JYVÄSKYLÄ STUDIES IN COMPUTING
261

Johanna Silvennoinen

Apperceiving Visual Elements in Human-technology Interaction Design

JYVÄSKYLÄN YLIOPISTO

JYVÄSKYLÄ STUDIES IN COMPUTING 261

Johanna Silvennoinen

Apperceiving Visual Elements in Human-technology Interaction Design

Esitetään Jyväskylän yliopiston informaatioteknologian tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston Ylistönrinteellä, salissa YlistöKem1
maaliskuun 29. päivänä 2017 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Information Technology of the University of Jyväskylä,
in Ylistönrinne, auditorium YlistöKem1, on March 29, 2017 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Apperceiving Visual Elements in Human-technology Interaction Design

JYVÄSKYLÄ STUDIES IN COMPUTING 261

Johanna Silvennoinen

Apperceiving Visual Elements in Human-technology Interaction Design

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2017

Editors
Marja-Leena Rantalainen
Faculty of Information Technology, University of Jyväskylä
Pekka Olsbo, Ville Korkiakangas
Publishing Unit, University Library of Jyväskylä

Cover picture: *Apperceiver* by Johanna Silvennoinen.

Permanent link to this publication: http://urn.fi/URN:ISBN:978-951-39-7002-4

URN:ISBN:978-951-39-7002-4
ISBN 978-951-39-7002-4 (PDF)

ISBN 978-951-39-7001-7 (nid.)
ISSN 1456-5390

Jyväskylä University Printing House, Jyväskylä 2017

Dedicated with loving memory to
Jouni Silvennoinen

ABSTRACT

Silvennoinen, Johanna Maria
Apperceiving Visual Elements in Human-technology Interaction Design
Jyväskylä: University of Jyväskylä, 2017, 83 p. (+ included articles)
(Jyväskylä Studies in Computing
ISSN 1456-5390; 261)
ISBN 978-951-39-7001-7 (nid.)
ISBN 978-951-39-7002-4 (PDF)

Visual design of technological artefacts is an integral part of peoples' experiences in technology-interaction. Visual product properties are capable of eliciting affective responses and multisensorial experiences in human-technology interaction. Current research in the field of human-technology interaction focuses on visual, emotional and multisensory aspects of interaction in addition to functionality and usability. However, the focus has not been on how performative aspects of visual elements affect technology-interaction as a cognitive sense making process shaping human experiences. To design technological contact points to be made sense of, the substance of visual representations requires clarification to conduct argument-based technology-design, and to base design solutions on scientific results. Therefore, research is required to explicate what visual experience is in human-technology interaction, how its constituent factors and underlying dynamics can be studied, and how to design with this research-based knowledge.

In this thesis, visual elements contributing to cognitive and affective processes of visual experience in human-technology interaction are examined from an interactionist perspective. The focus is on the role of visual elements in visual usability, aesthetic appeal and emotional aspects in experiencing technological artefacts and to explicate visual experience in appraising visual stimuli via apperception. The explication of visual experience as a cognitive-affective process contributes fundamentally to how visual representations of technological artefacts are made sense of and experienced, and thus, provides a basis for argument-based visual technology-design. As a result of an interactionist approach in examining visual element appraisals in human-technology interaction, a theoretical framework is presented. The framework integrates different dimensions of visual experience with interactionist methodological position and functions as a basis for argument-based visual design. The constituent dimensions of visual experience are visual usability and aesthetic appeal, which are the concepts with which visual experiences are studied and explicated in detail as operationalised in the experiments presented in the seven attached articles. The framework of visual experience can be utilised as a discourse tool in research and design of visual technological designs, and as an explanatory framework for argument-based visual design.

Keywords: visual elements, apperception, aesthetic appeal, visual experience, argument-based design, human-technology interaction

Author Johanna Silvennoinen
Dept. of Computer Science and Information Systems
University of Jyväskylä
Finland
johanna.silvennoinen@jyu.fi

Supervisors Pertti Saariluoma
Dept. of Computer Science and Information Systems
University of Jyväskylä
Finland

Annika Waenerberg
Department of Art and Culture Studies
University of Jyväskylä
Finland

Reviewers Jonna Häkkilä
Faculty of Arts and Design
University of Lapland
Finland

Satu Jumisko-Pyykkö
Department of Pervasive Computing
Tampere University of Technology
Finland
and
Industrial Engineering & Innovation Sciences
Technical University of Eindhoven
The Netherlands

Opponent Paul Hekkert
Department of Industrial Design
Delft University of Technology
The Netherlands

ACKNOWLEDGEMENTS

Conducting a doctoral thesis is an intriguing and complex task to accomplish. It requires multitude of skills and abilities, which also include external enablers. Therefore, I have many people's support to be grateful of. First of all, my first supervisor Pertti Saariluoma, Professor of Cognitive Science, has enlivened my viewpoints on several topics concerning cognitive science, design and human perspective to technology-design. I am truly grateful of all the support and encouragement you have provided me during this process. My second supervisor Annika Waenerberg, Professor of Art History, has been important in advising and guiding my thinking regarding the visual substance of my work. I am astonished of the way you think of the visual in this world and the insights, which linger between various disciplines and fields. I am also grateful to the two external reviewers for their valuable comments.

People with whom I have had the pleasure of collaborating with, Jussi, Rebekah, Tuomo, Piia, Marlene, Sari, and Alice, I could not be more grateful of being able to work with you. Jussi, our discussions and the articles written together have had an enormous impact on my thinking. I sincerely thank you of everything. By combining our forces, we have created theoretical and methodological contributions to our research field, and this work continues. Tuomo, thank you for being able to work in your project (Optimum) in the beginning of my thesis. This possibility taught me various new things, which have resulted in efficient and pleasurable collaboration also in research and in teaching. Rebekah, our *"human sun"*, I adore your enthusiasm and look forward on our work on multisensory experience research and design, which intrigues me greatly. I would also like to thank Laura, Emma, and Tiia (our RMUE-project team) for your support, insightful meetings, and the encouraging and inspirational work environment that you have created for all of us. Piia, our work lives in the Laboratory of User Psychology, what we call as home, has indeed functioned as a home due to your presence, support and listening. Naomi, I thank you sincerely of the magnificent song you created for my Thesis mascot *"The Uncorn"* and also of the wonderful songs for our experiments that enliven our collaboration. Without UCIT (Academy of Finland -funded National Doctoral School Program in User-Centred Information Technology) research stay in Technische Universität Berlin would not have been possible, and, thus, I would not have had the possibility of meeting, Marlene, Sari, and Alice. This collaboration has aided me in my pursuits and I am grateful of it.

My family has always supported me, and also during this process. I am happy that my mother has endured my everlasting questioning age, which does not seem to ever end. This way of making sense and experiencing the world around me has year by year growth the researcher in me. I cannot thank you enough for your patience, support, and for wakening the questioning attitude in me towards all things encountered. In addition, your saying: *"Research is much fun!"*, which annoyed me at times when I was younger, has proven to be explicitly true. My father, has is without no doubt guided my working without being present, as has Ulla Pohjamo. My siblings, Kimmo, Saana, and Arttu thank you for being there. My uncle, Pirkka, has been an influential person in my life, and has had a major influence on how I have come to be. My great aunt, Sirkka-Leena has supported me and my family. Also, my extended family, Arja, Jussi, Juho, Anna, Hanna, Heikki, Jaakko, Tuukka, Tuure, Touko, and Silmu, I am truly grateful of having you in my life, and enormously happy of belonging to this wonderful family. I cannot thank my friends enough for their support and, also patience of listening my wonderings, often emerging new ideas and of course occasional problems too, thank you, you are the best. My deepest gratitude goes to my spouse Mikko, hopefully, this comes as a no surprise to you, as I hope that during this hectic period of my life, I have remembered to express this often enough. Without you in my life, everything would be grayer. You help me in so many ways and bring joy, happiness, and safety, to name a few qualities that colour my days along with our three hairy children, Leda, Lana, and Taavi.

Last, but not least, I would like to thank COMAS (Doctoral Program in Computing and Mathematical Sciences of the Faculty of Information Technology, University of Jyväskylä), without the support of this doctoral school this work could not have been conducted. I would also like to thank you The Finnish Cultural Foundation of supporting me with a grant to finalise this thesis. Moreover, the staff in our department, enlivening coffee break discussions with colleagues, and the timely impact of our department's research community have aided me greatly to schedule my daily routines.

Para tu mente con todos los sentidos,

Jyväskylä 12.2.2016
Johanna Silvennoinen

FIGURES

TABLE

LIST OF INCLUDED ARTICLES

I. Silvennoinen, J., Vogel, M., & Kujala, S. (2014). Experiencing visual usability and aesthetics in two mobile application contexts. *Journal of Usability Studies, 10*(1), 46-62.

II. Gross, A., & Silvennoinen, J. (2014). Surprise as a design strategy in goal-oriented mobile applications. In *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics* (pp. 4716-4726).

III. Silvennoinen, J. M., & Jokinen, J. P. P. (2016). Appraisals of salient visual elements in web page design. *Advances in Human-Computer Interaction,* Article ID 3676704, 14 pages.

IV. Jokinen, J. P. P., Silvennoinen, J., Perälä, P., & Saariluoma, P. (2015). Quick affective judgments: Validation of a method for primed product comparisons. In *Proceedings of the 2015 Conference on Human Factors in Computing Systems – CHI '15* (pp. 2221-2230). New York: ACM.

V. Silvennoinen, J. M., Kujala, T., & Jokinen, J. P. P. (unpublished manuscript). Semantic distance as a critical design factor for in-car infotainment systems. In review in *Applied Ergonomics.*

VI. Silvennoinen, J. M., & Jokinen, J. P. P. (2016). Aesthetic appeal and visual usability in four icon design eras. In *Proceedings of the 2016 Conference on Human Factors in Computing Systems – CHI '16* (pp. 4390-4400). New York: ACM.

VII. Silvennoinen, J. M., Rousi, R., Jokinen, J. P. P., & Perälä, P. M. H. (2015). Apperception as a multisensory process in material experience. In *Proceedings of the 19th International Academic Mindtrek Conference (pp. 144-151). ACM.*

Contributions in the articles: In *Article I*, I am responsible for the main line of thought concerning the substance of the study, the second author was responsible for conducting the experiments, and the third author acted in a supervisor's role. All the authors cowrote the paper. *Article II* consisted of joint writing, I regarding visuality and its connection to emotions, the first author was responsible for the sections concerning surprise. The experiment was planned together, and the second author conducted the experiment in practice. Results were jointly produced based on the data analysis. *Articles III, V,* and *VII* were written in joint collaboration with all the authors, but I as the first author formulated the main ideas of the research problems and substance contributions were firstly outlined by my thinking, and then discussed with the other authors. *Article VI* resulted from joint collaboration, starting from planning the idea and research problem to be investigated. I as the first author was responsible for the main theoretical concepts presented. Regarding *article IV*, all the authors worked in collaboration in planning the experiment. The last author functioned in a supervisor´s role, third author was responsible of conducting the experiment. The first author and I, as the second author, were responsible of writing the results of the study and deriving the contributions of the study. The first author was responsible for building the theoretical background of the study.

CONTENTS

1 INTRODUCTION

In human-technology interaction (HTI) visual interfaces are concrete contact points of structures and abstract information totalities to be obtained by people, and the key to interact with different technological artefacts. Technological designs are embedded into our everyday lives and affect our interactions and actions in the world. What is visually presented to people is just the ice berg of the totality of the interactive system. Visual product properties are capable of evoking both affective responses and multisensorial experiences in human-technology interaction. The way some combination of information is designed to appear can be conducted in numerous ways. To design technological contact points to be made sense of, the substance of visual representations requires clarification in order the visual to be tamed for technology-design. This calls for cognitive-affective understanding of the dynamics of visual experience starting from the lowest-level variables, i.e. visual elements to mental information contents of experiences via apperception in appraisal process. The explication of visual experience as a cognitive-affective process contributes to how visual representations of technological artefacts are made sense of and experienced by humans, and also provides the basis for argument-based visual technology-design.

HTI is always multisensorial and affective by its nature. We make sense and experience technological artefacts through the senses in a cognitive-affective manner. The dominance of visual modality among the senses (e.g., Goldstein, 1999), and thus visual substance in experiencing artefacts has led to diverse research fields concentrating on visual phenomenon, such as, visual cognition, visual culture, art history, aesthetics (including computational, empirical, evolutionary, and neuroaesthetics), visual communication, visual literacy research, visual analytics, information visualisation, and semiotics. Due to the various dimensions involved in experiencing visual entities, the complexity of the phenomenon of visual experience has gathered interest among scholars from various disciplines in resolving the dynamics of the visual and how it is experienced. However, despite of all the different research areas and methodologies devoted to disclose the contents of the visual, it is not either unambiguous how the contents of the visual differ from each other or what are the underlying constructs through which the visual is approached and operationalised in research procedures.

