	0.630
T1	0.111	0.113	0.035	3.151
T2	0.053	0.054	0.026	2.054
T3	0.011	0.011	0.033	0.328
U1	0.134	0.133	0.033	4.041
U2	0.212	0.211	0.036	5.952
U3	0.031	0.033	0.027	1.186
U4	0.062	0.063	0.041	1.510

Table 11: Bootstrapping procedure outer loadings of formative indicators

	Original Sample (O), outer loading	Sample Mean (M), outer loading
C1	0.927	0.926
C2	0.836	0.834
C3	0.875	0.874
P1	0.908	0.907
P2	0.780	0.778
P3	0.769	0.767
T1	0.912	0.911
T2	0.856	0.855
T3	0.888	0.886
U1	0.905	0.904
U2	0.933	0.933
U3	0.891	0.890
U4	0.925	0.924

Convergent validity

Convergent validity shows to what extent the selected indicators correlate positively with other indicators measuring the same construct (Hair, et al., 2013). To assess convergent validity, a redundancy analysis can be carried out for each latent variable separately, which involves the use of an existing formative latent variable as an exogenous latent variable to predict an endogenous latent variable operationalized through one or more reflectively measured indicators (Wong, 2013). In our case we only have one formative latent variable (Satisfying User Experience), so we only need to carry out this procedure once.

Since all the reflective indicators used in this model are a part of a Satisfying User Experience, we use them all as reflective indicators of Satisfying User Experience. All the indicators behind each endogenous latent variable describe a different subcharacteristic of the main construct Satisfying User Experience. For an example, O1, O2 and O3 each describe different aspects of Operability, and none of them can thus be chosen as a global, summarizing indicator of Operability and thus satisfying user experience.

The strength of the path coefficient linking the two latent constructs together indicates the validity of the formative indicators used in the model. A desired path coefficient value is 0.90, or at least 0.80 and above (Hair, et al., 2013, p. 121). In our case the path coefficient value, 0.97, between the two latent constructs is well above the desired level 0.9. Thus, according to convergent validity the formative indicators seem to represent the latent variable Satisfying User Experience well, converting to a very good R^2 value of 0.941 (see Figure 11).

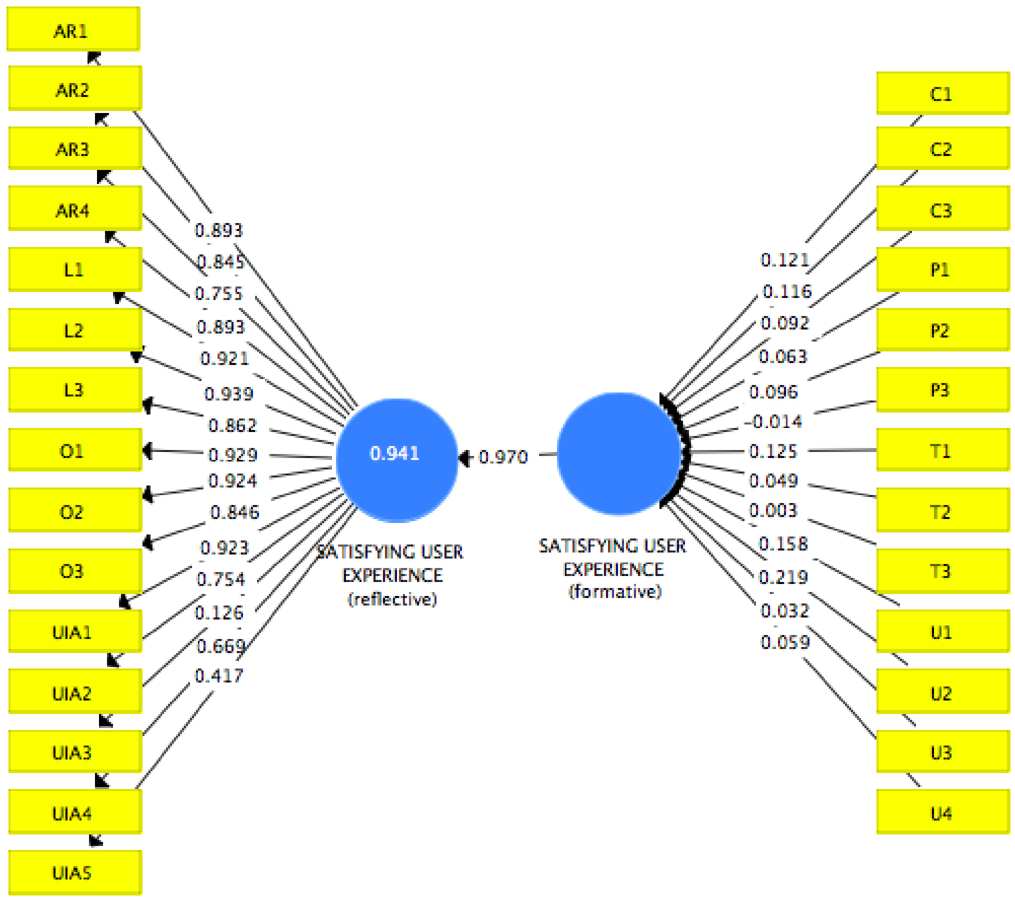

Figure 11. Convergent validity of the formative measurement model.

Collinearity of indicators

If indicators are highly correlated with one another in a formative measurement model, a problem of collinearity may occur. When there are more than two indicators involved, the situation is called multi-collinearity (Hair, et al., 2013).

Multi-collinearity can be problematic, since it has an impact on the estimation of weights and their statistical significance. Collinearity also boosts standard errors, and thus reduces the ability to demonstrate that the estimated weights are significantly different from zero (Hair, et al., 2013). These issues become even more problematic when the sample size is small, since there, standard errors are generally larger. Collinearity can be assessed by computing the tolerance or VIF values of formative indicators (Hair, et al., 2013).

Variance inflation factor (VIF) values can be used to check collinearity (Wong, 2013). Substantial correlations between formative indicators results in unstable estimates for the indicator coefficients. Since formative indicators are hypothesized to explain unique variance in the construct, and not common variance like the reflective indicators, high correlations among indicators is not expected, if not undesirable (Cenfetelli & Bassellier, 2009).

Indicators with a non-significant relationship with the latent construct and a VIF greater than 10 are redundant, and should be considered for sequential elimination (Diamantopoulus, et al., 2008). The lower the VIF numbers, the better. Acceptable levels vary from 10 (no collinearity is commonly accepted) to 3.33 (excellent), depending on the research (Cenfetelli & Bassellier, 2009).

In the context of PLS-SEM, a VIF value above 5 and a tolerance value of less than 0.20 are both signs of a potential collinearity problem (Hair, et al., 2013). For an example a VIF value of 4 implies that the standard error has been doubled ($\sqrt{4} = 2.00$) due to collinearity (Hair, et al., 2013).

As we can see from our data, several formative indicators show signs of possible collinearity problems (see Table 12). Formative indicators C1, P1, T1, T3, U1, U2, U3 and U4 have VIF values over 5, and have a tolerance value below the recommended level 0.20. On the other hand, none of the formative indicators exceed the VIF value of 10 that is commonly considered critical.

In addition to that, removing formative indicators from the measurement model can be more problematic than having signs of collinearity, since formative indicators are assumed to fully cover the construct at hand (in this case Satisfying User Experience). If important indicators are removed, this affects the content validity and the essence of how the formative construct is interpreted in the model. Since all of the indicators are vital and unique parts of SUE, they were decided to be kept in the model even though the VIF values are not ideal in several indicators.

Table 12: VIF values for detecting collinearity of formative indicators

	VIF	Tolerance (1/VIF)
C1	6.350	0.157
C2	3.325	0.301
C3	4.034	0.248
P1	6.100	0.164
P2	3.201	0.312
P3	3.419	0.292
T1	5.940	0.168
T2	4.321	0.231
T3	5.947	0.168
U1	6.435	0.155
U2	7.101	0.141
U3	5.145	0.194
U4	7.500	0.133

4.2 Analysis of the structural model

The first step in the analysis of the structural model is to examine the collinearity of the structural model, since the path coefficients might be biased if the constructs involve significant levels of collinearity (Hair, et al., 2013). The analysis of the structural model means the assessment of the inner model consisting of only latent variables. The most important criteria for assessing the structural model are the value of the target endogenous variable (R^2), the significance of path coefficients and the outer model significance (Wong, 2013).

Target endogenous variable variance

The target endogenous latent variable Satisfying User Experience has a *coefficient of determination* (R^2) value of 0.947, which means that 94.7% of the variance in Satisfying User Experience is being explained by the four other latent variables (Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability). This is a very high level of explanation since already 0.75 is considered substantial (Wong, 2013).

This is an interesting finding, because the two other subcharacteristics of Usability (User Error Protection and Accessibility) defined in the ISO/IEC 25010:2011 standard were completely left out from the path model. This supports the initial hypothesis, that these two constructs are not as relevant for the user's own evaluation of perceived Satisfying User Experience.

This does not criticize the ISO/IEC 25010:2011 standard, since there is always a difference in what should be considered theoretically important, and what users may not still even notice. Accessibility and User Error Protection are both subcharacteristics that do not usually become evident before problems related to them arise. When they do arise though, they can affect the overall user experience significantly, or even ruin it completely (e.g. a person with a disability not being able to use the system at all due to Accessibility problems).

Inner model path coefficients

The path coefficients, marked by the numbers on the arrows (see Figure 12, with the green circle referring to the target endogenous variable) explain how strong the effect of one variable is on another variable (Wong, 2013). The weight of the path coefficients shows the relative statistical importance of each construct. In general, for a data set that has up to 1000 samples, the standardized path coefficient should be larger than 0.20 in order to demonstrate its significance, though it must also be noted that the relative statistical importance of a variable is not necessarily equal to the operational importance of the variable (Wong, 2013). The inner model suggests that Operability has the strongest effect on Satisfying User experience (0.410), followed by User Interface Aesthetics (0.302), Learnability (0.202) and Appropriateness Recognizability (0.117).

As predicted from the existing research, User Interface Aesthetics had an important role in the creation of a Satisfying User Experience. User Interface Aesthetics alone has a direct effect size of 0.312, being the second most important variable right after Operability, which has a direct effect size of 0.410.

Inner model path coefficient significance

The significance of the inner model path coefficients can be measured with the bootstrapping procedure using *T*-statistics. In a two-tailed *t*-test with a significance level of 0.05, the path coefficient will be significant if the *T*-statistics is larger than 1.96. The bootstrapping procedure shows that all of the path coefficients in our model are significant, with the lowest value being 3.322 (Appropriateness Recognizability) and the highest 9.435 (User Interface Aesthetics). See Table 13 for the T-statistics.

Table 13: T-statistics of structural model path coefficients

	Satisfying User Experience
Appropriateness Recognizability	3.322
Learnability	4.430
Operability	8.685
User Interface Aesthetics	9.435

Outer model significance

The bootstrapping procedure *T*-statistics should also be higher than 1.96 for all the outer loadings. As we can see from Table 14, all of the *T*-statistics are larger than significantly 1.96 so we can say that the outer model loadings are highly significant. The outer model *T*-statistics are also shown in brackets in Figure 12.

Table 14: T-statistics of outer loadings

	Appropriateness Recognizability	Learnability	Operability	User Interface Aesthetics
AR1	146.777			
AR2	71.176			
AR3	33.643			
AR4	88.297			
L1		131.683		
L2		255.712		
L3		91.710		
O1			192.064	
O2			221.551	
O3			83.546	
UIA1				58.290
UIA2				110.000
UIA3				6.377
UIA4				64.583
UIA5				17.080

Problems with the structural model

As predicted already from the measurement models, there were problems with the collinearity among indicators, and these problems expectedly recur in the structural model as well. This can be seen for an example from the VIF values of the predictor constructs, where especially Operability and Learnability had high values (see Table 15).

Table 15: Structural model VIF values

	Satisfying User Experience
Appropriateness Recognizability	7.181
Learnability	11.250
Operability	10.369
User Interface Aesthetics	2.558

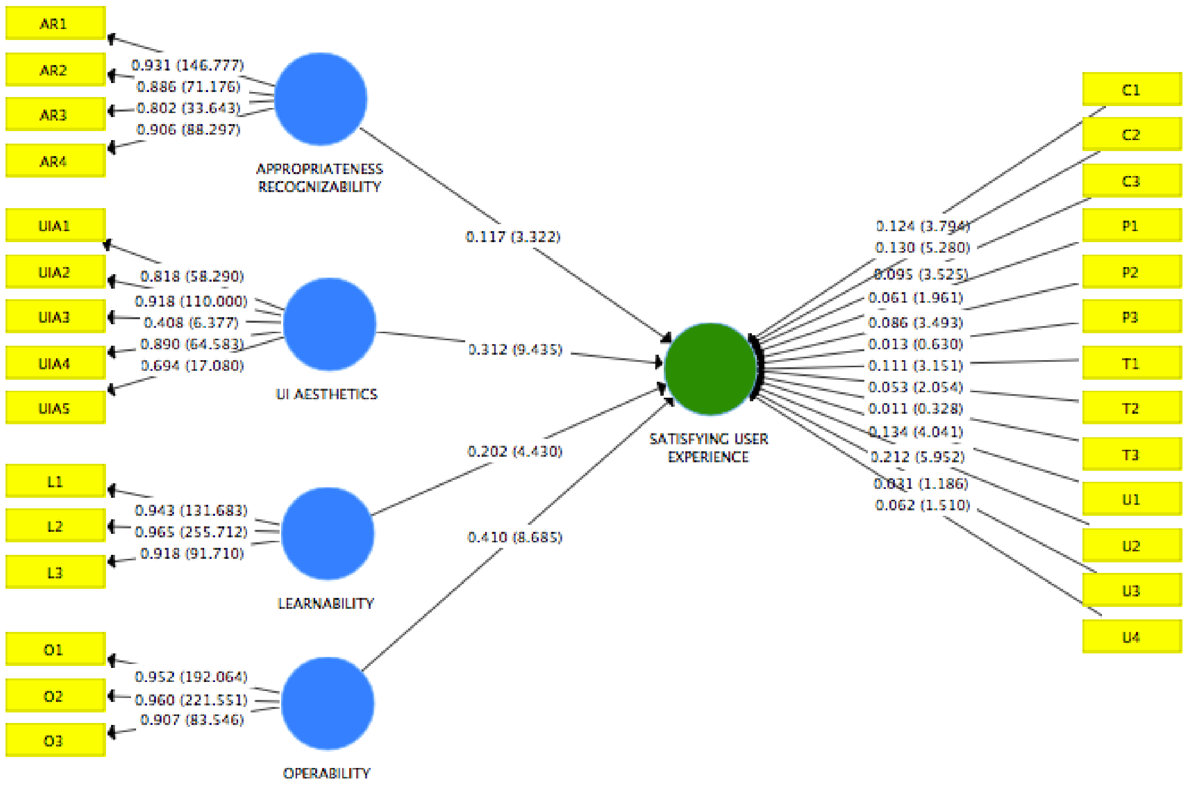

Figure 12. PLS-SEM path model estimation results.

5 REFLECTION AND CONCLUSIONS

As initially hypothesized on the grounds of existing theory, Usability and its chosen subcharacteristics (Appropriateness Recognizability, User Interface Aesthetics, Learnability and Operability) from the ISO/IEC 25010:2011 standard were found to be accurate predictors of Satisfying User Experience. Together, they explained 94.7% of the variance in the target endogenous variable Satisfying User Experience, when already 75% is regarded as substantial.

The high explanation level of the chosen Product Quality characteristics alone also supports the initial hypothesis, that it would be difficult for users to evaluate issues related to Accessibility and User Error Protection in the empirical setting of this study. The fact that the missing of these two subcharacteristics was not manifested as a low R^2 value, supports the hypothesis that users do not consider these Usability attributes in their evaluation, as long as problems related to them do not arise.

All together the results indicate, that the hypothesized user experience model constructed in this study was pertinent, even if it faced some validity issues due to the similarity of the latent constructs Appropriateness Recognizability, Learnability and Operability. The most important single construct contributing to Satisfying User Experience was Operability, followed by User Interface Aesthetics, and Learnability, and finally Appropriateness Recognizability, which was the least significant from the four constructs.

What is especially notable, is that User Interface Aesthetics was the second most important variable contributing Satisfying User Experience. As the ISO/IEC 25010:2011 standard defined, User Interface Aesthetics is the “degree to which a user interface enables pleasing and satisfying interaction for the user”, so it was rightly deducted that its contribution to Quality-in-Use Satisfaction (transformed into Satisfying User Experience in this study) was indeed significant. This also supports the finding of for an example Schenkman and Jönsson (2010), who found beauty to be the best single predictor of overall judgement of webpages. Regardless of its long, and at times difficult, journey to be acknowledged as one of the key aspects of information system design, it time and time again proves its position beside the classical usability indicators, as it also did in this study.

The strong role of User Interface Aesthetics as a predictor in the overall judgment of webpages, added to the validity issues witnessed in this study between all the other latent variables contributing to Satisfying User Experience, may suggest that User Interface Aesthetics is in fact one of the most distinct characteristics of information systems that users distinguish, and by which they evaluate the overall user experience. Even though Operability was the strongest predictor of Satisfying User Experience, it faced collinearity problems with both Learnability and Appropriateness Recognizability, in addition to which, its indicators also loaded strongly to the indicators of both Learnability and Appropriateness Recognizability, but not User Interface Aesthetics. This demonstrates, that users find it hard to discriminate whether system characteristics of these constructs are in fact related to Operability, Learnability or Appropriateness Recognizability. Thus, the results, and especially the relative contributions of Operability, Learnability and Appropriateness Recognizability to Satisfying User Experience must be approached with caution.

The two most important theoretical sources for constructing the model in this study were the ISO/IEC 25010:2011 standard and its predecessors, and an impressively extensive publication "The Encyclopedia of HCI, 2nd Ed." (2014) published by the Interaction Design Foundation (IDF), consisting of 4000+ pages written by 100+ leading interaction design professionals from Ivy League professors to hands-on designers in the field of HCI. The encyclopedia covers all together 52 of the most relevant current issues related to interaction design, varying from topics like "User Experience and Experience Design" (Hassenzahl, 2014) and "Usability Evaluation" (Cockton, 2014) to "Visual Aesthetics" (Tractinsky, 2014) and "Emotion and Website Design" (Cyr, 2014), all widely referred to in this study. Thus it can be stated, that this research and the hypothesized model built for the study were based on significant state-of-the-art research, and information of high quality standards.

As mentioned in the theory section regarding the ISO/IEC 25010:2011 standard, Product Quality, such as Usability subcharacteristics used in this study, can be measured through Quality-in-Use by actual user interactions, which is what this study carried out in the empirical study. When Product Quality merges into Quality-in-Use, the intrinsic and static qualities of the system activate due to human-computer interaction. When a human interacts with a system, it instantly becomes a personal, context-dependent user experience. Today, the most popular view in the HCI field if that the user is the best evaluator of usability and user experience, similar to the classical philosophy "the customer is always right", made popular in the field of retail regarding customer satisfaction (Farrington, 1914). This in its part demonstrates the user-centered design revolution going on in the field of interaction design.

Even though some researchers have criticized whether users, who are not educated on the matters of interaction design, are even valid evaluators of usability and user experience in the first place (Hornbaek, 2006), they still seemed to value the same user experience attributes that were chosen for the constructed model in this study. In the end, the model was based on a popular theoretical consensus in the field of HCI research and international standards, so probably the most notable theoretical findings are primarily based on user perceptions, bringing the theory and practice full circle, and thus giving the user the value it really deserves in interaction design.

Based on the findings of the empirical study, users saw Operability, User Interface Aesthetics, Learnability and Appropriateness Recognizability all as important predictors of Satisfying User Experience, where only Appropriateness Recognizability was statistically not that significant. Still, it should also remembered that the relative statistical importance of a variable is not necessarily equal to the operational importance of the variable (Wong, 2013), so even if not demonstrating ideal statistical importance, the position of Appropriateness Recognizability in the user experience model is still justified on the grounds of theoretical knowledge.

What acts as a secondary finding in this study, is that even though ISO (2011) guides researchers in many ways on how to use the ISO standards for empirical measurement, it fails to warn researchers on the likely issues of overlapping subcharacteristics that are likely to result in statistical validity issues. Issues related to validity were in fact faced in this study, even though the measurement recommendations of ISO (2011) were followed, and best practices were used when building the final questionnaire (e.g. Lavie & Tractinsky, 2004; Hornbaek, 2006; ISO, 2011). When developing its future instructions for measurement, possible issues with variable validity in common statistical analysis tools, such as SEM in general, and more specifically in PLS-SEM, should be noted.