The complexity and multiple dimensions of human experiencing and making sense of the visual necessitates insights in understanding and explicating it. The process of visual experience, as a conscious mental phenomenon, involves various cognitive and affective processes, such as, attention, perception, apperception, mental representations with infromation contents (Saariluoma 2005), as well as aesthetic appraisal (Silvennoinen & Jokinen 2016b). Therefore, inside the scope of this thesis are the fields of visual design, visual communication design, empirical aesthetics, visual aesthetics in HTI and emotional design. Various other fields have focused on understanding how we experience the visual, but omit cognitive-affective explications of experience as a conscious mental phenomenon. This thesis approaches the issue of visual experience of technological artefacts from the viewpoint of cognitive-affective process as a conscious mental occurrence.

In the domain of HTI, investigating human experiences in encountering and interacting with technological artefacts is at present emphasised both in research and design of technologies (e.g., Norman, 2004; Hassenzahl & Tractinsky, 2006; Koskinen & Battarbee, 2003). Research focused on experiential aspects of HTI indicates that the scientific explanation of human behaviour is achievable only with a relevant framework including cognition and emotion (Law, Roto, Hassenzahl, Vermeeren, & Kort, 2009; Zhang, 2013). Even though the ways of interacting with technological designs are artefact-specific, the processes of the interaction are not (Hekkert & Schifferstein, 2008), and thus, a framework for explaining visual technology-experiences independent of spefific design genres can be pursued.

Due to the recent paradigmatic shift from functionality and usability to more holistic aspects of HTI has brought about numerous attempts to depicher the structure of pleasurable visual technology-experiences. Visual designs convey expressive, symbolic, aesthetic, and affective meanings that extend beyond traditional functionality and usability (e.g., Crilly, Moultrie, & Clarkson, 2004; Desmet & Hekkert, 2007; Krippendorff, 1989; 2006; Postrel, 2003). For this reason, technological artefacts are not only valued for their functionality and usability, but also for aesthetics, visual design and emotions induced in technology-interaction that are essential in eliciting experiences (e.g. Desmet & Hekkert, 2007; Hassenzahl, 2001; Hassenzahl, 2008; Hassenzahl & Monk, 2010; Lavie & Tractinsky, 2004; Thüring & Mahlke; 2007; Tractinsky, Katz, & Ikar, 2000). Further, modern technological artefacts are laden with expectations such as, requirements for functionality, ease-of-use, affordability, attractiveness, safety and recyclability, as attributes expected to be inherited in products (Demirbilek & Sener, 2003). Moreover, appraising visual designs of a technological artefacts, such as user interfaces, visual appearance plays a significant role in evoking interest to interact and to compare different products (Crilly et al., 2004).

Presently accepted design paradigms underline design artefacts as mediators of shaping the relationship between humans and the world (Verbeek, 2005, p. 208). The essentiality in this is the formulations of the problems to which to design for. One approach in understanding the problem space for design is Life-based design, in which human life is set as the starting point for defining the problem space (Saariluoma & Leikas, 2010; Saariluoma, Cañas, & Leikas, 2016). User interface design, in turn, can still be seen as an engineering field, even in studying or designing aesthetics of visual experience and technology-interaction. The origins of the field have influenced and still influence how aesthetic and visual design are defined and approached in research settings.

Current research of experiencing visual designs in HTI has mainly focused on the overall visual impression of technological artefatcs (e.g., Hassenzahl & Monk, 2010; Tractinsky et al., 2000; van Schaik & Ling, 2008), and as means to enhance techonology-experiences with aesthetic appeal (e.g., Moshagen & Thielsch, 2010). More detailed approaches to visual experience have concentrated, for example, on the role of typography (e.g., Tsonos & Kouroupetroglou, 2011), Gestalt laws (e.g. Chang, Dooley, & Tuovinen, 2002), and on high-level visual elements (e.g., Tractinsky, 2012). High-level visual elements as contrasting design attributes in examining what contributes to aesthetic appeal have been studied in terms of, for instance, novelty (Wei-Ken & Lin-Lin, 2012), unity and prototypicality (Veryzer & Hutchinson, 1998), and concerning the interplay between typicality and novelty (Hekkert, Snelders, & Van Wieringen, 2003). Research on visual experience in HTI lacks knowledge of experiencing low-level visual attributes (Reppa & McDougall, 2015), or, psychophysical properties (Hekkert & Leder, 2008), that is, visual elements, such as color and size (Mullet & Sano, 1995). To understand technology-experiences affected by these visual properties novel knowledge of the underlying cognitive and affective dynamics of visual experience is required. Further, knowledge of experiences of low-level visual elements in technology-interaction can be utilised in designing for visual experiences.

Moreover, as the focus of prior research has been on experiencing the overall visual appearance (commonly studied also in terms of aesthetic appeal, aesthetics or beauty) of technological products, also the operationalisation of visual appearance is often conducted as a one-dimensional construct. Experiencing overall visual appearance has been operationalised with contructs, such as low-high aesthetics (e.g., Tractinsky et al., 2000), unattractive-attractive (e.g., Lindgaard, Fernandes, Dudek, & Brown, 2006), non-appealing-appealing (e.g., Sonderegger & Sauer, 2010), and pleasant-unpleasant (e.g., Thielsch & Hirschfeld, 2012). The operationalisation of the visual as a one-dimensional construct is the outcome of the research area's not holistic but parallel pluralist perspectives that do not connect to each other, and lack foundational analysis of visual experience. This way, research on visual experience in HTI is scattered (Udsen & Jørgensen, 2005). This reductionist viewpoint to aesthetics in technology-experiences has concluded with a restricted definition of aesthetics, which leaves out multiple viewpoints in studying aesthetics in HTI. Thus foundational differences or lack of them in conceptualisation of visual experience in HTI research questions the reliability of such research. In contemporary accounts to philosophy of aesthetics, visual experience is considered to involve various cognitive and affective processes and seen as an interpretative play (e.g. Carroll, 2001), not merely as an immediate response without interwining reasoning. Visual experience as an immediate response is however an often utilised theoretical standing point in examining aesthetic appraisals (e.g., Marković, 2012; Moshagen & Thielsch, 2010; Santanaya, 1955). Thus, research on visual experience in HTI needs explication of theoretical and methodological grounds. Also problems in designing for visual experiences occur due to unsolid theoretical grounds.

Further, several studies approach visual experience from an objectivist point of view, as describing the visual elements in technological designs as determinants of aesthetic appeal (e.g. Bauerly & Liu, 2006; Kim, Lee & Choi, 2003; Lin, Yeh, & Wei, 2013; Ngo & Byrne, 2001; Tuch, Presslaber, Stöcklin, Opwis, & Bargas-Avila, 2012). In contrast, another viewpoint to studying visual experience approach the phenomenon from subjectivist accounts (e.g. Lavie & Tractinsky, 2004; Moshagen & Thieslch, 2010), in which visual experience occurs in top-down processes of the perceiver (e.g., 'beauty is in the eye of the beholder'). However, visual experience occurs in the intersection between the objectivist and subjectivist approaches. Visual experience is a mental phenomenon including mental information contents, and involves multiple underlying cognitive and affective processes affected by visual entities constructed of visual elements (e.g. Silvennoinen & Jokinen 2016b). Mental representations consist of mental information contents, which can be of non-perceivable kinds, such as 'imaginative' and 'timeless' (Saariluoma, 1995; 1997; 2003; 2005; Saariluoma & Jokinen, 2014; Jokinen, Silvennoinen, Saariluoma, & Perälä, 2015). These represented mental contents are informed by the visual elements of technological artefacts and apperceived in appraisal processes (Saariluoma, 2005), and are the things that make design artefacts meaningful to us. Thus, interactionist approach, combining the objective and subjective accounts to visual experience in HTI is required to investigate the underlying dynamics of such experience, and to inform argument-based visual technology-design enabling understandable and experiential encounters with technology.

The scope of this thesis is extended from human-computer interaction (HCI) to HTI in order to include more extensive view to technological artefacts. The research area of HTI can be seen to include visual aspects in relation to emotion in HCI studies and in product experiences studies, due to the broader view on technological artefacts. Technological development has partly enabled the current shift in research focus. Advancements in computer graphics have opened a variety of new design possibilities, which increase the importance of visual design of user interfaces providing emotional experiences (Ngo & Byrne, 2001), as well as considering how to design for different senses in interacting with and experiencing technological artefacts (e.g., Obrist, Velasco, Vi, Ranasinghe, Israr, Cheok, Spence, & Gopalakrishnakone, 2016). Multimodal user interfaces, including images, texts, sounds and animations, possess abilities in eliciting more various emotions with numerous nuances that was possible with only text-based user interface (Cassell, Sullivan, Prevost & Churchill, 2000). In addition, technological changes are emerging in accelerating speed, volume and scale, but the operations and workings of the human mind remain more stable from a scientific stance. From design practice point of view, design needed to incorporate elements from fine arts, modern mass production, and traditional craftsmanship, and thus, not to differentiate design from arts, crafts or industry (Parsons, 2016).

My way of approaching the visual in HTI is to clarify visual experience as a process informed by the constituting components of visual representations with an interactionist approach that expands the traditional view in HCI and HTI from the information processing paradigm to visual experience as a cognitive-affective mental phenomenon. In so doing, the theoretical and methodological research position needs to be explicated because it fundamentally affects the operationalisation of the studied phenomenon, methodology choice, as well as the results from which visual design implications are derived from. Research on visual design in HTI has until now largely omitted the study of the performative aspects of visual elements as eliciting visual, emotional, and multisensorial experiences as a mental phenomenon from an interactionist perspective.

1.1 Definitions of central concepts

This thesis is concerned of apperceiving visual elements in HTI design. These central concepts are introduced below. First, apperception is defined and explicated by contrasting the concept with perception. Second, visual elements are described on the basis of visual language. Third, HTI is defined by extending HCI in terms of the C (computer), and fourth the concept of design and argument-based design are discussed.

Apperception integrates new and already existing information into a subjectively meaningful mental representation. The ways we make sense of and experience encounters with technological artefacts depends not only on new perceived sensory information, but also on already existing mental information possessed due to prior experiences and encounters (Saariluoma, 1995; 2003; 2005). Thus, apperception can be defined as *'seeing something as something'* (Husserl, 1936; Kant, 1787; Saariluoma, 2003; 2005). How technology-experience occurs in people's minds can be explained with how the object of experience is sensibly represented in this mental process of apperception. Therefore, apperception is not mere perception, but integrates and functions as a unifying process in experience resulted from impressions formed by the composition and integration of different information sources from the various human senses. In an appraisal process, various mental contents are derived from different information sources (Jokinen et al., 2015; Silvennoinen, Rousi, Jokinen, & Perälä, 2015; Smith & Kirby, 2001).

In this thesis, visual elements are the constructing units of pictorial representations and are seen as the lowest-level variables from a bottom-up perspective, i.e., from smallest visual units to more complex visual units of pictorial representations, contributing to visual experiences. Different kinds of visual language hierarchies exist between different levels of design elements. For instance, according to Mullet & Sano (1995), visual elements are point, line, volume and plane. Hekkert and Leder (2008) define these formal qualities of artefacts as psychophysiological properties, or as properties that can be quantified. According to Post (2016) visual properties are, such as line and shape, and according to Mullet and Sano (1995) visual characteristics are, such as size and colour. Highest-level visual elements are design factors by which these elements are designed to interact with each other, such as symmetry, balance, continuity or visual rhythm (Mullet & Sano, 1995; Post, 2016). According to Evans and Thomas (2013) three hierarchical levels of visual language can be differentiated consisting of design elements (e.g., shape, space, and line), primary principles (e.g., unity, variety, hierarchy, and proportion), and support principles (e.g., scale, balance, and rhythm). However, in this thesis, the definition of visual elements does not separate between the most detailed visual components from design factors, but considers visual elements as the constructing units of visual representations and the compositional factors between them. Further a more fundamental viewpoint to the levels of visual experience combines top-down and bottom-up processes. Visual experience as an active process occurs in the interaction of combining sensory information with expectations, and knowledge (Valkola, 2004) in appraising sensory information via apperception (Saariluoma, 1995; 2003; 2005).

Visual representation that draws on the theories of pictorial elements and visual language of two-dimensional representations (Arnheim, 1974; Kepes, 1944) are utilised as theoretical vehicles to examine how visual design of technological artefacts are experienced. Theory of visual language serves as a starting point due to the affective role of aesthetic impressions conveyed by visual representations of eliciting experiences (Tractinsky, 2000), that may promote positive feelings (Norman, 2004) due to the emotional nature of an aesthetic experience (Dewey, 1958; Hekkert, 2006).The dispensation of visual language theory is in that it provides knowledge of visual elements, such as size, value, hue, orientation, contrast, texture, shape, proportion and position (Mullet & Sano, 1995) that are seen as communicative constructs of visual language.