The virtue of aiming to create theoretically comprehensive definitions, and at the same time striving to be able to use them as such in empirical, statistical applications, poses a kind of conflict of interests. Theoretical definitions aim to cover the phenomenen holistically, without leaving out anything critical. Statistical methodologies, such as SEM, aim to prove causal processes through structural equations, in which redundant measures can become problematic regarding the validity of the results derived from the theoretically all-encompassing model.

Contributions and implications of this study to the field of HCI

This study contributed to the field of user experience research by combining the ISO/IEC 25010:2011 standard into a new kind of a reduced model, connecting both Product Quality and Quality-in-Use attributes that can be measured quantifiably. In this study, users evaluated Product Quality attributes, namely Usability subcharacteristics, through their personal interactive experience of Quality-in-Use by visiting three different websites and evaluating their different user experience characteristics through a 7-point Likert-type scale in the questionnaire. No similar studies combining the ISO/IEC 25010:2011 standard into a quantifiable empirical model had come across in the extensive theoretical review on the field of usability, user experience and user interface aesthetics. Thus, this brings a partly new approach to studying these user experience attributes concurrently in a single theoretical and empirical framework in HCI.

Studies using the chosen statistical methodology, PLS-SEM, do not seem to be common in the field of usability, user experience and user interface aesthetics studies, even though the methodology is widely popular especially in social sciences (Hair, et al., 2013). Thus, this study brings an important methodological case presentation to the field of HCI, which can be used in possible future research studying similar phenomena. The faced validity issues in this study act as a learning point demonstration for future research, so even better path models regarding similar issues can be constructed in the future.

The results of this study can, in addition to their theoretical contributions, act as a guidance for user experience designers in their work. Both the theoretical section and the results of the empirical study give valuable advice on what aspects should be stressed when designing interactive experiences. The study discloses both theoretical and practical recommendations regarding the whole information system design process, from the psychological meaning of an experience for the user to the practical, more technical, recommendations on what aspects should be considered and how they should be applied to interaction design. In general, the study demonstrates a turning point in the field of HCI, where it merges deeper and wider into the surrounding sciences of for an example psychology, neurology, anthropology, and even philosophy and aesthetics.

Limitations of the generalization of the results

When considering the wider use and application of the study results, the limits regarding the generalization of the results must also be kept in mind, in addition to the validity issues. The empirical study included 149 respondents, of which 88.6% were under 24 years old, and of which 85.9% were Finnish. For example, aesthetical tastes have been found to differ by factors such as gender (Moss, et al., 2006), nationality (Cyr, et al., 2009) and culture (Cyr, et al., 2010). The taste of young, Finnish university students will thus probably differ greatly from people who come from a drastically different background.

Also the selection of case websites also naturally affects the data retrieved from the questionnaire responses. For an example, choosing three very similar and classically designed websites would have probably resulted in slightly different results compared to our results, which were derived from the evaluation of three websites significantly different from one another. We must also remember that in this study, aesthetics, usability and user experience were measured only subjectively. When studying both objective and subjective measures, results often differ (Hornbaek, 2006).

It must also be remembered that this study has been limited to empirically studying solely how the reflective Product Quality constructs Appropriateness Recognizability, User Interface Aesthetics, Learnability, Operability and the formative indicators of Satisfaction in Quality-in-Use contribute to Satisfying User Experience. It is not certain that the chosen formative indicators related to Comfort, Pleasure, Trust and Usefulness exhaustively cover the construct of Satisfying User Experience, even though the theory strongly indicates towards that conception. The theoretical model by default makes this assumption when calculating the structural equations using a formative measurement model in PLS-SEM.

Future research

It would also be interesting to carry out a similar PLS-SEM study using a new combination of constructs in the user experience model, different to ISO/IEC 25010:2011, which in the end is only one way of simplifying the complex concept of user experience into a set of manageable and statistically quantifiable constructs.

Also, it would be interesting to further study if, and if yes, to what extent indicators related to constructs like Effectiveness, Efficiency, Freedom from Risk and Context Coverage named as parts of Quality-in-Use in ISO 25010:2011 contribute to Satisfying User Experience. Also, it would also be interesting to conduct a similar empirical study that would take into account Accessibility and User Error Protection as subcharacteristics of Usability in the user experience model, and see how it would affect the results. This would require using a diverse respondent group including respondents with limits regarding general Accessibility, and creating a test setting where users would encounter issues related to User Error Protection.

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APPENDIX A: The questionnaire

User experience of web interfaces

Welcome to Karoliina Pärnänen's Master's Thesis questionnaire considering the user experience of web interfaces!

The questionnaire takes about **20-25 minutes** to finish.

This questionnaire should be done on a **desktop** so that you can have **two browser windows open simultaneously** (one for the questionnaire, one for another website).

First I am going to ask a few background questions about you.

Next -->

8% completed

User experience of web interfaces

Gender *

- Male
- Female

Age *

- 17 or less
- 18-23
- 24-29
- 30-35
- 36-41
- 42-47
- 52-57
- 58 or more

Nationality *

Afghan

<-- Previous Next -->

16% completed

User experience of web interfaces

I have studied subjects related to design/art or been interested in them as a hobby. I would consider my level of expertise as: *

- No experience
- Beginner
- Intermediate
- Advanced
- Semi-professional
- Expert/professional

I have studied subjects related to information systems and their development or been interested in them as a hobby. I would consider my level of expertise as: *

- No experience
- Beginner
- Intermediate
- Advanced
- Semi-professional
- Expert/professional

I have practical experience of software development and/or design. I would consider my level of expertise as: *

- No experience
- Beginner
- Intermediate
- Advanced
- Semi-professional
- Expert/professional

<-- Previous Next -->

25% completed

User experience of web interfaces

The actual questionnaire is about to begin.

The questionnaire includes **three** different websites of **festivals** being held around Europe in 2015 and **three** sets of questions you will answer after visiting each website.

- There is **no time limit** and you can browse on the websites **for as much as you like**.
- When completing the tasks, try to **act as you normally would** in a website like this. This is not a test!
- When answering the questions, there are **no right or wrong** answers - only your personal experience matters!

When you feel like you have understood these instructions, click "Next" to proceed.

<-- Previous   Next -->

33% completed

User experience of web interfaces

Dimensions Festival

The first website you are going to visit is http://www.dimensionsfestival.com/ - please **right-click to open the link in a new tab or window.**

At http://www.dimensionsfestival.com/, please complete the following tasks, not necessarily in this order.

1. Find the festival **dates** and the **location/address.**
2. Find the festival **programme** and browse through it.
    - **Pick one** performance that interests you the most and read more about it.
3. Find information about the **accommodation** like camping, hotels or other accomodation (it is also an option that no information is provided).
4. Find out the festival **cost** and **try "buying" a ticket** to this festival without giving any actual payment details (e.g. add the tickets to a shopping cart and see how you would buy the tickets in practice). If there are multiple ticket types, you can choose any option you like.

If you fail to accomplish some of the tasks, you can just **skip them** and **continue.** Still, try to accomplish them all.

When you feel like you are ready, click "Next" to answer the questions considering your user experience with this web interface.

<-- Previous   Next -->

41% completed

User experience of web interfaces

Please answer the following statements about Dimensions Festival.

1 = STRONGLY DISAGREE
7 = STRONGLY AGREE *

	1	2	3	4	5	6	7
It was NOT tiring to use this website.							
I easily understood what the website and interface were meant for.							
I found it easy to control the interface while completing the tasks.							
This interface was comfortable to look at (i.e. it didn't irritate my eyes).							
I could see myself identifying personally with this website.							
The website built trust towards the organization in question.							
It was easy to recover from possible errors or navigation faults.							
The elements in the interface were self-explanatory.							
The interface was intuitive.							
It was a pleasure to use this interface.							
I found this interface useful for completing the required tasks.							
The interface was creative.							
I was able to easily achieve all the practical goals and tasks I had set for this interface.							
I was able to learn how to use all the functionalities in this interface needed to complete the required tasks.							
It was easy to do the tasks with the system.							
The website was reliable.							
It was easy to learn to use this system							
I could easily tell whether I could accomplish the given tasks through this interface.							
The interface was clear.							
I felt successful after completing the required tasks.							
I could trust that the interface would behave as intended.							
The interface looked pleasant.							
I found it easy to start using this system.							
The interface was fascinating.							
I was satisfied with the results and consequences of use in this interface.							
The website evoked pleasant mental images and/or memories.							
The interface was attractive/aesthetic.							
I felt comfortable using this website.							

<-- Previous   Next -->

50% completed

User experience of web interfaces

Reworks Festival

The next website you are going to visit is http://reworks.gr/en/ - please **right-click to open the link in a new tab or window.**

At http://reworks.gr/en/ please complete the following tasks (same as in the previous website), not necessarily in this order.

1. Find the festival **dates** and the **location/address.**
2. Find the festival **programme** and browse through it.
   - **Pick one** performance that interests you the most and read more about it.
3. Find information about the **accommodation** like camping, hotels or other accomodation (it is also an option that no information is provided).
4. Find out the festival **cost** and **try "buying" a ticket** to this festival without giving any actual payment details (you can for example add the tickets to a shopping cart and see how you would buy the tickets in practice). If there are multiple ticket types, you can choose any option you like.

If you fail to accomplish some of the tasks, you can just **skip them** and **continue**. Still, try to accomplish them all.

When you feel like you are ready, press continue to answer the questions considering your user experience with this web interface.

<-- Previous | Next -->

58% completed

User experience of web interfaces

Please answer to the following statements about Reworks Festival website.

1 = STRONGLY DISAGREE
7 = STRONGLY AGREE *

	1	2	3	4	5	6	7
It was easy to recover from possible errors or navigation faults.							
It was easy to learn to use this system							
I felt comfortable using this website.							
I could see myself identifying personally with this website.							
The website evoked pleasant mental images and/or memories.							
The interface was clear.							
The website was reliable.							
I found it easy to control the interface while completing the tasks.							
It was NOT tiring to use this website.							
The interface was fascinating.							
This interface was comfortable to look at (i.e. it didn't irritate my eyes).							
It was easy to do the tasks with the system.							
I felt successful after completing the required tasks.							
The interface was intuitive.							
I was able to easily achieve all the practical goals and tasks I had set for this interface.							
I easily understood what the website and interface were meant for.							
The interface was attractive/aesthetic.							
The website built trust towards the organization in question.							
I could easily tell whether I could accomplish the given tasks through this interface.							
The interface looked pleasant.							
The interface was creative.							
I was able to learn how to use all the functionalities in this interface needed to complete the required tasks.							
The elements in the interface were self-explanatory.							
I found it easy to start using this system.							
It was a pleasure to use this interface.							
I found this interface useful for completing the required tasks.							
I could trust that the interface would behave as intended.							
I was satisfied with the results and consequences of use in this interface.							