When technological artefacts are experienced, numerous visual elements are encountered (Zettl, 1973). Visual elements are capable of guiding the interaction and communicating meanings in HTI (Galitz, 2007; Mullet & Sano, 1995; Schlatter & Levinson, 2013). However, visual technology-design is rather complex, for instance, due to the numerous possible combinations of visual elements, the non-existence of universal design formula to be applied in all the different design context concerning the low-level visual elements, and the difficulty to design for exact predetermined experiences. Same information content can be designed to appear in various visual ways, which can be experienced differently. In addition, low-level visual elements are capable in eliciting different meanings, concerning such as, representations of time, destruction, and warmth (e.g., Arnheim, 1969; Jankovíc & Markovíc, 2009; Palmer & Schloss, 2010). In encountering and contemplating visual technology-designs, affective appraisals are in the core of visual experiences. The quality dimensions of such experiences can differ, and, therefore in this thesis the term aesthetic appeal is utilised to depict affective qualities of visual experiences.

The term aesthetic appeal differs from aesthetic experience in that it does not posit the occurrence of aesthetic experience as an exceptional state of mind, but is more neutral by indicating the visual representation's capability to attract interest. The term visual appeal is often utilised in studying visual experiences in HTI (Lindgaard, Fernandes, Dudek, & Brown, 2006; Hassenzahl, 2004). Visual appeal refers to the power of visual stimuli to attract or elicit interest (e.g. Reppa & McDougall, 2015), but due to the nature of visual experience as a mental phenomenon, different mental information contents can be represented that content-wise pertain to other senses, not merely on vision. For instance, through vision we can mentally represent pleasant smoothness of a material, which sets expectations for physical tactile experiences. Therefore, aesthetic appeal is more descriptive of these mental processes than the term visual appeal, as it does not restrict the represented mental contents only to primarily visual entities.

When visual experiences are examined in HTI, in terms of technological artefacts and not solely of computers as in HCI, the artefact under investigation does not determine the scope of the research in much extent. The computer in HCI determines research relatively strictly. In HTI, the dynamics between theory, methodology, and substance may differ from HCI. In HTI research, theory and methodology are emphasised more than the choice of stimuli (whether the stimulus is defined as a computer or as technology) due to the human perspective rooted in cognitive science. Saariluoma et al. (2016) define the basic paradigms in HTI with four fundamental issues: functionalities and technical user interface design, fluency and ease of use, elements of experience and liking, and the position of technology in human actions. Researchers in the HTI domain usually take a position regarding to which research issue defines the key questions in HTI design. However, in order to fulfil the objective of science and to gain deeper understanding of the research paradigms in the field, it is of utmost importance to study thought elements, because they keep research programmes and discourses together (Saariluoma et al., 2016).

In addition, current discourse in HCI research underlines that computers are required to be defined in broader terms (e.g., Bødker, 2006; Thüring, & Mahlke, 2007), as computers have become embedded in multiple ways to our everyday lives. The foundations of HCI are in research and design of using systems efficiently (Card, Newell, & Moran, 1983). Longer research traditions exist in the field of HTI than in HCI concerning visual experiences, which is not still even comparable to the amount of knowledge in art history, art education, and culture studies, which have focused on visual and pictorial representations for centuries. Recently, also the research area of HCI is experiencing a broadening of research scope from a narrow view of usabilityand efficiency to more holistic considerations of human experience (e.g. Zimmerman & Forlizzi, 2008). A broader view to human experience includes research regarding emotions, visual experience, and more recently multisensory design and experience in HCI (e.g., Obrist, et al., 2016). In art and culture studies the emotionally evocative aspects of visual representations have been studied from diverse viewpoints, for instance, emotions conveyed by art in different epochs or emotions of artists in creating artefacts. The research area of product experience approaches the dimensions of experiencing artefacts from more detailed grounds and from a holistic point of view (Desmet & Hekkert, 2007; Hekkert & Schifferstein, 2008). Moreover, emotions in product experiences have been studied more extensively than the role of visual elements in products eliciting emotions in HCI. Thus, the articles in this compiled thesis contribute to the research area of HTI.

Defining the concept of design can be seen as problematic because as a phenomenon, it changes in time (Forsey, 2016). However, the definition of design can be pursued, as there are some foundational ideas mainifested as properties that are not affected by changes in time, such as automobiles change in time but consists of some essential properties that last (Parsons, 2016). A practice oriented definition considers design as a means to achieve desired outcomes (Petroski, 2006), thus this entails that design would be everything where objects are utilised for reaching a purposeful goal. Design can also be considered as changing the world in a substantial way by bringing a new kind of thing into being (Jones, 1970). Hence, designing would not only produce a thing into a world that is merely a new representation of something already existing, that would also change the world in terms of objects, but in a substantial way that changes ways of acting or thinking, or provide new ways of action. Therefore, designing is seen as two-fold, to create solutions as things and to create novel processes for existing things (Parsons, 2016). But in these kind of broad definitions a problem is faced concerning the role of inventiveness and creativity in bringing new kind of things into being (Parsons, 2016). If these viewpoints are taken into account, the essential core of design is highlighted, as a conceptual and cognitive activity different from physical actions of production, accompanied with problem-solving and rational connection between the designed product and the creative process (Parsons, 2016).

To design is to create plans as intentional solutions to a problem with a creation of a new kind of a thing or object (Bamford, 1990), which also creates certain means of action (Houkes and Vermaas, 2010), and is adequate to succeed in answering to the given problem (Parsons, 2016). The focus of such formulations is on functionality, which is important in itself, but not enough in the current design paradigm. Nowadays, design aesthetics can be seen as a part of the established discipline of philosophy of aesthetics (Forsey, 2016). Thus, design is an aesthetic phenomenon, despite of its foundational functional nature and familiarity in everyday settings. Designs as objects of aesthetic attention have their own specific set of characteristics, i.e. an ontology, that places it in the discipline of philosophy of aesthetics, but differs from arts and crafts (Forsey, 2016).

It is also important to notice that design is not deterministically pursued to be aesthetically pleasing or only to appeal to the visual domain. Design can avoid the appealing appearance or neglect it, such as, objects that are only meant to be touched and the purposes of the object would be communicated via touch, and aesthetic appeal would not be considered as an important quality of the object (Parsons, 2016). Aesthetics of touch, of sound and of the other senses, affects the overall experience of an artefact, and also the properties made sense of experienced through the various senses construct the overall experience.

Design needs to connect inner and outer environments to function as a solution to a given problem in a certain context (Simon, 1969). Technology-designs can be defined as man-made and artificial (Simon, 1969). A design artefact is not only a result of a problem-solving process, as it is also a metaphysical suggestion that expresses designer's mental world and perspectives to human life influencing the design decisions (Pallasmaa, 2009, p.108). In explicating the ontology of design in the discipline of philsophy of aesthetics, with the simplest terms, 'design' is set against nature, and 'designed' against the natural, which imply that design incorporates the intentional and consciously planned (Forsey, 2016, pp. 16). Thus, design does not only involve objects, but also on contrary to the natural, everything altered, for instance, food that we eat, our bodies, and even in some cases our pets (Forsey, 2016). Art is by defintion a candidate for aesthetic appraisal, but design requires more detailed analysis to be conceptualised as such. For instance, design objects incorporate different authorship than works of art.

These approaches to designing include intuitiveness of design as action and the scientific explications supporting the actions, which are combined in argument-based design (Saariluoma, 2005). Design explicated with scientific results rose as a new paradigm in the 1960's, as means to make design more reliable, justified and transparent (Parsons, 2016). However, the scientific design method in its pursue to objectivity and rationality demarcalised into mathematical solutions (Parsons, 2016). Experience-design is a cognitive-affective task which involves creativity, and intuition, as stated in the argument-based design through explanatory frameworks. Thus, argument-based design comprises the scientific explications as basis for design solutions with the processes of human mind infroming conducted design solutions (Saariluoma, 2005).

The central concepts defined above are connected to each other in theorisation of the visual experience process: in HTI visual elements of technological artefacts are apperceived in an appraisal process, in which cognitive and affective processes are intrinsically intertwined (Silvennoinen et al., 2015; Silvennoinen & Jokinen, 2016b). In sum, the definitions of the concepts are: First, apperception integrates new and already existing information into a subjectively meaningful mental representation. The ways we make sense of and experience encounters with technological artefacts depends not only on new perceived sensory information, but also on already existing mental information possessed due to prior experiences and encounters (Saariluoma, 1995; 2003; 2005). Apperceived mental contents can also refer to as non-perceivable kinds of mental contents, such as 'futuristic' or 'challenging', which are not properties of a concrete object per se. Second, visual elements are the low-level constructing units of pictorial representations, such as colour, size and symmetry. Thus, the focus is on low-level visual elements and not on high-level visual elements as contrasting design attributes, such as unity and prototypicality (Veryzer & Hutchinson, 1998), and typicality and novelty (Hekkert, et al, 2003). Third, HTI is a multidisciplinary research field that is grounded in cognitive science and is involved in HCI and product experience research from the perspective of human as a cognitive-affective being interacting with technological designs. Fourth, the concept of design means something that is man-made, artificial and incorporates the intentional and consciously planned, and is based on human life. In addition, to design is to solve problems, to create plans as intentional solutions to a problem, with creating a new kind of solution which also creates certain means of action, and is adequate in answering the given problem. Fifth, argument-based design comprises scientific explications as explanatory frameworks as basis for design solutions with the processes of human mind informing design decisions.

1.2 Research Objectives and Questions

The objective of the thesis is to clarify visual technology-experiences based on the apperceptions of visual elements as the constructing units of technological artefacts. The objectives of the study are threefold: first, to build a theoretical understanding and explication (framework) of visual experiences in HTI, second, apply suitable methodological stances to be taken into use in investigating visual technology-experiences, and third, develop a theory-based frame for argument-based visual design. The objectives are important in order to improve theoretical grounds of visual experience in HTI, methodology that takes into account the underlying dynamics of visual experience through explicit and accurate operationalisation, and to diminish current deficits in visual technology-design. For instance, common deficits in visual user interface design guidelines originate from too high-level generalisations without explicated scientific basis for argument-based design. For this reason, more in-depth understanding of experiential aspects elicited by visual product properties is required for enriching visual technology-design. Design principles, guidelines, and conventions are not always research-based, rather practice-based without acknowledgement of the underlying theoretical grounds.

As an example of this deficit in visual technology-design, CRAP (contrast-repetition-alignment-proximity) is a commonly used design principle (e.g., Reynolds, 2013; Williams, 2009). The four constructs of the principle are a selected combination from numerous possible design principles. For example, Lidwell, Holden, and Butler (2003) present 120 design principles to be applied in all visual design contexts, and from these 28 principles are commonly agreed principles of visual design, such as the mere exposure effect, and baby-face bias. Concerning CRAP, for some reason, these four principles have an established status in user interface design practice and popularised with an ambiguous name. Alignment and proximity are Gestalt laws (Koffka, 1935), repetition is a powerful visual method studied in the arts extensively, and contrast as presented in the CRAP refers to visual cognition and operations of the human visual system. Thus, CRAP involves variety of information contents from different disciplines and from different eras, align with implicit assumptions of how visual representations are cognised.

Visual design is considered as a highly complex practice, thus, the popularisation of the principles can be seen as method to make the design knowledge more easily accessible and acceptable in order to increase the possibility of the designs to be universally experienced as aesthetic. However, as mentioned above, to conduct argument-based technology-design, and to base design solutions on scientific results, research is required to explicate what is visual experience in HTI, how its constituent factors and underlying dynamics can be studied, and how to design with this research-based knowledge. Thus, the research questions of this thesis are:

RQ1: *How the visual dimension of technology is experienced?*

First research question is explicated with the constituents of visual experience (visual usability and aesthetic appeal) in appraisal process via apperception. *Article I* focuses on the constituent factors of visual experience in terms of visual usability and aesthetic appeal in experiencing colour and perceived 2- and 3-dimensionality. *Article II* connects the visual experience process to the design elements by presenting the connection of appraising unexpected events by manipulating visual elements (color, shape, size, and texture), and thus, explains the logic appraising visual elements for certain experience goals in a specific design context. *Article III* further explicates the role of visual usability in appraising the most salient visual elements (centered, symmetrical, and balanced composition of web page designs). *Article IV* presents theoretical grounds for connecting appraisals via apperception of visual elements and proposes a novel method in examining these mental contents. *Article V* operationalises visual usability in terms of semantic distance and indicates the connection of visual metaphor designs to visual usability. *Article VI* explicates the underlying dynamics between the constituent factors of visual experience in HTI in appraising aesthetic appeal (operationalised with affective primes from the traditional accounts of aesthetics) and visual usability (operationalised with the concept of semantic distance). *Article VII* informs the dynamics of visual experience by comparing the logic of appraisal process within tactile experience.

RQ2: *How visual experience and its underlying dynamics in HTI can be examined?*

This research question is explicated with a methodological position of interactionist approach in combining subjective and objective accounts of visual experience research. *Article I* presents the operations of the constituent factors of visual experience by appraising colour and perceived dimensionality in different types of technological designs. *Article II* answers to this research question in presenting an explicit operationalisation of visual elements and its connection to appraisals of unexpected events. This enables detailed analysis on how the characteristics of visual elements are appraised, and thus, connects the visual substance to the appraised emotion dimension. *Article III* presents an interactionist approach to examine visual elements in visual technology-experiences by the most salient visual elements (font size, font colour, background picture, background colour, colour and contrast, diagonal, horizontal and vertical lines, alignment, centering, imbalance, balance, asymmetry, symmetry, grouping, and negative space) in web site designs within a specific group of participants. *Article IV* presents a novel method of primed product comparisons in investigating mentally represented information contents in appraisal process via apperception in appraising different product shapes. *Article V* indicates the appraisals of not only one visual element in sense making process, but the role of competing pictorial representations of attention in examining visual usability. In this article an extended version of the primed product comparisons method in investigating optimised set of pictorial representations for efficient HTI is presented. *Article VI* indicates with primed product comparisons method the importance of explicit operationalisations of the constituent factors of visual experience in HTI and explicates the necessity of interactionist approach to be extended from the traditional paradigm of processing fluency. *Article VII* explicates appraisal process by examining the logic of appraisals between vision and touch, and thus, indicates the complexity of examining visual experiences, also indicating that by examining appraisals of tactile experiences, visual experiences can be understood in more detail.

RQ3: *How to design for visual experiences in technology-interaction?*

This research question is answered with argument-based design, in which the resulting framework of visual experience functions as an explanatory framework for conducting argument-based visual design. *Article I* presents design insights into the role of colour and perceived dimensionality in different types of mobile applications. *Article II* describes the role of designing unexpected events with visual elements and their ability in eliciting surprise. *Article III* informs future programmers' appraisals of most salient visual elements and explicates the experienced saliency of specific visual elements with appraisal theory of emotion. *Article IV* presents a method of primed product comparisons, which can be utilised in studying apperceptions in appraisal process to inform design decisions. *Article V* presents an extended version of the primed product comparisons method in detecting optimised set of pictorial representations (simplistic black-and-white shape metaphors for in-car navigations system's functionalities) for designing efficient visual usability in HTI. *Article VI* informs the possibilities to design for aesthetic appraisal with the focus on efficient visual usability in increasing aesthetic appeal, and also presents the influence of design eras in appraising the aesthetic dimensions and the visual usability dimensions of pictorial representations. *Article VII* explains the difference in appraising perceptual stimuli affects via vision and touch and the implications of these to multisensory technology-design.

2 AESTHETICS, USABILITY, AND VISUAL LANGUAGE

According to Vitrivius (first century BCE), intrinsically intertwined design dimensions of artefacts (as man-made objects) are *firmitas* as durability, *utilitas* as usefulness and context suitability, and *venustas* as aesthetics. These three dimensions of design were the core in his writings of architecture. Considering HTI as a design domain, firmitas stands for functionality, utilitas for usability, and venustas for aesthetics. The importance of the visual dimension in technology-design has been gradually included to the research and design of HTI. For example, one fundamental design principle in HTI is *"to make things visible"* (Norman, 1988, p. 13). The nature of design principles differs between functionality, usability, and aesthetics, such as that, genuine design principles exist only in functionality and usability (Parsons, 2016), but in terms of visual experiences the principles for designing for specific visual experiences are to be derived in a different manner and the foundations of the visual design principles require critical assessment. From design practice point of view, design needed to incorporate best elements from fine arts, modern mass production, and traditional craftsmanship, and thus, not to differentiate design from arts, crafts or industry (Parsons, 2016).

Research on visual design of user interfaces started to gain interest among scholars in the research area of HCI approximately from 1980´s. Initially the focus was on graphical user interface elements, such as icons and menu structures. Research mainly concentrated on the communicative ability of these graphical user interface elements than on affective experiences of them. Aesthetics as an important dimension in HCI research has been referred to as a discipline of engineering aesthetics or aesthetic ergonomics (Liu, 2003), hedonomics, i.e. hedonic ergonomics (Hancock, Pepe, & Murphy, 2005; Oron-Gilad & Hancock, 2009), and as visual aesthetics in HCI (Tractinsky, 2012). Visual aesthetics in HCI as a discipline has been stated to initiate from the mid-nineties. In the domain of product design, from the beginning of 1950s, the focus was mainly on functionality, aesthetics and utilitarian ethics. Emotions as important factors in product design and experience started to emerge from the beginning of the 1990s (Ho & Siu, 2012).

Aesthetic experience can be defined, for example, as a direct immediate response resulting as an exceptional state of mind, which differs from so-called everyday experiences (Marković, 2012). Aesthetic experience as an immediate response without intervening reasoning is a commonly utilised definition of aesthetic appraisal in studying experiences of visual aesthetics in HCI (e.g., Moshagen & Thielsch, 2010; Tractinsky, Cokhavi, Kirschenbaum & Sharfi, 2006). Commonly in HTI studies the aesthetic is associated with beauty (e.g. Karvonen, 2000; Tractinsky, 2000). Thus, aesthetic and beautiful are implicitly used as synonyms. This implicit theoretical standing point of how visual technological designs are experienced has led to operationalisations of visual experience as a one-dimensional construct. Conversely, aesthetic experience can be defined as an interpretative interaction with various states and actions (Carroll, 2001). If defined as an immediate response, aesthetic experience can be defined as a sensation, or pertaining to a sensation. Considering aesthetic experience as a sensation, aesthetic experience can involve various sensory modalities, from which the visual domain has received most attention in general cognitive psychological research (Eysenck & Keane, 2005).

It is thus not surprising, that the discussion of the importance of aesthetic experience when people interact with technological artefacts started from the visual domain (e.g. Tractinsky et al., 2000). Thus, discussion of aesthetics turns implicitly into discussion on visual aesthetics (e.g., Lavie & Tractinsky, 2004). In such cases, the term visual appeal is often used. Visual appeal refers to the power of the visual stimuli to attract or evoke interest in users (e.g. Reppa & McDougall, 2015). In addition to *visual appeal* (Lindgaard, Fernandes, Dudek, & Brown, 2006; Hassenzahl, 2004), this notion has been conceptualised with such terms as *apparent usability* (Kurosu, & Kashimura, 1995), *appeal* (Schenkman, & Jönsson, 2000), *beauty* (Karvonen, 2000), *web appearance* (Kim, & Stoel, 2004), *web aesthetics* (Tractinsky, & Lowengart, 2007), *web page aesthetics* (Robins, & Holmes, 2008), *visual complexity* (Deng, & Poole, 2010), and *perceived visual aesthetics of web sites* (Lavie, & Tractinsky, 2004; Moshagen, & Thielsch, 2010). However, in this thesis, the more neutral term *visual experience* is utilised, as it does not presuppose the quality of the experience during an encounter with visual stimuli, and represents the experience in a holistic manner involving cognitive and affective processes.

Usability in aesthetic-usability research has been conceptualised with different definitions, such as *apparent usability* (Kurosu & Kashimura, 1995), *perceived usability* (Hassenzahl & Monk, 2010; Sonderegger & Sauer, 2010), and *expected usability* (Thielsch, Engel, & Hirschfeld, 2015). The methodological approaches and definitions of perceived usability vary, and the usability evaluations have focused on visual inspection of a whole user interface, especially regarding its interactive elements, such as menus (Thielsch et al., 2015). As usability incorporates a variety of definitions and approaches, in this thesis term *visual usability* is utilised, by focusing on how people mentally represent visual elements and how the visual aspects of objects relate to the functions afforded by them (Silvennoinen & Jokinen, 2016a; Silvennoinen & Jokinen 2016b). Thus, visual usability in HTI refers to how intuitively and fluently visual information can be interpreted and understood in terms of goals, and how visual elements of a technological artefact, such as lines, colours, visual rhythm, and symmetry guide the interaction (Schlatter & Levinson, 2013; Silvennoinen, et al., 2014).

According to Tractinsky (2013) visual aesthetics should be considered, defined, and studied in a broader sense as a combining factor in experiencing technological artefacts. This viewpoint highlights visual aesthetics as a dimension that augments other aspects of the design and the overall experience. The conceptualisation of this approach have been critisised of contributing to theory of no-theory in terms of aesthetics, and to experience as a process model (Bardzell, 2012).

2.1 Aesthetic-usability Effect

If HCI (or HTI) is considered as an engineering field, do we still live, from a value-based perspective, in a modernistic era in user interface design? This consideration emerges intuitively in research and design settings, as the focus in technology-design is often in 'form follows function' and thus decoration (ornamentation in modernistic era by Loos) is considered as an unnecessary eye-candy. The modernistic focus in producing meanings by deleting ornamentation was not to exclude meaning and symbolic expressions from designs, but to bring these aspects forth with the functional properties of designs. This also stems from long-lasting tradition of linking artefacts' fitness for its purpose and functionality to aesthetic appeal.

Already Socrates was claimed to have stated: *"Whatever is useful we call beautiful"* (Tatarkiewicz, 1962-7; 2005, 100-1004). In HCI, Tractinsky's influential article: what is usable is beautiful (2000), opened the field for investigations of the aesthetic-usability effect. At the same time, within information processing paradigm in psychology of arts the hypothesis: '*Is beauty in the processing experience of the viewer*' (Reber, Schwarz, & Winkielman, 2004) was examined. Thus, the two standing points in design, functionality and processing fluency, and their role in experiencing designs, affect the way visual experience in terms of designed objects is approached and examined. Thus, the concept of visual usability (Schlatter and Levinson, 2013; Silvennoinen and Jokinen, 2016a; 2016b) and, for instance, Gestalt principles (Koffka, 1935; Wertheimer; 1938) are considered as more reliable design principles than the quest for aesthetic experiences informed by specific relationships of visual elements, and especially concerning affective mental contents in apperceptive process informing the design solutions.

HCI has been criticised by the lack of meta-research, due to the tight industry relationship, thus, the field is ruled by technological innovations (e.g., Liu, Goncalves, Ferreira, Xiao, Hosio, & Kostakos, 2014). Meta analyses and replication studies are not in favour in the core publication forums of the research field (e.g. Liu, et al., 2014). However, one phenomena related to visual experiences with technological products have been studied extensively, the abovementioned aesthetic-usability effect. Research results show that visual attractiveness and perceived usability are related (Thüring & Mahlke, 2007; Tractinsky et al., 2006; Sonderegger, Zbinden, Uebelbacher, & Sauer, 2012; Tractinsky, 2012). It has claimed that what is beautiful is also usable (Tractinsky et al., 2000). Several studies have reported a positive relationship between perceived usability and visual aesthetic appeal, in which aesthetic appeal increases how well interactive artefacts are cognised (Hassenzahl & Monk, 2010; Kurosu & Kashimura, 1995; Lindgaard & Dudek, 2003; Thüring & Mahlke, 2007; Tractinsky, 2000).

In addition, evaluations of aesthetic appeal are at least partly conducted quickly and these immediate judgments function as critical determinants of first impressions of the encountered artefacts (Lindgaard, Fernandes, Dudek, & Brown, 2006; Papachristos & Avouris, 2013; Tractinsky et al., 2006; Jokinen, Silvennoinen, Perälä & Saariluoma, 2015; Thielsch & Hirschfeld, 2012). However, this line of research involves multiple reported research outcomes, not due to the lack of replication studies or meta-research, but due to the lack of foundational analysis on the studied concepts. Therefore, differing dynamics of aesthetic-usability effect have been presented. For instance, aesthetic appeal can positively influence technology-interaction (Moshagen, Musch & Göritz, 2009), enhance performance in accomplishing difficult tasks (Norman, 2004), lead to overall increase as well as decrease in performance, and function as motivator in continuing of using the technological artefact (Sonderegger & Sauer, 2010).

Aesthetics in HCI is studied with constructs in isolation from millennia of aesthetic research. Of course, technological artefacts, such as user interfaces as pictorial representations, differ from conceptual art or for example, oil paintings due to their artefactual nature. User interfaces are not generally considered as art, but as design artefacts with strong emphasis on their usefulness, usability and more recently also on experiential aspects. These foundational assumptions and research positions to technological artefacts and the experiences elicited by them influence the ways the phenomenon is studied. The differing research results of aesthetic-usability effect might also be due to the lack of understanding performative aspects of visual elements and the underlying processes of visual experience.

Combining factors within usability and aesthetic appeal can be explained, for instance, with psychological research on processing fluency, which functions as a foundational basis in information processing paradigm of aesthetic appeal (Reber et al., 2004). The focus is on examining how cognitive information processing fluency influences aesthetic evaluations of visual stimuli. Research on the aesthetic-usability effect often sets this paradigm as the basis whether implicitly or explicitly in investigating the variables influencing the effect. Reber et al. (2004) propose that the more fluently stimuli can be processed the more aesthetic and pleasurable the stimulus is experienced as.

Emphasis on cognitive fluency in visual experience has also lead to another sub-research area within visual aesthetics in HTI, in which the fastness of first impressions of aesthetic evaluations and the consequences of it are investigated. This line of research suggests that because aesthetic information is evaluated immediately, it is largely responsible for the first impressions of technological artefacts (Tractinsky, Cokhavi, Kirschenbaum, & Sharifi, 2006). It also reported that aesthetic evaluations can be carried out in 50ms (Lindgaard, Fernandes, Dudek, & Brown, 2006), and that these evaluations are consistent (Tractinsky et al., 2006). Immediate assessments of attractiveness have also investigated to influence affective evaluations (Tractinsky et al., 2006) concerning, for instance, trustworthiness (Cyr, Head, & Larios, 2010). However, these ultra-rapid exposures to visual stimuli have been critised in terms of what is possible to be perceived in such a short time (Thielsch, & Hirschfeld, 2012). In addition, what is possible to be cognised or experienced in such a short exposure of visual stimuli should be under consideration within this line of research.