<-- Previous   Next -->

66% completed

User experience of web interfaces

TodaysArt Festival

The final website you are going to visit is http://todaysart.nl/2015/teaser/ - please **right-click to open the link in a new tab or window.**

At http://todaysart.nl/2015/teaser/ please complete the following tasks (same as in the previous website), not necessarily in this order.

1. Find the festival **dates** and the **location/address.**
2. Find the festival **programme** and browse through it.
   - **Pick one** performance that interests you the most (does not have to be a musical performance) and read more about it.
3. Find information about the **accommodation** like camping, hotels or other accomodation (it is also an option that no information is provided).
4. Find out the festival **cost** and **try "buying" a ticket** to this festival without giving any actual payment details (you can for example add the tickets to a shopping cart and see how you would buy the tickets in practice). If there are multiple ticket types, you can choose any option you like.

If you fail to accomplish some of the tasks, you can just **skip them** and **continue**. Still, try to accomplish them all.

When you feel like you are ready, press continue to answer the final set of questions considering your user experience with this web interface.

<-- Previous | Next -->

75% completed

User experience of web interfaces

Please answer the following statements about TodaysArt Festival.

1 = STRONGLY DISAGREE
7 = STRONGLY AGREE *

	1	2	3	4	5	6	7
It was easy to do the tasks with the system.							
It was NOT tiring to use this website.							
The website built trust towards the organization in question.							
I found it easy to control the interface while completing the tasks.							
The website was reliable.							
I could trust that the interface would behave as intended.							
I felt comfortable using this website.							
I could see myself identifying personally with this website.							
I was able to easily achieve all the practical goals and tasks I had set for this interface.							
I easily understood what the website and interface were meant for.							
The interface was clear.							
The interface was intuitive.							
It was easy to recover from possible errors or navigation faults.							
I felt successful after completing the required tasks.							
I was able to learn how to use all the functionalities in this interface needed to complete the required tasks.							
I found this interface useful for completing the required tasks.							
The interface looked pleasant.							
I found it easy to start using this system.							
It was a pleasure to use this interface.							
It was easy to learn to use this system							
This interface was comfortable to look at (i.e. it didn't irritate my eyes).							
I could easily tell whether I could accomplish the given tasks through this interface.							
I was satisfied with the results and consequences of use in this interface.							
The interface was fascinating.							
The interface was creative.							
The elements in the interface were self-explanatory.							
The interface was attractive/aesthetic.							
The website evoked pleasant mental images and/or memories.							

<-- Previous   Next -->

83% completed

User experience of web interfaces

This is the end of the questionnaire! Congratulations for completing!

Which website did you like the most? *

- ○ First, Dimensions Festival
- ○ Second, Reworks Festival
- ○ Third, TodaysArt Festival

Why did you like it the most?

[ ]

<-- Previous | Next -->

91% completed

User experience of web interfaces

I hope you enjoyed answering this questionnaire. Thank you for your participation and the time you sacrificed for science!

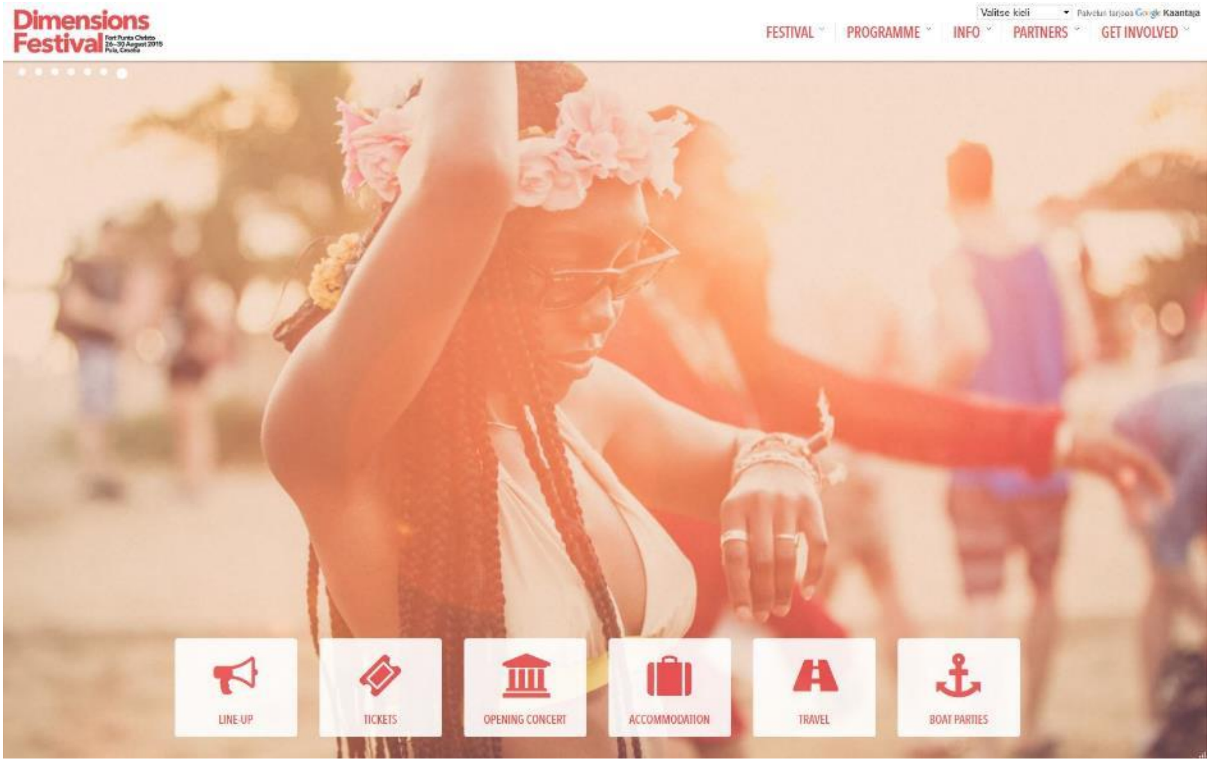
Remember to click "Submit"!

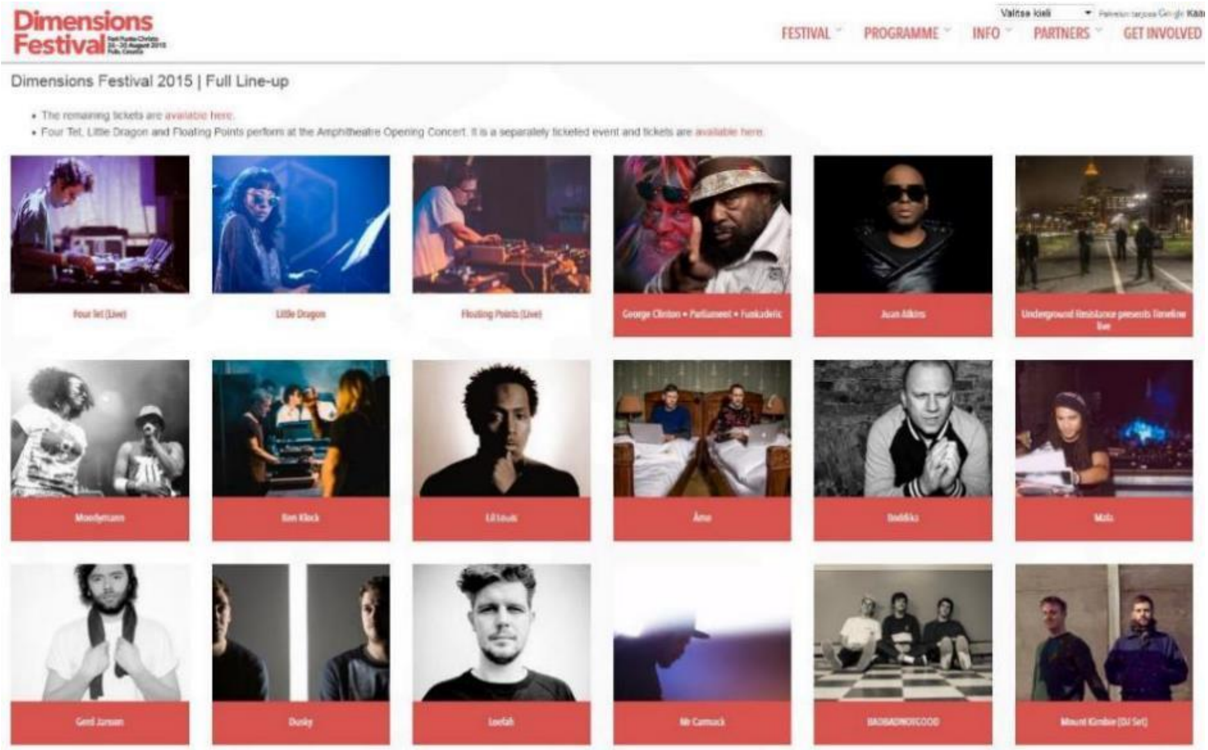
Submit | <-- Previous

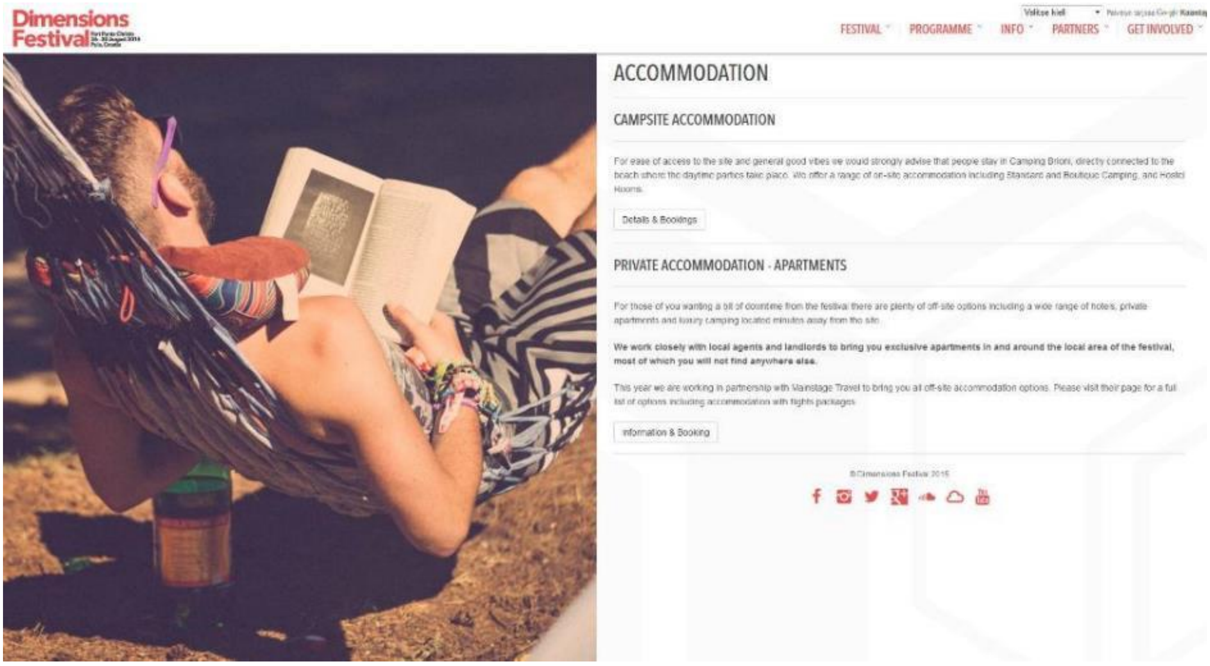
100% completed

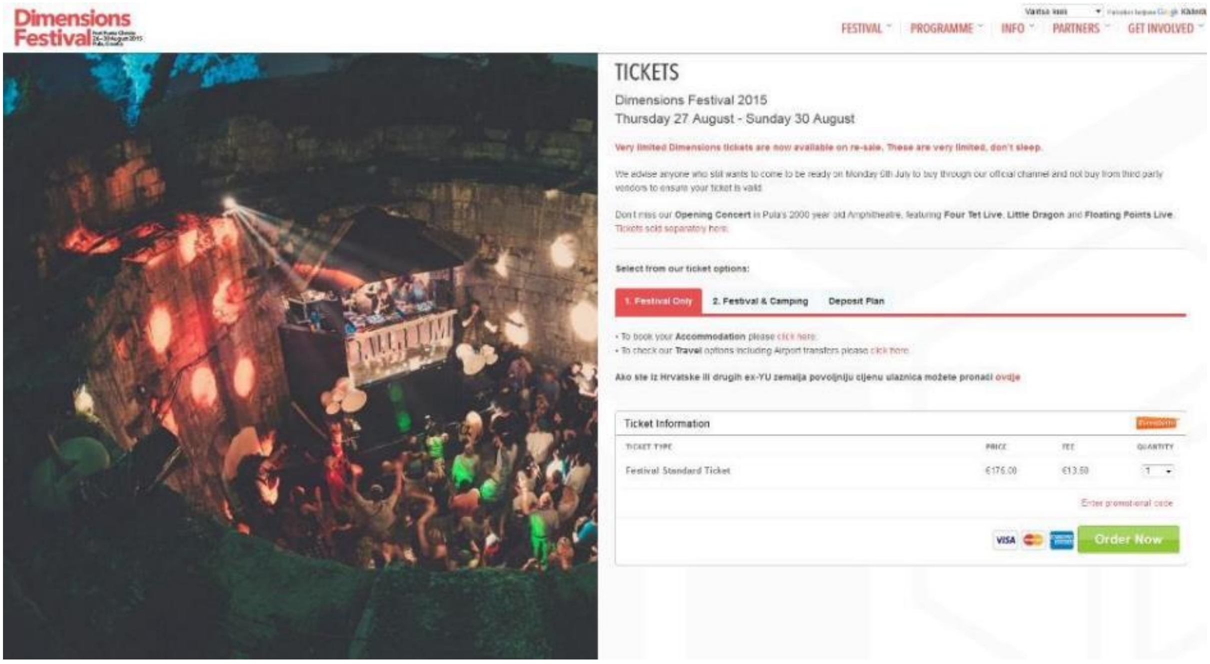
APPENDIX B: The case websites

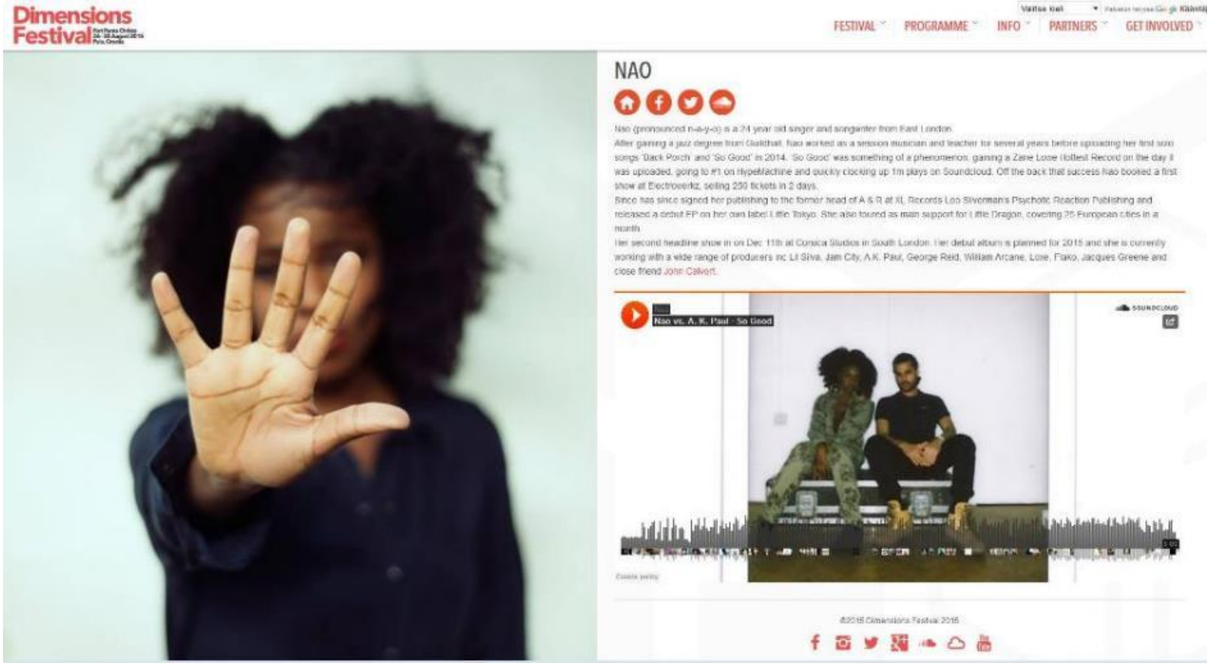
Dimensions Festival






Dimensions
Festival
FESTIVAL
PROGRAMME
INFO
PARTNERS
GET INVOLVED
ACCOMMODATION
CAMPSITE ACCOMMODATION
For ease of access to the site and general good vibes we would strongly advise that people stay in Camping Brioni, directly connected to the beach where the daytime parties take place. We offer a range of on-site accommodation including Standard and Boutique Camping, and Hostel Rooms.
Details & Bookings
PRIVATE ACCOMMODATION - APARTMENTS
For those of you wanting a bit of downtime from the festival there are plenty of off-site options including a wide range of hotels, private apartments and luxury camping located minutes away from the site.
We work closely with local agents and landlords to bring you exclusive apartments in and around the local area of the festival, most of which you will not find anywhere else.
This year we are working in partnership with Mainstage Travel to bring you all off-site accommodation options. Please visit their page for a full list of options including accommodation with flights packages.
Information & Booking