2.2 Visual Usability

Visual usability defines visual design as a cognitive tool, in which the visual presentation of information aims at aiding thinking processes. Thus, visual designs can be considered as tools for cognition (Ware, 2012), as the same manner as hammer is an extension of the user's hand, visual design is an extension of the user's mind. Visual usability and visual aesthetics in HTI research exist partly in their own paths. Visual usability in HTI focuses on performative aspects of visual elements, design principles (Schlatter & Levinson, 2013), and functionalities afforded by the visual elements (Silvennoinen et al., 2014; Silvennoinen & Jokinen, 2016a; 2016b). In addition, research conducted in the field of visual usability takes into consideration physiological viewpoints of perception, such as colour blindness and the effects on aging to vision. Visual usability refers to the way how visual elements guide users' behaviour in cognitive sense making processes, for instance, how visual elements serve as focalisers of gaze and action, and what kind of emotional and multisensorial mental contents are represented in interaction with them (Silvennoinen & Jokinen, 2016a). Visual usability can be seen as mediator between aesthetics and usability in perceiving interfaces. In addition, not merely perceiving interfaces, but apperceiving affects the ways how visual representations are experienced and responded to. More profound understanding of how visual elements are experienced contributes to enhanced visual usability of user interfaces (Schlatter & Levinson, 2013; Silvennoinen, Vogel, & Kujala, 2014), that is, how people represent visual elements and how the visual aspects of objects relate to the functions afforded by them (Silvennoinen & Jokinen, 2016a; Silvennoinen, & Jokinen, 2016b).

Designing comprehensible and pleasurable visual usability for HTI requires knowledge of the operations of the human visual system (e.g. visual perception, visual cognition, and attention) in line with the performative aspects of visual elements, combining what is seen with the eye and what is represented in the mind. Visual elements in visual usability of technological artefacts can be approached with performative aspects of visual entities. For example, Arnheim (1969) and Zettl (1973) have identified internal characteristics or forces that operate within the boundaries of a pictorial representation. These field forces can be latent or active forces. Latent forces are hidden spatial and structural forces that, influence objects within the frame, and can be referred to the way like magnetic fields operate. The existence of these hidden forces is detected when visual elements are organised in a pictorial composition.

Indicating the perceived visual usability of visual element's intended meaning and function is needed for the artefact to be self-instructing, and enhance emotionally comfortable HTI. Concentrating on comprehensibility and intuitiveness of artefact's visual elements in representing intended meanings and functions is an important dimension of the sense-making process of visual experience in HTI. Intuitive communication between technological artefact and a person accomplished through intentional design aims towards pleasurable experiences of using the product (Norman, 1988). Pleasure and intuitiveness from visual usability design perspective are highlighted in resulting as comprehensibility and comfort.

In addition to visual usability, the research area of information visualisation is also involved in examining mentally represented functionalities of visual representations. Until recently, the term visualisation meant constructing a visual image in the mind of the perceiver (Shorter Oxford English Dictionary, 1972). In current research, visualisation has approached more as a pictorial presentation of data or concepts. Thus, being an internal construct of the mind, a visualisation has become an external artefact supporting, for instance decision making. Information visualisation can be utilised as a one way to approach visual usability in HTI when interpreting large amounts of data. In addition, the way different visual elements are scientifically and through design practice connotated to communicate specific meanings in information visualisations, can be utilised in analysing the communicative aspects of visual elements in HTI design. Moreover, as visual user interface design often follows specific design conventions in accordance to different user interface genres in order not to conflict visual design solutions with user expectations (Papachristos & Avouris, 2013), information visualisation as a separate research area has more standardised ways of designing meanings and specific conventions in visual communication conveyed through visual elements (Ware, 2010).

2.3 Visual Language

While much focus has been directed at understanding the psychological underlying mechanisms of verbal and written language and communication, examination of the essential and important characteristics of visual language has received less attention (Changizi, 2009). Understanding how to command visual language, designers can effectively influence human behavior. Typographic design is used and understood as a method to impart emphasis, hierarchy, and give meaning to communications. However, there are no research-based rules to guide designing or interpreting typographic meaning, nor for visual design. Thus, there is no universal design language to be applied to all disciplines involved in visual communication and design. Visual elements in technological artefacts are capable on inducing emotions and, thus, influencing experiences in HTI. Experiences conveyed through visual elements are always interpreted in contextual environments interacting with specific technological artefacts. Therefore, it is important to understand the role of visual elements in specific contexts, and how changing contextual factors influence the experiences. In addition, although research has focused on the relationship between emotional experience and visual design, the focus has been on the overall visual impression and not on visual elements.

There are cultural meanings attached to, for instance, reading direction to images (Kress & Van Leeuwen, 1996), and competence of interpreting complexity of visual representations. Visual design regarding design elements can conclude into numerous different combinations, which are experienced in different contexts, cultures and times and by different viewers. Therefore, it there is no optimal combination of visual design to be applied in all contexts, which would evoke same specific affective contents of experience. For example, a cross-cultural study of preferences of visual elements in website design between Asian and Western people alter in terms of visual clutter in websites. Asian websites are often filled with different animations drawing attention. Colour schemes are more vivid, bright, and varied in relation to Western websites (Reinecke & Bernstein, 2011). This visual diversity resulting in complexity is often considered as visual clutter and information overload among Western people, who prefer structured and websites with fewer visual elements (Marcus & Gould, 2001). In addition, Asian people are more familiar, and thus, efficient in distinguishing objects of attention and details from complex visual compositions (Nisbett, 2003).

Suggestions of optimal shapes and forms that would be universally experienced positively have been presented. For example, Ramachandran (2004) posits that universalistic aesthetic design principles, independent of any application domain, exist and can be explained through the evolution of human information processing system. Gestalt psychologists have suggested principles for design through which organisational properties would be preferred to be perceived, such as the law of similarity (visual elements that are perceived similarly according to, for instance shape, size or colour are consider to belong together), and the law of Prägnanz (i.e. the law of good or optimal form), in which complex patterns and structures are tend to be perceived as simplistic as possible. Simplifying or abstractive approach to design can be seen as a powerful and complex process in which viewers are invited to mentally construct the remaining part of the visual representation (Wilde & Wilde, 2000). This idea is implied in Mies van der Rohe's idea of *less is more* (Johnson, 1947, p. 49). However, general skepticism is involved in the discussion regarding optimal visual elements evoking positive emotions, for example due to the cultural and subjectivist dimensions of visual experiences (due to apperception). Research has been mainly conducted in isolation with abstract elements detached from actual artefacts, and to detect the role of these elements in experiencing products, objects and artefacts can be difficult (e.g. Hekkert & Leder, 2008).

In studying the visual dimension of technology there can be seen a division to low-level visual elements as constructing units of pictorial representations (e.g., shape, colour, texture, and symmetry) and to high-level elements as contrasting design attributes, such as unity and prototypicality (Veryzer, & Hutchinson, 1998), typicality and novelty (Hekkert et al., 2003; Wei-Ken & Lin-Lin, 2012). High-level attributes have been examined in more extent than low-level visual elements (Tractinsky, 2012). For instance, optimal match in design can be achieved with MAYA (most advanced yet acceptable) –principle (Hekkert et al., 2003). Technological artefacts which incorporate balance between familiarity and novelty promote aesthetic appeal. In addition to MAYA-principles, Hekkert and Leder (2008) present that the principle of maximum effect for minimum means plays an important role in design aesthetics. Ideas and models that are constructed based on only few elements, but communicate a bigger solution or phenomenon are considered as pleasurable. The principle of optimal match also involves multisensory design, in that the information and impressions conveyed with different sensory modalities are required to be consistent throughout the artefact to elicit positive and pleasurable experiences. Unity in variety as an aesthetic design principle (Dickie, 1997; Post, Blijlevens, & Hekkert, 2016; Post, Nguyen, & Hekkert, 2017) or simplicity in complexity are utilised for optimising pleasure in balancing the opposing forces in a meaningful way. This principle could be achieved, for instance with tensional symmetry in pictorial representations.

The lowest-level variables of visual language, visual elements (Mullet & Sano, 1995) also defined as low-level attributes (Tractinsky, 2012), and psychophysical properties (Hekkert & Leder, 2008) communicate with and through the elements. The communicative interaction is always coloured with the context in which the experience occurs (e.g. Demirbilek & Sener, 2003). Experienced saliency of visual elements is affected by the environment in which the elements are encountered, and the environment also affects the emotional experience. Highly complex environments can make the product properties less salient (Forlizzi, Mutlu, & DiSalvo, 2004). Experiencing technological artefacts, all design properties are affected by each other. The form of the artefact creates primary impression of the artefact, and generates assumptions and beliefs of other product attributes (Berkowitz, 1987). In addition, emotions elicited by artefact's design properties affect following appraisals of artefact or system attributes, generating stances towards encountered technological artefacts (Sun & Zhang, 2006).

3 COGNISING THE VISUAL IN TECHNOLOGY-EXPERIENCE

We can perceive and experience objects surrounding us without seeing them or comprehending them (e.g., Schirato & Webb, 2004). Thus, perception refers to the objects in the visual field, attention to those, which we see, and comprehension and apperception to the way how we make them meaningful to us. The goal of cognitive science is to understand the representations and processes in our minds that affect these capacities, to understand how the mind works and how the represented information contents shape and are shaped by our experiences and interactions. Thus, fundamental cognitive and affective processes that affect visual technology-experience are in question.

Mental representations have information contents and the cognitive processes through which mental representations and its contents are constructed are the key in understanding how people make sense and experience technological artefacts (e.g., Saariluoma, 1995; 2003; 2005). Mental representations include both perceivable and non-perceivable contents (Saariluoma, 2003). The experienced contents make the technological artifacts meaningful to us. Apperception can be defined as *"seeing something as something"* (Husserl, 1936; Kant, 1787; Saariluoma, 2003; 2005), thus it differs from sensations that function through sensing raw-data, and perception, which involves interpretation (Gibson, 1997). The difference between mere sensation and perception (also apperception) is a representational difference. In perceptions and apperceptions certain relationships between the object of the experience and the subject of the experience are represented (Siegel, 2006).

Modern accounts of cognitive science involve research concerning the contents of mental representations in understanding and explaining experiences. The workings of the mind are not explicated only with traditional paradigms of capacity and information processing fluency, but with for instance, apperception, emotions, mental information contents (Saariluoma, 2005). An information processing approach in HTI focuses on human information processing of attributes in technological artefacts (Hassenzahl, 2004). Thus, recent research on experience as a mental phenomenon and its information contents has not been in the core of examining visual experiences in HTI. An influential perspective to product and technology-experiences was presented by Norman (2004), which influenced the way different design dimensions are acknowledged in HTI research. In visual technology-experiences aesthetic evaluations can be explained by considering cognitive and emotional processes at three different levels, visceral, behavioral and reflective. Visceral responses to stimuli in the environment have developed partly through evolutionary mechanisms, and are performed quickly with little cognitive processing. Thus, responses to the stimuli are quite automatic. Behavioural and reflexive levels are characterised by increasingly elaborated and more distinct motivational, cognitive and emotional processes with slower reactions to stimuli, tendency towards more optimal responses, and greater individual variability.

3.1 Apperception and Appraisal in Visual Experience

Visual experience occurs in the apperceptive appraisal process in which conscious feelings and mental information content of the encountered visual representations are represented. Subjective experience, such as visual experience, is the feeling component of appraisal, and is represented mentally (Saariluoma, 2003; Scherer, 2009). In case of aesthetic and emotional experience, the interest is in the affective contents of those representations. These contents are assimilated from sensory stimuli, but not as raw sensory data. The appraisal process is apperceptive, which means that existing memory-based rules for representing a stimulus are used to subjectively make sense of it (Saariluoma, 2003). By studying the lowest level elements (as the constructing units of visual representations in technological artefacts) the underlying dynamics of visual experience can be explicated in more detail. Thus, establishing the connection between visual elements and the emotion response is one of the key elements in developing theory for describing visual elements in HTI.

Numerous visual language systems have been created to communicate meanings to the interpreters, but this always involves apperception, which is influenced by previous experiences of the interpreter. Even though the focus is on visual experience, people mentally represent contents that are not bound with visual properties of the technological artefacts, such as themes, and physical feelings. Visual experiences are enriched with represented mental information contents. Information contents of mental representations in HTI are the experiential dimensions through which we make sense (apperceive) of what we see (or touch, or hear) and what makes the encountered technology meaningful to us.