Dimensions
Festival
FESTIVAL
PROGRAMME
INFO
PARTNERS
GET INVOLVED
TICKETS
Dimensions Festival 2015
Thursday 27 August - Sunday 30 August
Very limited Dimensions tickets are now available on re-sale. These are very limited, don't sleep.
We advise anyone who still wants to come to be ready on Monday 6th July to buy through our official channel and not buy from third party vendors to ensure your ticket is valid.
Don't miss our Opening Concert in Pula's 2000 year old Amphitheatre, featuring Four Tet Live, Little Dragon and Floating Points Live.
Tickets sold separately here.
Select from our ticket options:
1. Festival Only
2. Festival & Camping
Deposit Plan
• To book your Accommodation please click here.
• To check our Travel options including Airport transfers please click here.
Ako ste iz Hrvatske ili drugih ex-YU zemalja povoljniju cijenu ulaznica možete pronaći ovdje
Ticket Information
TICKET TYPE
PRICE
FEE
QUANTITY
Festival Standard Ticket
€175.00
€13.50
1
Enter promotional code
VISA
Order Now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GET INVOLVED
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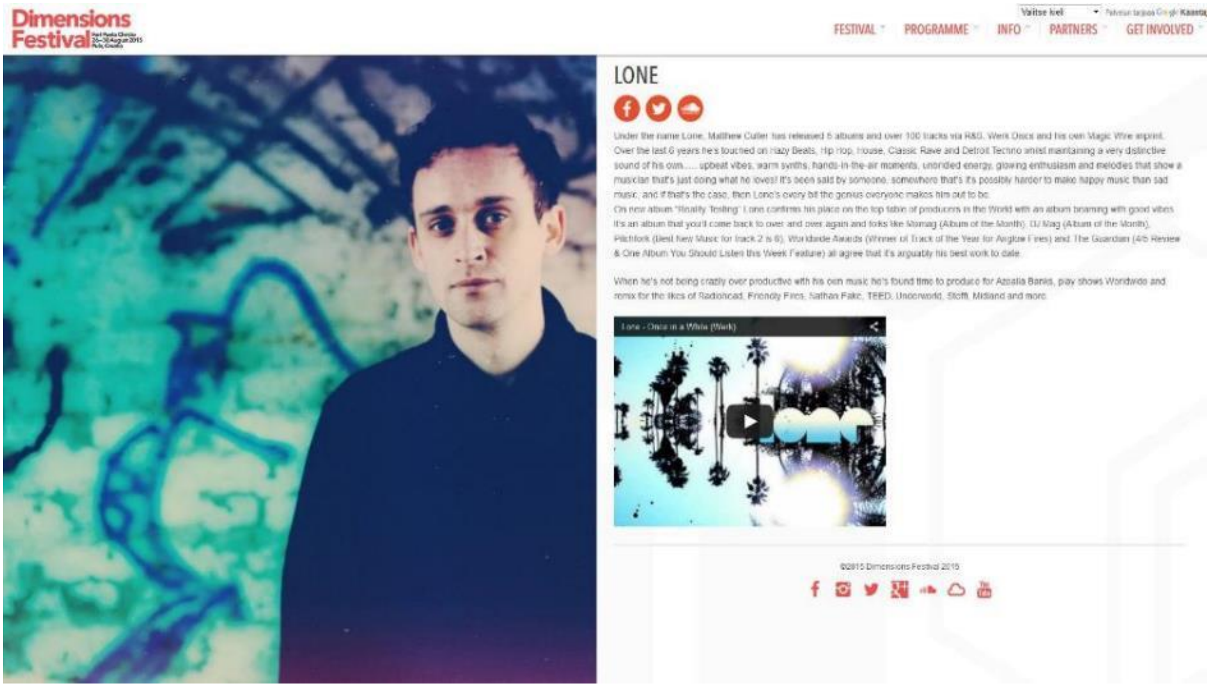
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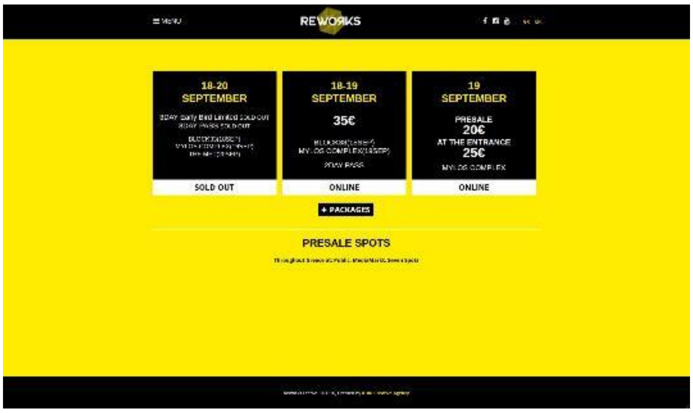
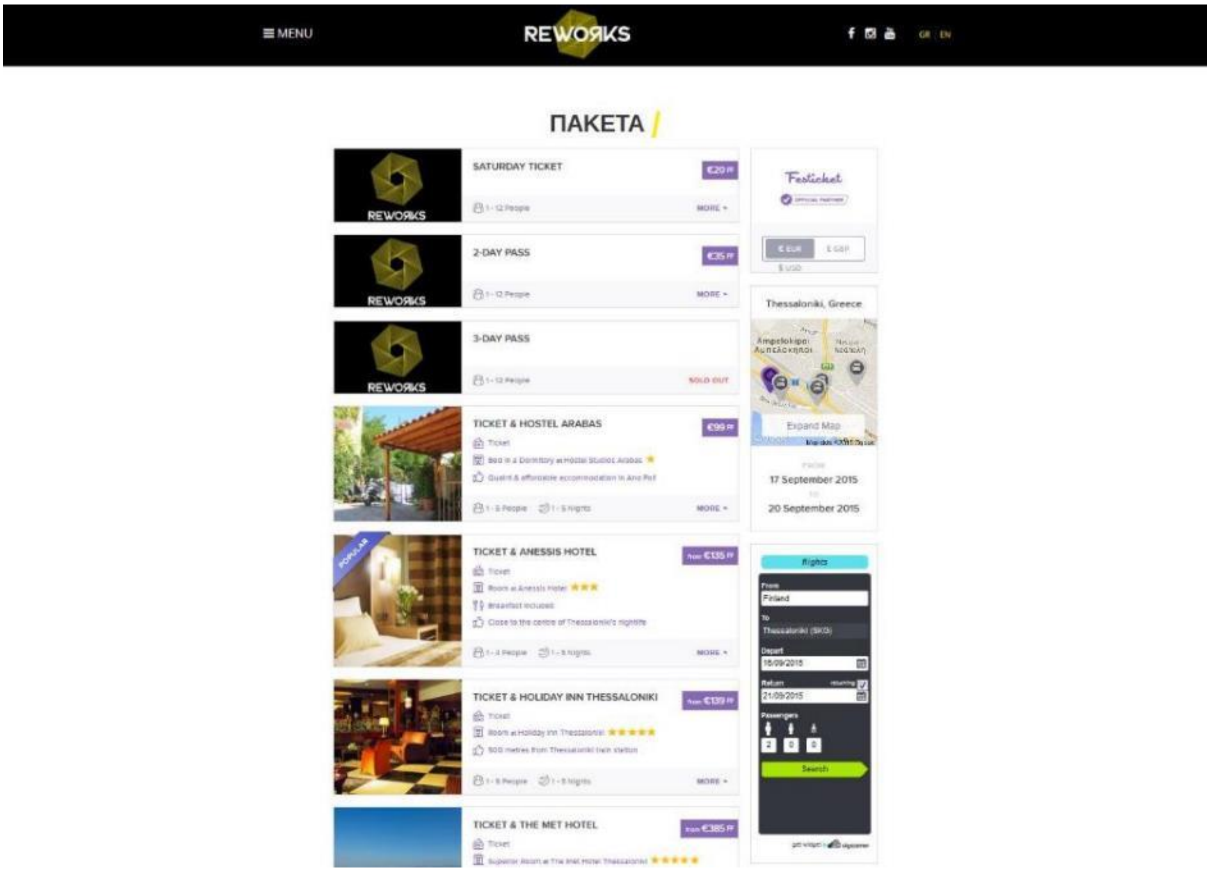
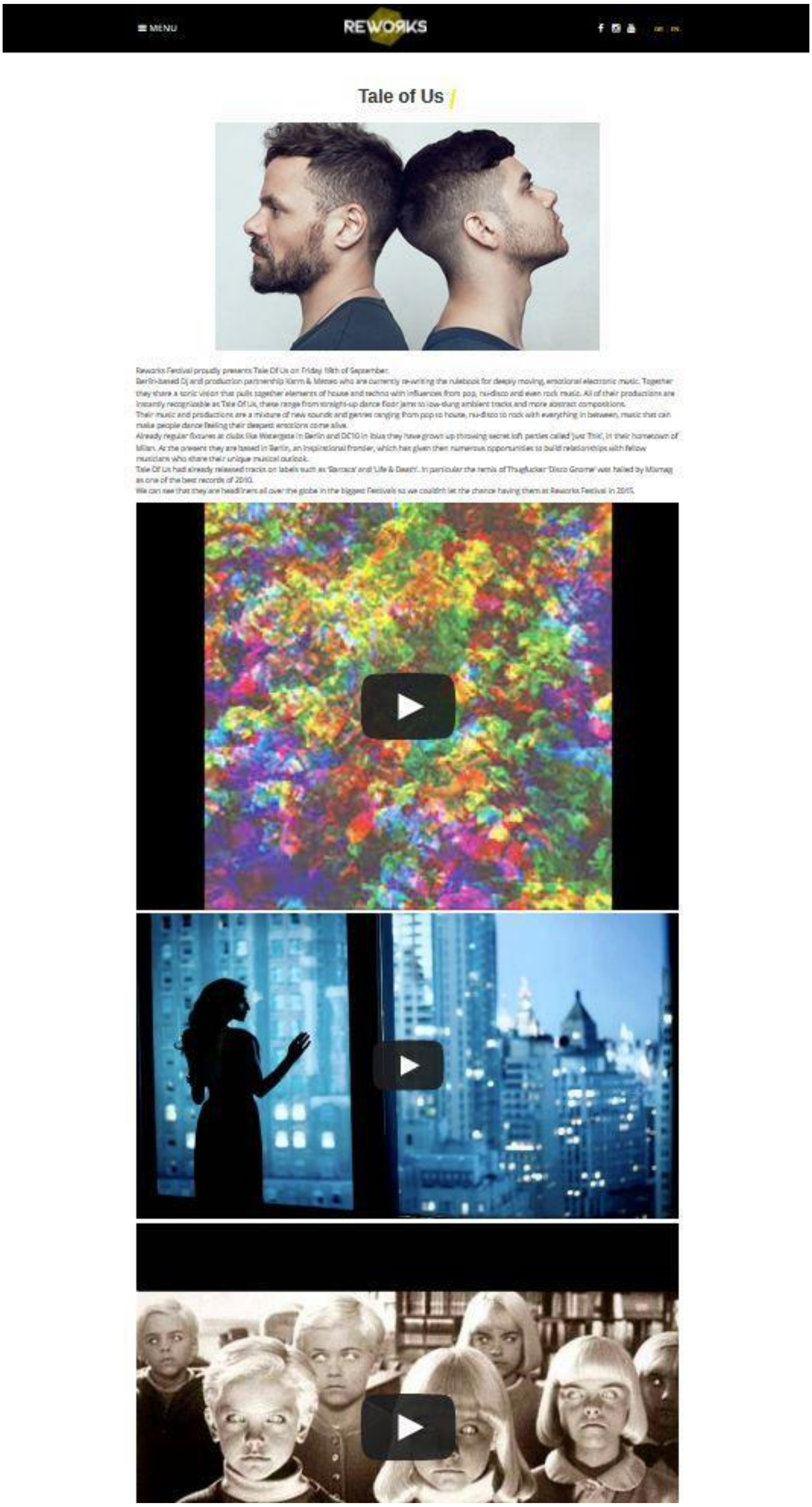
LONE

Reworks Festival

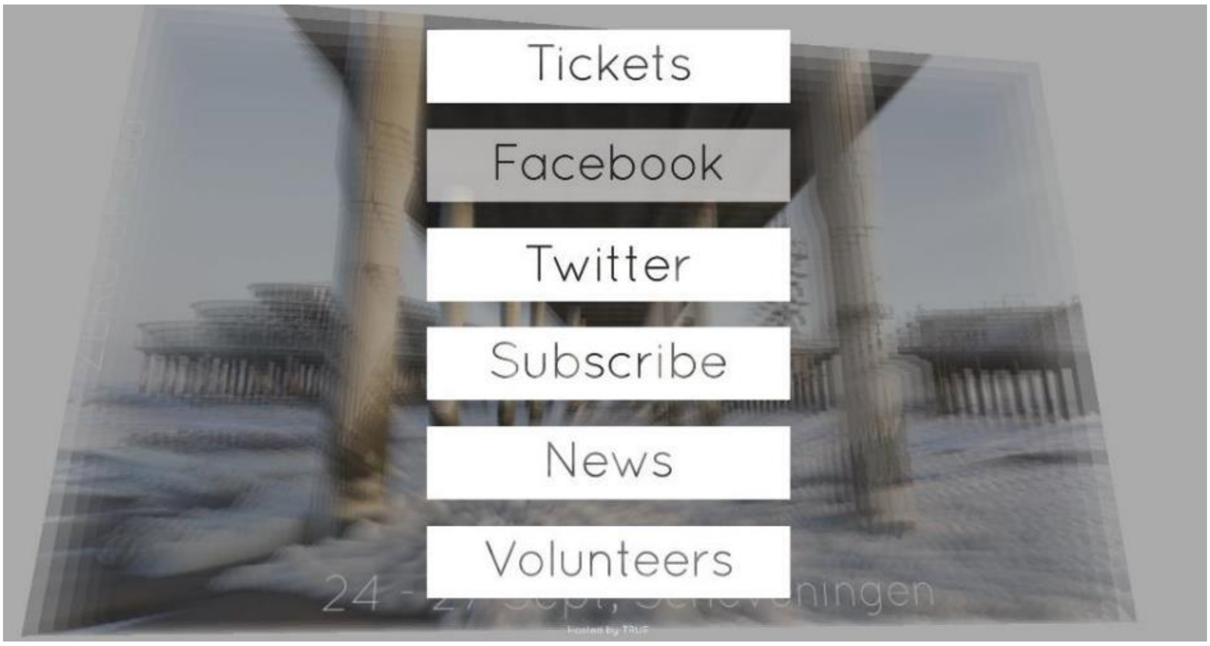

REWORKS
18-20
SEPTEMBER
SOLD OUT
18-19
SEPTEMBER
35€
ONLINE
19
SEPTEMBER
PRESALE
20€
AT THE ENTRANCE
25€
ONLINE
+ PACKAGES
PRESALE SPOTS


HOME
PROFILE
LINE UP
TICKETS
PACKAGES
NEWS
PRESS
CONTACT

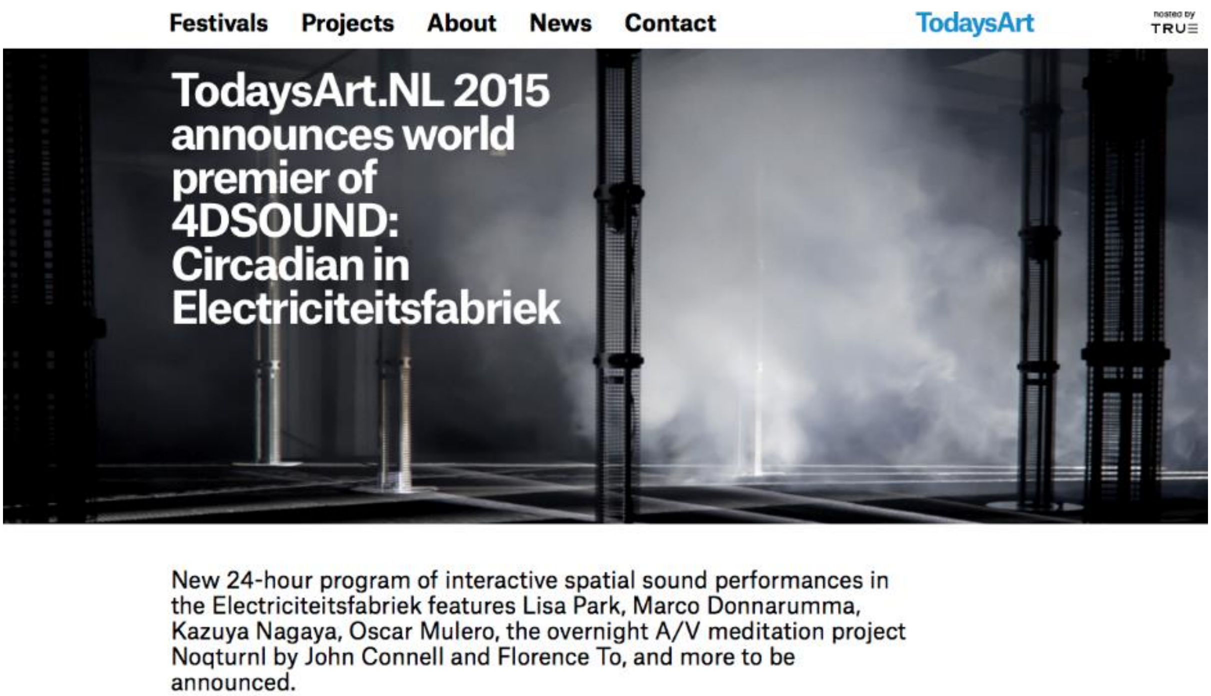

MENU
REWORKS
GR EN
ПАКЕТА
SATURDAY TICKET
€20
2-DAY PASS
€35
3-DAY PASS
SOLD OUT
TICKET & HOSTEL ARABAS
€99
TICKET & ANESSIS HOTEL
€135
TICKET & HOLIDAY INN THESSALONIKI
€139
TICKET & THE MET HOTEL
€385
Festicket
Thessaloniki, Greece
Expand Map
17 September 2015
20 September 2015
Flights
Finland
Search


MENU
REWORKS
Tale of Us
Reworks Festival proudly presents Tale Of Us on Friday 18th of September.
Berlin-based Dj and production partnership Karm & Matteo who are currently re-writing the rulebook for deeply moving, emotional electronic music. Together they share a sonic vision that pulls together elements of house and techno with influences from pop, nu-disco and even rock music. All of their productions are instantly recognizable as Tale Of Us, these range from straight-up dance floor jams to low-slung ambient tracks and more abstract compositions.
Their music and productions are a mixture of new sounds and genres ranging from pop to house, nu-disco to rock with everything in between, music that can make people dance feeling their deepest emotions come alive.
Already regular fixtures at clubs like Watergate in Berlin and DC10 in Ibiza they have grown up throwing secret loft parties called 'Just This', in their hometown of Milan. At the present they are based in Berlin, an inspirational frontier, which has given them numerous opportunities to build relationships with fellow musicians who share their unique musical outlook.
Tale Of Us had already released tracks on labels such as 'Barraca' and 'Life & Death'. In particular the remix of Thugfucker 'Disco Gnome' was hailed by Mixmag as one of the best records of 2010.
We can see that they are headliners all over the globe in the biggest Festivals so we couldn't let the chance having them at Reworks Festival in 2015.