Studying cognitive processes and the mental contents represented in appraising technological artefacts provide research-based basis to explicate visual experiences from cognitive perspective. Experiencing visual representations have been studied with the focus on perception, thus, higher lever cognitive processes, such as apperception (restructuring, reflection, and construction) have gathered less attention. These cognitive processes are the underlying mental activities in making sense of pictorial representations in HTI. Hence, perception does not possess the ability to theoretically explain the rich and complex phenomena of visual experience in its vastness. Theoretical language of visual experience and visual language of artefacts require common ground to be explicated for argument-based design via explanatory framework (Saariluoma, 2005). Cognising the visual can be seen as a specific type of human problem solving activity, which involves different mental contents with altering underlying dynamics, such as the interplay between aesthetic appeal and visual usability.

The essential nature of a mental representation is that it is always about something (Newell & Simon, 1972). In HTI, mental representation can be about the technology (Saariluoma, et al., 2013), the interaction itself (Diefenbach, Lenz, & Hassenzahl, 2013), or the states of the user (Desmet, 2012). Mental information content is the meaningful and subjective information part of the mental representation. It makes sense to the subject and is therefore closer to how experience is understood in HTI (Saariluoma, 2005; Saariluoma et al., 2013). Mental contents are represented through appraisal processes derived from different information sources (Jokinen et al., 2015; Silvennoinen, et al., 2015; Smith & Kirby, 2001). Appraisal starts with the perceptual stimuli including aspects of the stimuli directly detected and easily perceived. Associative processing involves automatic and fast retrieval of memory contents to associate meaning to events. Reasoning processes construct linguistically encoded meanings.

Because our thoughts influence our actions, the way to make sense and explain human behaviour is to refer to the contents of the mental representations of the user (Saariluoma, 2003). What makes technological artefacts meaningful to the people interacting with them, are the mentally represented qualities attributed to the artefacts. How these experiences occur in people's minds is the mental process of apperception. Appraisal theory defines emotion as a process, not as a state (Folkman & Lazarus, 1985), and as a cognitive evaluation of an event, which establishes the personal significance of the event (Frijda, 1988; Lazarus, 1991; Scherer, 2005; 2009). In appraisal process, apperceptive identification of perceivable physical qualities are associated with more abstract meanings and involves higher order reasoning. Appraising a material as warm, for example, involves a relatively direct process of touch perception and temperature recognition. Yet, to appraise the same material as useful requires a more complex process of retrieving associative mental information and reasoning (Smith & Kirby, 2001).

Appraisal theory proposes a framework, which expresses how emotions result from subjective evaluations of events (Frijda, 1988; Scherer, 2009). Utilitarian emotions, such as fear and joy, facilitate subject's adaptive response to events in the environment, whereas aesthetic emotions have less immediate adaptive relevance, and are more related to the intrinsic qualities of the event or the object under appraisal (Scherer, 2005). The part of experience concerning the intrinsic aesthetic quality of an object is often called a hedonic component, which is related to product appeal alongside utility evaluation (Hassenzahl, 2001). Aesthetic and hedonic emotions are, however, also difficult to conceptualise, and numerous perspectives into what aesthetic experience exist. Appraisal theory explains emotion in term of mental processes, applying it successfully into aesthetic visual experience and connects visual elements with certain experience outcomes. Appraisal theory has been utilised in examining emotional responses in product experiences, due to the explanatory power of appraisal theory in explaining emotion as a process (Demir, Desmet, & Hekkert, 2009). Thus, appraisal theory possesses explanatory power in explicating the relation between visual experience and a design artefact in how a subjective experience raises from appraisal process in encountering a design artefact. This further allows the design of such experiments, where the details of appraisal process can be manipulated and the relationship between design artefacts and experiences examined.

Due to the analysis of affective responses on multiple appraisal information levels, appraisal theory can be used as a framework for relating to each other the different levels of abstraction in the affective qualities. For example, judging an object as 'imaginative' or as 'sophisticated' clearly requires reasoning. Conversely, one can identify low-level affects, requiring only the very fast perceptive information sources. The analysis of affects on different appraisal levels does not mean that every affect should explicitly belong to one of the levels. Rather, what the appraisal process means is that during the process, information from different levels are combined to form the affective evaluation. However, different affects can be expected to require differing amounts of information. Thus, some affects rely more on perceptual information, for example, than reasoning. This is also dependent on context and the stimulus, not only on affect (Jokinen, 2015b).

Numerous approaches and viewpoints on how emotions can be defined and how emotions occur have been presented, due to the he significance of emotions in diverse contexts of human life. For example, Smith & Lazarus, (1993) have suggested guilt, sadness, anger and fear or anxiety as basic emotions. Scherer (1997) presented guilt, joy, sadness fear, anger, shame, and disgust as the emotion categories of appraisal dimensions. According to Russell (1980) emotions are interrelated and vary in two dimensions, arousal and valence. The intensity of the emotional response is reflected in terms of arousal. Valence in direct emotional responses ranges from positive to negative responses. According to Zhang (2013) affect functions as an overarching concept to more specific concepts including moods, feelings and emotions. Emotions emerge as responses to person´s goals, needs and concerns, and to their appraised relevance to events in specific situations and environments. After the activation of emotions, subjective feelings are experienced, which can be for instance, joy or anger. In addition, emotions are intentional and object-directed, in that emotions emerge and involve a relation to specific objects (Frijda, 1994). Moods can be understood as unintentional and not object-directed, and therefore, are more general by their nature. According to Hekkert and Leder (2008) aesthetic pleasure cannot be considered as an emotion, because pleasure results through sensory perception of an object, without motivational or guiding concerns. Thus, whether aesthetic responses lead to some kinds of emotions is a complex process, which requires deeper understanding concerning the appraisal processes underlying emotions.

However, in emotion research many suggestions of aesthetic emotions have been made, usually referring to emotions, such as interest, surprise and fascination (e.g. Silvia, 2005). According to Silvia (2009) aesthetic appraisal contains a variety of specific emotions, such as anger, pleasure, surprise, pride, disgust, regret, embarrassment, contempt, confusion, shame and guilt. There is an ongoing debate of aesthetic emotions regarding, for instance, their role as emotions of unique affective qualities. However, product experiences involve more diverse emotional dimensions, such as designing for surprise and rich experiences, which also include negative emotions. Rafaeli and Vilnai-Yavetz (2004) propose a theoretical framework through which technological artefacts could be examined from instrumental, aesthetic and symbolic perspectives. In addition, aesthetic attributes of artefacts create emotional responses which also affect other constituents in experiencing artefacts, and that each dimensions of the framework evokes emotions.

Studies connecting visual elements of technological designs to emotion responses have reported different relations between visual elements and emotions, that are context-dependent. In online environments, visual design elements include, for example, colours, images and shapes. These visual characteristics are capable of eliciting emotional appeal in appraising online environments (Cyr, Head, Larios, & Pan, 2009; Zhang, 2013). Karvonen (2000) discusses how beauty of simplicity in user interface design affects feeling of trust in online environments. Lindgaard, Dudek, Sen, Sumegi and Noonan (2011) also investigated the relation between aesthetic appeal and trust in website design and found a strong correlation between these factors. Cyr (2013) highlights enjoyment, involvement, satisfaction and trust as essential emotions in the field of e-commerce, and continues that these emotions are important in other online contexts also. Cyr, Head, and Larios (2010) detected that colour appeal in web site design strongly affects trust. Colour is seen as a primary visual element in design (e.g., Poulin, 2011). Colour studies have attempted to unravel the effects of colours HTI. Warm and cool colours (e.g., Coursaris, Swierenga, & Watrall, 2008) have been studied with physiological measures concluding that warm colours provoke activation and stimulation, and cool colours affect in the opposite way (Levy, 1984). However, according to Gardano (1986) subjective evaluations of colours in relation to emotion vary in great extent. Same colour can evoke negative and positive emotions in different viewers.

Kim, Lee and Choi (2003) presented relationships between key design factors and 13 emotional dimensions in interacting with websites. Hsiao and Chen (2006) proposed a framework though which affective responses elicited by physical shapes of products can be investigated in more detail. The framework includes four dimensions. First dimension is trend factor, second the emotion factor, third the complexity factor, and fourth the potency factor. In their study, they found out eight shape elements eliciting affective responses, such as line type, surface type, element amount, unity level. Every identified shape included three sub-levels according to the shape's feature characteristics. For example, line type as a shape included three characteristics, straight, curve, straight and curve. In addition, five shape manipulation levels were detected, which are prototypical, symbolic, functional, comfortable and pleasurable level. Shape elements are important regarding emotional design of product features, and shape manipulations represent cognitive features, including for example semantic meanings. Variations in roundness and proportions of shapes alter according to design trends, and through these shape qualities evaluations of the perceived age of the product are conducted (Demirbilek & Sener, 2003). Cuteness is often conveyed through roundness of shapes. According to Lidwell et al. (2003) this design approach is called baby-face bias, in which objects with baby-faced features are experienced as cute, innocent and honest. In addition, Salgado-Montejo, Salgado, Alvarado, and Spence (2016) found in their research that concave lines are experienced as happy and convex lines are associated with sadness.

Most of the research regarding emotions elicited by technological artefacts has concentrated on positive emotions (e.g. Norman, 2004) and for instance, designing for well-being (Desmet & Pohlmeyer, 2013). Jordan (2000) has presented four dimensions for positive and pleasurable product experiences, physio-pleasure, social-pleasure, psycho-pleasure and ideo-pleasure. Designing for surprise and humor have been studied in experiencing artefacts. According to Ludden, Schifferstein and Hekkert (2009) surprise as a design strategy in classical product design is beneficial in product experiences. Surprising products are considered as more fun to use, more recognizable, and also including elevated word of mouth. By conflicting information for different sensory modalities, products can be designed to elicit surprise. These incongruities in sensory information can be conducted for instance, by conflicting information with visual and tactual modalities. In order the artefact to be experienced as positively surprising the product design need to aim at appropriate level of unexpectedness. The type and the context of using the product have an important role (Gross & Silvennoinen, 2014). Negative emotions play also an important role in experiencing artefacts. Recently research concentrating on the relationships between emotions and artefacts, has also started to focus on the role of negative emotions (Silvia & Brown, 2007). Fokkinga and Desmet (2013) propose different ways for designing negative emotions, such as sadness and disgust. They aim towards designing for rich experiences, in which negative emotions are integral parts in experience, in addition to positive emotions.

Specific visual product properties and low-level visual design elements cannot be reliably formulated as a unified universalistic design theory in relation to emotional dimensions elicited by them. However, research concentrating on visual elements eliciting emotions in HTI informs and provides insights into how experiences occur and about the connection of emotional meanings to the encountered artefacts. In addition, there are several factors influencing the results of such studies, and the results are therefore only applicable to specific context and cannot be generalised as pervasive design guidelines. Factors that need to be taken into account are, such as, the type of the system or product, the context of use (e.g., entertainment and work), the purpose of the technological artefact intended by designers and activated through individual´s personal goals (these can also include creative use of technology in a manner, that designers have not even thought about), cultural differences (including national, ideological, sub-cultural, social groups), individual differences (such as previous experiences, expectations, generations, individual taste), to name a few.

4 METHODOLOGY: INTERACTIONIST APPROACH

As mentioned before, a solid investigation of visual experience in HTI as cognitive-affective phenomenon necessitates an interactionist approach, combining the objective and subjective accounts to visual experience in HTI to resolve the underlying dynamics of such experience, and to inform argument-based visual technology-design enabling understandable and experiential encounters with technology. In this section, theoretical, conceptual, and methodological research positions are explicated in relation to the operationalisation of the concepts depicting the studied phenomenon and selection of methods for the above purpose. In Table 1 theoretical and conceptual decisions reported in the articles included in this thesis are presented, along with the operationalisations of the concepts, methods, and study contexts.

TABLE 1 Methodological procedures

Art.	Theory	Concepts	Operationalisations	Method	Study context
I	Holistic user experience (e.g., Isomäki, 2009) Visual Language (e.g., Arnheim, 1974; Kepes, 1944)	Visual experience and preferences, visual elements	User experience (hedonic and pragmatic components), Visual elements (manipulations of colour & 2- and 3-dimensionality)	Attrakdiff-mini: semantic differential (SD) of pragmatic qualities, identification, stimulation, attractiveness (Hassenzahl & Monk, 2010), Liking SDs, open-ended questions	Anticipated use phase, goal-oriented & entertainment mobile applications
II	Appraisal (e.g., Scherer, 2009; Silvia, 2007), Visual Language (e.g., Arnheim, 1974; Kepes, 1944)	Unexpected events, surprise & visual elements	Exposure times & manipulation of visual characteristics (color, shape, size, and texture)	SAM (Bradley & Lang, 1980) & meCUE (Thüring & Mahlke, 2007)	Goal-oriented mobile application

III	Appraisal (e.g., Scherer, 2009) Visual Language (e.g., Arnheim, 1974; Kepes, 1944)	Visual experience, appraisal, salient visual elements	Content analysis of salient visual elements and emotion themes	3E (expressing emotions and experiences template (Tähti & Niemelä, 2006)	Web pages with similar textual content but altering designs
IV	Appraisal in user experience (e.g., Jokinen et al., 2015)	Experience, conscious, mental contents, apperception	Priming, reaction time, appraisal information source affects, reaction times in preferences through comparisons	Method of primed product comparisons and SD questionnaire (Jokinen, et al., 2015)	Experiences of design forms
V	Information processing fluency (Reber et al., 2004)	Visual usability	Semantic distance through priming, reaction times, and preference scores	Two-fold version of the method of primed product comparisons (Jokinen et al., 2015; Silvennoinen & Jokinen, 2016b)	Time- and safety critical interaction, in-car infotainment system user interface
VI	Visual experience and appraisal (Silvennoinen & Jokinen, 2016b), information processing fluency (Reber et al., 2004)	Aesthetic appraisal & visual usability	Four affects from traditional accounts of aesthetic & four functions of visual usability operationalised as semantic distance	Method of primed product comparisons (Jokinen et al., 2015; Silvennoinen & Jokinen, 2016b)	Operating systems icons from four different designs eras
VII	Apperception (Saariluoma, 2005) and appraisal process (Smith & Kirby, 2001)	Appraisal, apperception, material experience	Appraisal information source of perceptual stimuli, affect SDs (Osgood, May, & Miron, 1975) between vision and touch	SDs (Osgood et al., 1975) with 8 affect pairs per stimuli	Ten different materials as stimuli appraised via sight or touch

4.1 Theoretical position

Visual totalities constructed of perceivable elements elicit different mental information contents in apperceptive appraisal processes in unifying already existing information contents with the newly encountered ones. This does not, however, posit that knowledge could not be obtained regarding visual experiences of technological artefacts that affect multiple areas of our lives. The phenomenon under investigation is required to be divided into its constituent factors through careful operationalisation in order to be examined. Thus, explicit operationalisation of the concepts utilised in studying visual experience in technology-interaction is required in order to understand the visual and its relation to other HTI phenomena, such as perceived usability.

Additionally, design artefacts are affected by the experiential interaction goals appreciated in the time of their creation. The complexity of visual experience and aesthetic appraisals as cognitive-affective mental phenomenon is affected by the instability of aesthetics and the difficulty of measuring it. Aesthetic appreciations, values, and thus judgments change in time, which also affects the concepts with which visual experience is approached with (e.g. Carroll, 2001). Belief and value systems of different eras affect the ways of operationalising studied phenomena. For instance, a change in measurement unit indicates a change in value and belief systems, which affects what is designed and how. This change leads to new set of design implications and influences research practices. For instance, in designing urban environments the measurement unit has shifted from cars to humans, which has led to a new design paradigm.

In HCI studies, aesthetics of interaction and emotional design are the core focus points in the time of writing this thesis, with emerging interest on the role of multiple senses affecting technology-experiences. User experience goals, such as user engagement, immersion, and surprise are also in focus in different interaction contexts, such as entertainment, work, sports, and leisure. Whatever is highlighted in every era functions as a representation of the current values of that time. This also implies methodological decisions through which constructs of different phenomena are studied and measured by.

Although experience is subjective and often private, it can be approached and explicated by verbalisation and thus elicited with interviews or protocol analysis (Ericsson & Simon, 1984), or with questionnaires (Bargas-Avila & Hornbæk, 2011). According to content-based approach (Saariluoma, 2003), through differences in conceptual contents or information contents of mental representations, it is possible to explain differences in human behavior, and thus, differences in appraising visual stimuli. Therefore, to understand and explain visual experiences in appraising technological designs different methods enable in obtaining knowledge of the experience process from different perspectives. Different methods enable the examination of experiences, as emotions are considered to be difficult to verbalise, as are sensory experiences if sensory specific vocabularies are not utilised in facilitating the experience description. For this reason, different methods are needed. Deductive, theory-based, hypotheses can reveal certain aspects and inductive explanatory approaches other aspects. For instance, we can set some affects as the measurement units based on results of previous research indicating elicitators of visual properties appraised as pleasurable and satisfying in some specific design contexts, or to investigate visual properties of apperceptive attention. Through the combination of these methodological standing points, visual experiences can be understood and explained in more detail.

In HTI research different methodological positions can be taken and explained in terms of intentionality relating to ontology and causality relating to epistemology, leading to four methodological positions, which are behaviourism, cognitivism, neuroscience, and subjectivism illustrated in Figure 1 (Jokinen, 2015b). These four methodological positions in HTI originate of whether intentionality and causal explanations are expected. Intentionality is a feature of mental state that is about something and represents something (Fodor, 1985a). Intentionality is in the relationships between individuals and objects that are mentally represented (Jokinen, 2015b), thus, intentional mental states involve mental contents of what is represented (Saariluoma, 1997). Objects can be seen differently in terms of intentionality, what is in focus of the perceiver and, for example, what is represented to the object. Thus, a same design artefact can be mentally represented with numerous varying mental contents by different people, depending on the goals, needs and desires of a person.

Causality is in the core of explaining events via cause and action, and thus, functions as a foundation for explaining events by manipulation and control which brings out the effect. In HTI research the concept of interaction refers to a causal relationship between the technological artefact and the human. (Jokinen, 2015b).

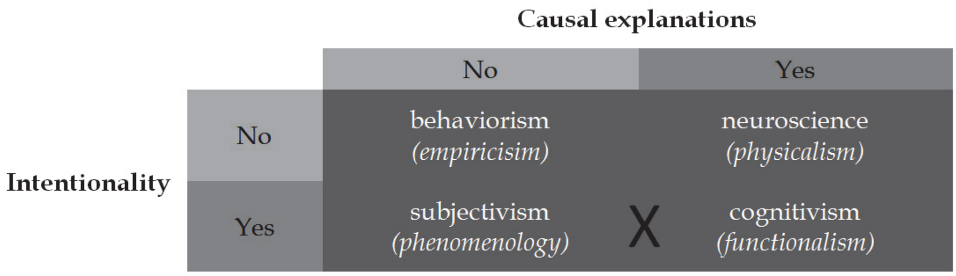


FIGURE 1 Four methodological positions in HTI (Jokinen, 2015b).

The methodological positions can be utilised in HTI research to explicate underlying assumptions of studied phenomenon. Without explication of methodological positions, the way the studied phenomenon is investigated can lead to contradictory conclusions and not to measure the phenomenon actually in question. In *behaviourism*, the focus is on observable, objectively measured events (Skinner, 1969). Thus, the explication of studied phenomenon follows explanations from stimulus to response, not taking into account what happens in the mind of the subject.

In HTI research behaviouristic stances are often undertaken, even though not explicitly indicated as such, the same stance applies to visual experience studies in HTI in terms of empirical aesthetics. However, behavioural measurements can be utilised in studying mental events, such as visual experiences, if strong cognitive theory functions as the basis of the research formulations. Thus, explaining phenomenon in question, the strength of the solutions to the problem in question is dependent on the capacity of the utilised constructs of concepts, laws and facts (Laudan, 1977; Saariluoma, 2005; Saariluoma & Oulasvirta, 2010; Jokinen, 2015b).

Traditional account to cognitivism conceptualises human mind to a computer, also termed as computational-representational theory of mind (e.g., Frankish & Ramsey, 2012). Paradigms of capacity and information processing fluency have originated from the metaphor of mind as a computer. The mind processes information similarly to a production system such as a computer with sensory input and motor output responses (Newell & Simon, 1972). This notion can be associated with the philosophical position of functionalism, indicating that mental states are identified by their causal links to sensory inputs, other mental states and motor outputs (Jokinen, 2015b). In HTI this means that it is feasible to determine research experiments as interventions to the process of technology use, which can then be examined in detail.

Neuroscience, in turn, takes a physicalist stance to human mode of thinking in terms of the brain. Intentionality is seen as physically observable functions in human nervous system. In HTI research that takes a neuroscientist position, technology use is investigated by analysing the neural basis of mental functions (Jokinen, 2015b). In order to fulfil the objectives of cognitive science in HTI, a complementary addition to research settings is needed to be able to study how mental contents can be connected to neural systems.

A contrasting stance to neuroscience is offered by subjectivist approaches originating from phenomenology, which asserts that scientific and other ontologies depend on how we fundamentally experience the world. Hence, scientific analysis is fundamentally intertwined with the explication of the meaning of existence. As Heidegger (1927) and Husserl (1913) claim, the central idea in phenomenology is to study the structure of experience. The methodological position that is in line with the phenomenological thought is here referred to as subjectivism, because it emphasises the need to focus on the experience of the subject instead of the objective results produced by experiments (Jokinen, 2015b). Intentionality in terms of subjectivism means that people have mental representations which have information contents. Saariluoma (2003) defines experience as the conscious part of mental representation. Further, human behaviour can be examined and explained by studying the mental contents of people.

A commonly accepted stance originating from phenomenology is constructivism, which assumes that experiences are not passive observations of the environment but involves active interpretation in constructing experiences. For example, the content of mental content is affected by one's culture, but the cognitive process in which mental contents are processed, can be studied by cognitive psychology (Jokinen, 2015b). In HTI, and especially from the viewpoint of visual experience, both the cognitive channel and mental contents are intertwined in an experience. It seems that the most suitable form of subjectivism in the study of visual experience is in line with Fodor's (1985b) notion of cognition being saturated with perception, and thus, all that can be known is determined by one's own epistemological framework.

This thesis is methodologically posited between subjectivism and cognitivism. Therefore, the methodological approach is referred to as interactionist approach, illustrated in the Figure 1 with an X-mark. Interactionist approach as formulated in the information processing fluency paradigm pertains to cognitivism as aesthetic appeal is considered as a result of cognitive fluency in processing visual information (e.g. Reber et al., 2004). Therefore, the interactionist approach utilised in this thesis is extended from the processing fluency paradigm to include subjectivist approach to the studied phenomenon due to the definitions of the visual substance in processing fluency paradigm.

4.2 Conceptual position

Conceptual postulates in science are implicit or tacit assumptions (Saariluoma, 1995). Limited capacity channel is the main postulate in psychology, but this does not apply to phenomenological stance of inquiry. Capacity focuses on information but not in the contents of this information as does phenomenology. Thus, phenomenology is essential in examining experience due to the contents of experiences. In addition, psychological stances are needed to be undertaken to understand how we see what we see. Phenomenology focuses on understanding experience as internal phenomenon by understanding internal event, intentions and explication is conducted with future tense. Traditional cognitive science explains experience as external event with causal explanations (the things that occurred for something to happen, causality explains events from the past). These both research paradigms involved in HTI explain present experience but from different perspectives, and contain different postulates of explicating and understanding human experience. Phenomenology gives the power in understanding the experience, but not to explain it. Thus, these scientific stances are required to be merged in order to understand and explain visual experience. These stances can be combined with objective measurements accompanied with strong theoretical background from which hypotheses are derived.

Besides of the theoretical standing points and the above-mentioned methodological decisions, the selection of the visual stimuli under investigation affects the results. Aesthetic stimuli in HCI research include, for instance, maps (Lavie, et al. 2011) and icons (Isherwood, 2009; McDougall & Isherwood, 2009), which are not commonly acknowledged as "aesthetic stimuli" in the psychology of aesthetics (Tinio & Smith, 2014). However, the utilised research approaches of visual studies in HCI follow same research procedures as in empirical aesthetics. Thus, the classification of visual stimuli as objects of art, design, or hybrids, partly determines the research paradigm to which it belongs.

In models of aesthetic appraisal and aesthetic judgement (e.g., Leder, Belke, Oeberst & Augustin, 2004), the process starts of recognising the stimuli as an object of art in order for an aesthetic experience to occur. Thus, despite of the research stances in psychology of arts and in empirical aesthetics (that majority of the research conducted in the field of visual aesthetics in HCI research is, whether implicitly or explicitly) the phenomenon of visual experience examined here would not be considered of belonging to this line of research due to the selection of stimuli. For instance, in numerous studies of visual aesthetics in HTI, operationalisations are not explicitly linked to the methodological foundations of empirical aesthetics (Berlyne, 1971; 1974), even though the problematisations and approaches follow similar procedures. This is partly explainable due to the practical industry relations of HTI, and especially of HCI (Liu et al., 2014), however this does not legitimise the neglect of explicating theoretical and methodological grounds.

Recently, the discourse of the role of aesthetic stimuli between 'art with a lower-case *a'* (e.g. popular culture) and 'art with upper-case *A* '(e.g. fine arts) involves considerations of other visual design artefacts and representations to belong to the same methodological paradigm as empirical aesthetics (Leder et al. 2004; Tinio & Smith, 2014), or to philosophy of aesthetics (Forsey, 2016). Occasionally design objects have been investigated as representatives of aesthetic stimuli (e.g. Hekkert, 2003) in line with objects of art (in sense of *techne*), fine arts, and crafts. Thus, technological artefacts, such as visual user interfaces, can be experienced as visually appealing, fascinating, or beautiful and, thus, elicit similar appraisals as in encountering objects of art, due to the nature of the process. Visual experience does not lie in the physical properties of an object, but occurs in perceiver's mind informed by the properties of an object in attention. Thus, a stimulus itself is not the sole determinator of such cognitive-affective processes in visual experiences. Thus, cognitive-affective approach to visual experience, does not differentiate between the nature of the stimuli, because aesthetics is not within the object, but occurs in the interaction between the stimuli and the perceiver. For instance, according to some specific beauty criterion of some design era, ugly objects or properties that are appraised as ugly in the style atmosphere of that time, can be apperceived as aesthetic in different times. It depends solely on the non-perceivable attributes attributed to the stimuli by the perceiver.