TodaysArt Festival




TodaysArt 2015
Inspired by the Pier and ZERO on Sea, TodaysArt creates a contemporary event filled with visual art, performances, interventions, club nights and presentations.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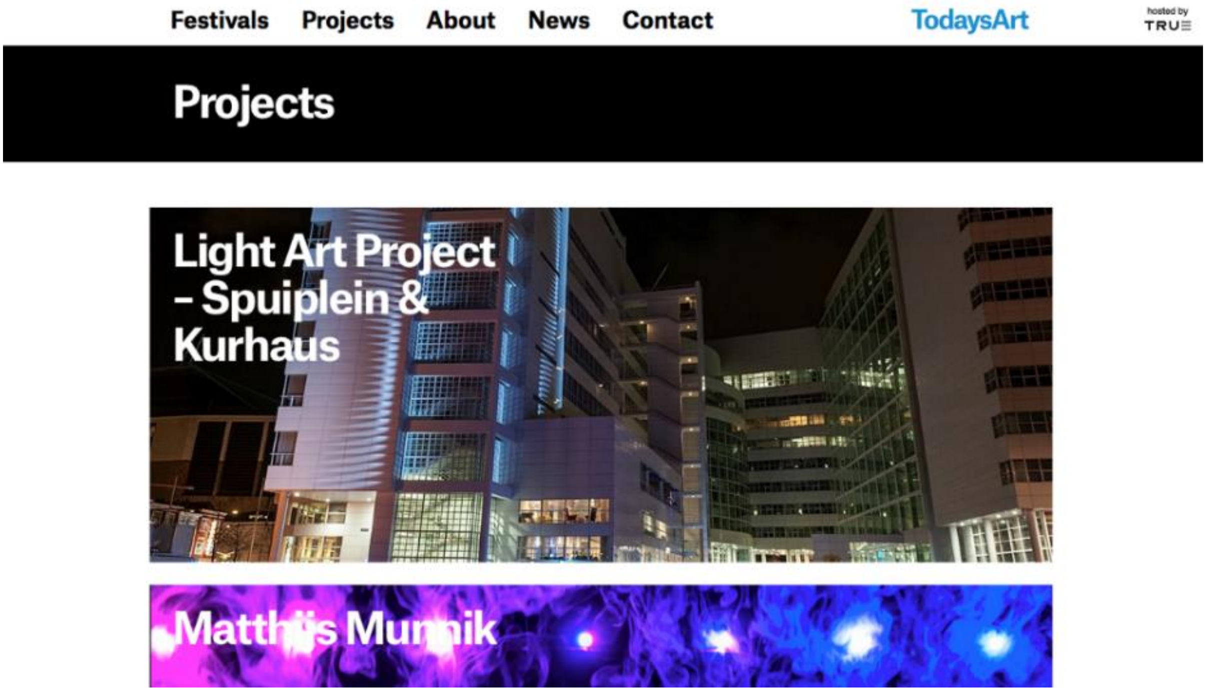
TodaysArt
hosted by TRUE
TodaysArt.NL 2015 announces world premier of 4DSOUND: Circadian in Electriciteitsfabriek
New 24-hour program of interactive spatial sound performances in the Electriciteitsfabriek features Lisa Park, Marco Donnarumma, Kazuya Nagaya, Oscar Mulero, the overnight A/V meditation project Noqturnl by John Connell and Florence To, and more to be announced.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hosted by
TRUE
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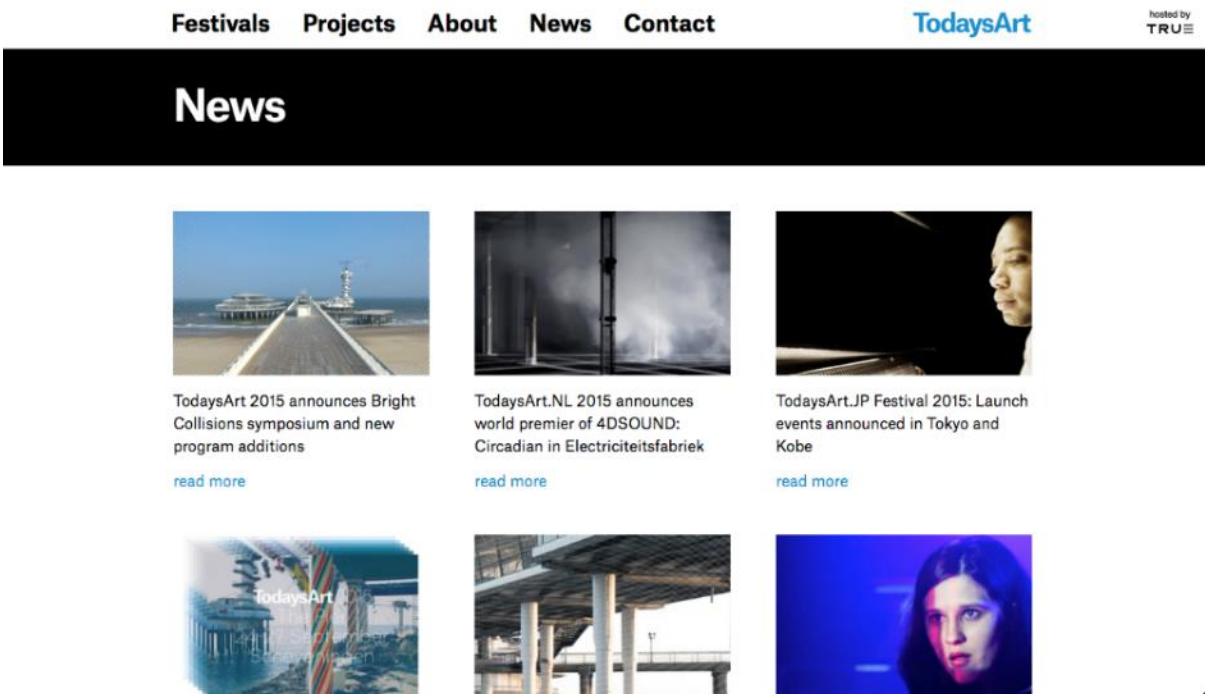
Light Art Project – Spuiplein & Kurhaus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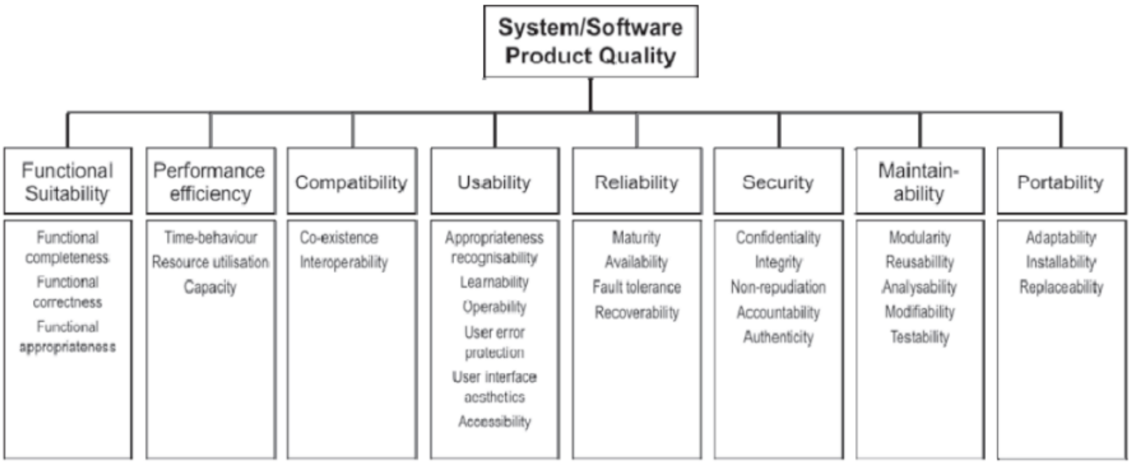
TodaysArt 2015 announces Bright Collisions symposium and new program additions
read more
TodaysArt.NL 2015 announces world premier of 4DSOUND: Circadian in Electriciteitsfabriek
read more
TodaysArt.JP Festival 2015: Launch events announced in Tokyo and Kobe
read more

APPENDIX C: The ISO standards

ISO/IEC 25010:2011 Product Quality model



The System/Software Product Quality characteristics are described in the ISO/IEC 25010:2011 standard as:

- **Functional Suitability.** Degree to which a product or system provides functions that meet stated and implied needs when used under specified conditions.
  - NOTE: Functional suitability is only concerned with whether the functions meet stated and implied needs, not the functional specifications.
- **Performance Efficiency.** Performance relative to the amount of resources used under stated conditions.
  - NOTE: Resources can include other software products, the software and hardware configuration of the system, and materials (e.g. print paper, storage media).
- **Compatibility.** Degree to which a product, system or component can exchange information with other products, systems or components, and/or perform its required functions, while sharing the same hardware or software environment.
  - NOTE: Adapted from ISO/IEC/IEEE 24765.
- **Usability.** Degree to which a product or system can be used by specified users to achieve specified goals with Effectiveness, Efficiency, and Satisfaction in specified context of use.
  - NOTE 1: Adapted from ISO 9241-210.

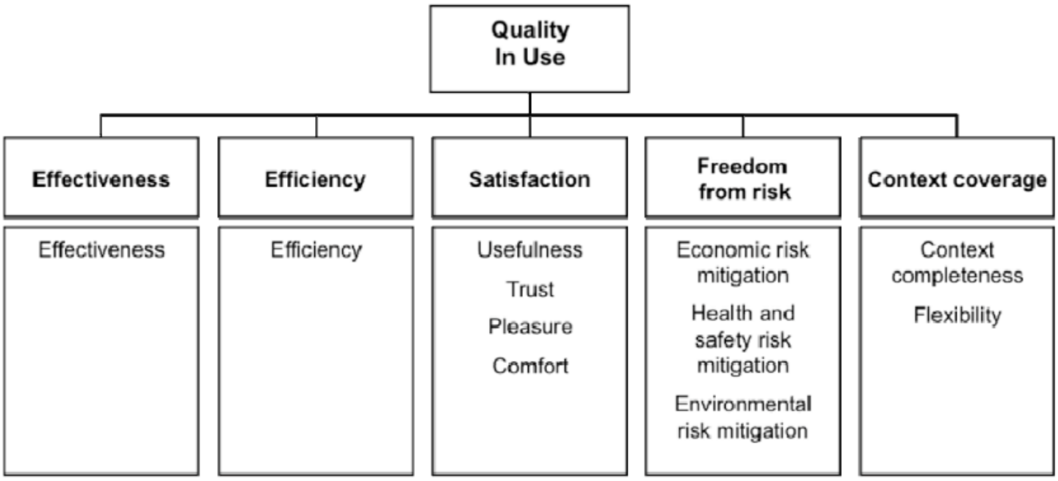
  - NOTE 2: Usability can either be specified or measured as a Product Quality characteristic in terms of its subcharacteristics, or specified or measured directly by measures that are a subset of Quality-in-Use.
- **Reliability.** Degree to which a system, product or component performs specified functions under specified conditions for a specified period of time.
  - NOTE 1: Adapted from ISO/IEC/IEEE 24765.
  - NOTE 2: Wear does not occur in software. Limitations in reliability are due to faults in requirements, design and implementation, or due to contextual changes.
  - NOTE 3: Dependability characteristics include availability and its inherent or external influencing factors, such as availability, reliability (including fault tolerance and recoverability), security (including confidentiality and integrity), maintainability, durability, and maintenance support.
- **Security.** Degree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization.
  - NOTE 1: As well as data stored in or by a product or system, security also applies to data in transmission.
  - NOTE 2: Survivability (the degree to which a product or system continues to fulfill its mission by providing essential services in a timely manner in spite of the presence of attacks) is covered by recoverability (the degree to which, in the event of an interruption or failure, a product or system can recover the data directly affected and re-establish the desired state of the system).
  - NOTE 3: Immunity (the degree to which a product or system is resistant to attack) is covered by integrity (degree to which a system product or component prevents unauthorized access to, or modification of, computer programs or data).
  - NOTE 4: Security contributes to Trust (degree to which a user or other stakeholder has confidence that a product or system will behave as intended).
- **Maintainability.** Degree of effectiveness and efficiency with which a product or system can be modified by the intended maintainers.
  - NOTE 1: Modifications can include corrections, improvements or adaptation of the software to changes in the environment, and in requirements and

functional specification. Modifications include those carried out by specialized support staff, and those carried out by business or operational staff, or end users.

    - NOTE 2: Maintainability includes installation of updates and upgrades.
    - NOTE 3: Maintainability can be interpreted as either an inherent capability of the product or system to facilitate maintenance activities, or the Quality-in-Use experienced by the maintainers for the goal of maintaining the product or system.

- **Portability.** Degree of effectiveness and efficiency with which a system, product or component can be transferred from one hardware, software or other operational or usage environment to another.
    - NOTE 1: Adapted from ISO/IEC/IEEE 24765.
    - NOTE 2: Portability can be interpreted as either an inherent capability of the product or system to facilitate porting activities, or the Quality-in-Use experienced for the goal of porting the product or system.

ISO/IEC 25010:2011 Quality-in-Use model



The Quality-in-Use characteristics are described in the ISO/IEC 25010:2011 standard as:

- **Effectiveness.** Accuracy and completeness with which users achieve specified goals.
- **Efficiency.** Resources expended in relation to the accuracy and completeness with which users achieve goals.
    - NOTE: Relevant sources can include time to complete the task (human resources), materials, or the financial cost of usage.
- **Satisfaction.** Degree to which user needs are satisfied when a product or system is used in a specific context of use.
    - NOTE 1: For a user who does not directly interact with the product or system, only purpose accomplishment and Trust are relevant.
    - NOTE 2: Satisfaction is the user's response to interaction with the product or system, and includes attitudes towards use of the product.
- **Freedom from Risk.** Degree to which a product or system mitigates the potential risk to economic status, human life, health, or the environment.
    - NOTE: Risk is a function of the probability of occurrence of a given threat and the potential adverse consequences of that threat's occurrence.
- **Context coverage.** Degree to which a product or system can be used with Effectiveness, Efficiency, Freedom from Risk and Satisfaction in both specified contexts of use and in contexts beyond those initially explicitly identified.
    - NOTE: Context of use is relevant both to Quality-in-Use and some Product Quality (sub)characteristics (where it is referred to as "specified conditions").