Visual elements imply formalistic accounts (e.g., Bell, 1958) of visual research by stating the object properties as a starting point or focus of attention. However, by examining apperceptions of these perceivable entities with an interactionist approach, formalistic accounts can only be utilised in defining the visual elements of visual language concerning physical object properties. Explicating experiences from formalistic perspective however cannot provide sufficient basis in examining visual elements in visual experiences due to the deterministic and universalistic foundations of formalism.

Even though represented mental contents are highly subjective (i.e. meaningful information contents apperceived in technology interaction coloured by already existing information contents), with careful operationalisation of the studied constructs, qualitative dimensions (also non-perceivable, such as timelessness and imaginative) attributed to the properties of technological artefacts can be examined. The need for strong theoretical underpinnings of visual experience is two-fold. In scientific research, only theoretically sound basis for operationalising measures and discussing the results can yield useful understanding, which goes beyond single case studies. However, the same is true also for design pursuits: although studying how designs affect experiences on a case-by-case basis has its benefits in informing design, this benefit is often limited to the narrow context of the particular design and experience goal. Therefore, being able to theoretically understand the concepts of design and visual experience already at the early steps of design is essential in HTI.

Recent attempts at solving the problem of relating visual design elements with user experience include two main approaches (Tractinsky, 2006), and an additional one combining these two. In the first, a screen-based design approach, often referred also as an objective approach, is utilised in detecting the specific bottom-up design factors influencing aesthetic experience and identifying design factors in the objects and their organization on a web page that impact on user experience (Bauerly & Liu, 2006; Kim et al., 2003; Lin et al., 2013; Ngo & Byrne, 2001; Park et al., 2004). Bottom-up approaches to visual processes (e.g., Gibson, 1979) place emphasis on the properties of the visual stimuli in guiding visual attention, for instance, saliency of the stimuli (Itti, 1998) and the Gestalt laws (Koffka, 1935; Wertheimer, 1938). Although this approach could work to support design for usability and has led to design guidelines for usability (e.g. Galitz, 2007), Tractinsky (2004), it raises doubts about its usefulness for designing aesthetics, because the design would need to address a very large number of combinations of design solutions with a wide range of individual differences in preferences. Since Plato, and probably even earlier, people have investigated the critical contributors of beauty. This line of thinking has led to identifying some visual features that consistently contribute to perceived beauty, such as symmetry and balance (Arnheim, 1974; Gombrich, 1995).

More recently, researchers of visual aesthetics in HCI have examined visual experiences from this perspective (Ivory, Sinha & Hearst, 2001; Kim et al., 2003; Miniukovich & De Angeli, 2015; Ngo & Byrne, 2001; Ngo, Teo, Byrne, 2003; Tuch et al., 2012). Some researchers argue for the prospect of identifying formal, objective, attributes that determine aesthetic judgment, and which will ultimately lead to automatic composition or checks of displays such as web pages (e.g., Ngo & Byrne, 2001). This approach has been criticized on the grounds that, aesthetic laws engrained in the object are "universalist" (Krippendorff, 2004), and thus, would not survive individual, cultural, and context differences (Martindale, Moore, & Borkum, 1990; Krippendorff, 2004). Similarly, Csikszentmihalyi (1991) argues that formal aspects only rarely make objects valuable to their owners. He speculates that people do not perceive formal attributes such as order or disorder in design according to mathematical principles. Still, despite the apparent subjective and context-dependent nature of aesthetic processes, studies have continued the quest for basic and formal principles of aesthetic properties of interactive systems. Such principles can be expressed as computational models aimed at achieving optimal design spaces. For example, Bauerly and Liu (2006) suggest that in basic images, symmetry and balance affect aesthetic appeal ratings. However, they also found that the strong relationship found between symmetry and aesthetic appeal diminished when tested with more realistic (i.e., context-dependent) web pages

The second approach to investigating the relationship between design elements and aesthetic appeal focuses on users' perceptions of aesthetics from top-down perspective (Lavie & Tractinsky, 2004; Moshagen & Thielsch, 2010). This subjective approach can be described with the saying 'beauty is in the eye of the beholder'. In contrast to the objectivist screen-based design approach, the top-down approach is often based on self-reports, such as questionnaires (Seckler, Opwis, & Tuch, 2015). The third approach, combining the bottom-up and top-down approaches is an interactionist approach, although this approach has not been utilised to a great extent in examining the interplay of visual elements and technology-experiences (Seckler et al., 2015). The interactionist perspective on aesthetic experience is based on the view that:

> "beauty is grounded in the processing experiences of the perceiver that emerge from the interaction of stimulus properties and perceivers' cognitive and affective processes"
> (Reber, et al, 2004)

In other words, visual experience is to be regarded as a relationship between an object and subject, rather than of tangible essence to be grasped or determined (Folkmann, 2013). In recent HCI research, the interactionist approach has been utilised in combining the objectivist and subjectivist perspectives. For instance, classical and expressive aesthetics (Lavie & Tractinsky, 2004) and VisaWi (Moshagen & Thielsch, 2010), considered as widely accepted measures of the subjective approach (Seckler et al., 2015), have been examined in terms of correlations to design elements detected in objectivist studies (Michailidou, Harper & Bechhofer, 2008; Altaboli & Lin, 2011). Another approach of connecting design elements and experience outcomes include computational aesthetics (Miniukovich & De Angeli, 2015; Ivory, Sinha & Hearst, 2001; Reinecke, Yeh, Miratrix, Mardiko, Zhao, Liu, & Gajos, 2013), which can be considered to follow the bottom-up approach in detecting visual user interface design elements and compositional structures important in affective design. Computational aesthetics lists a number of visual user interface measures, such as symmetry and visual clutter, and correlates these with subjectively perceived beauty. However, the approach offers no explanation on these correlations. For example, negative correlations of visual clutter and perceived beauty lacks explanation. Without a theoretical basis, correlative results are susceptible to confounding factors, which a theory would identify and allow the researcher to control methodologically (Seckler et al., 2015).

Often in HTI and especially in HCI the operationalisation of aesthetics is conducted on a very abstract level stimuli, which were designed, for instance, to have either 'low' or 'high aesthetics' (Tractinsky, 2000), pleasant or unpleasant (Sonderegger & Sauer, 2010), or non-appealing or appealing (Thielsch, 2012). In such examples, the decision of whether a stimulus has high or low aesthetic properties is left to an intuitive understanding, and thus no connection between the elements of the design and experience responses can be made. It is, however, possible to at least try to give concrete definitions on what visual appeal is and how it is connected to visual user interface design. Operationalisations in this thesis are conducted as presented in Table 1, taking into account both conceptual and procedural issues.

Numerous different design elements have been proposed to contribute to pleasant aesthetic experience. Plato's view to beautiful objects includes a combination of harmony, proportion and unity among visual elements. According to Aristotle universal dimensions of beauty are symmetry, order, and definiteness. Gestalt psychologists suggested for example symmetry and balance as contributors to beauty (Arnheim, 1974; Gombrich, 1995).

Various overlapping concepts have been used to conceptualise and operationalise appealing visual experience. For example, one can extract meaningful dimensions of visual experience with an Osgoodian method, where participants report their impressions of stimuli using Likert or semantic differential scales containing various adjectives. The responses are analysed using factor analysis, which reveals latent dimensions of affective experience (Osgood et al., 1975). The original model by Osgood contained three dimensions, evaluation, potency, and activity, but these are perhaps too general to be useful in assessing visual experience of various stimuli.

Studies more specific to the HCI context and user experience have revealed such dimensions of aesthetic appeal as overall impression, beauty, and meaningfulness (Schenkman & Jönsson, 2000) classical aesthetics (aesthetic, pleasant, clean, clear and symmetrical) and expressive aesthetics (creative, using special effects, original, sophisticated and fascinating) (Lavie & Tractinsky, 2004), and simplicity, diversity, colour, and craftsmanship (Moshagen & Thielsch, 2010).

4.3 Experiments

In order to study how visual experience can be understood as an appraisal process, where bottom-up and top-down sources of information dynamically influence the experience methodical decisions need to be decided according to these dimensions. As visual experience is a mental phenomenon, the study of such a phenomenon is a study of the human mind. In order to examine the workings of the human mind the conducted experiments need to interpretable within a theoretical framework that postulates mental representations (Thagard, 2005), and thus mental information contents.

In this thesis, the method of primed product comparisons was utilised and developed (Jokinen, Silvennoinen, Perälä, Saariluoma, 2015). In it, participants are required to quickly choose between two visual stimuli, given a prime (e.g., elegant, light, or sophisticated). The data is collected with preference scores between all the possible combinations of the stimuli, given a prime, as well as reaction times for the participants to conduct preferential judgements. The participant is first shown a prime and then two stimuli from which the participant then needs to choose the one that is preferred more, given the prime (Figure 2). The participant is asked to do this preferential judgment as quickly as possible. The resulting data contains prime-specific preferences as well as reaction times, indicating how quickly the participants were able to make the comparison. The benefit of the method in comparison to a method without stimuli comparisons, in which preference judgments would be conducted only by indicating whether some stimulus is considered to be something or not, or how much, is that the, comparison makes the appraisal relative.

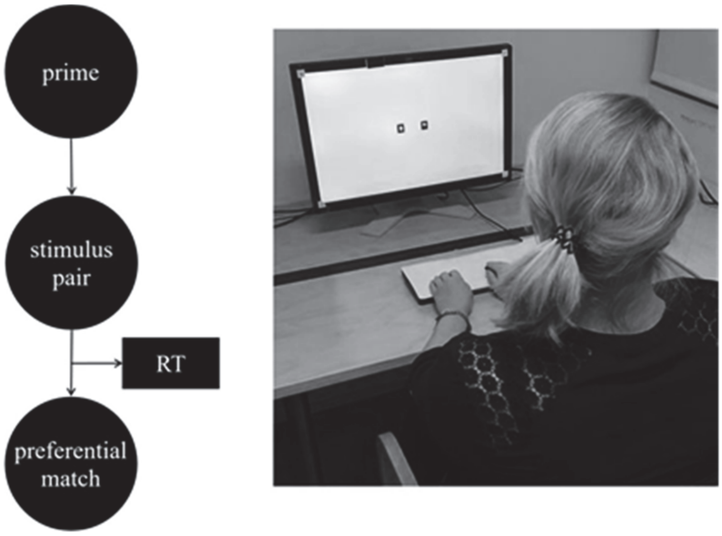


FIGURE 2 The procedure of primed product comparisons method and experimental set-up.

Further, the method of primed products comparisons connects the process of preferring one stimulus over another with the theoretical appraisal process of emotion, as it requires the participants to make their choice as quickly as possible. This is evident for example in the ability of the method to capture the effect of different appraisal levels on the time it takes to arrive at the preferential judgement. The method thus allows the investigation of the cognitive process, which eventually results in a conscious decision to prefer one stimulus over another.

In addition, inductive methods (e.g. 3E self-report method) are used to clarify without a priori determination what are apperceived as the essential visual elements in technological artefacts, and how these are experienced. An explorative research strategy is conducted by studying experiences of different visual elements and the performative aspects attached to them. Empirical data is gathered to analyse underlying cognitive and affective processes dynamics of visual experiences and the connections of apperceiving visual elements.

Data is collected by experiments containing data analysis of visual stimuli of different styles of mobile user interfaces (Articles I, II, and IV), websites (Article III) and icons in-vehicle user interface and in operating systems (Articles IV and VI). In addition, data is collected with experiments utilising the method of primed products comparisons, consisting of reaction time data with user preferences and priming procedures (Articles IV, V, VI), thinking aloud procedures (Article IV), questionnaires (Articles I, II, and IV), a semantic differential questionnaire (Articles IV, VII), and with 3E self-report method (Tähti & Niemelä, 2006), which allows users to express emotions and experiences non-verbally by writing and drawing (Article III).

The methods utilised were chosen to examine visual experience of technological designs due to their ability to reveal different perspectives to the studied phenomenon. For instance, established subjective measures, such as meCUE and Attrakdiff, were utilised in the first studies to investigate the role of visual elements in appraising visual elements. 3E-template was utilised to study the role of visual elements without a priori determination of the possible response-dimensions and concerning the most salient visual elements. However, in order to investigate visual technology-experience as a mental phenomenon the combination of subjective and objective data was required to further examine the experience process. Therefore, the method of primed product comparisons was developed and validated.

The methodological decisions for the studies in this thesis were influenced by the nature of the visual viewpoint. As the focus is on visual experience, no methods utilised to analysing the visual dimension of design artefacts were chosen. Therefore, many methods, for example, iconography (e.g., van Leeuwen, 2004) was not applicable due to the nature of the data, that the data along with the object of analysis are visual images, not visual experiences of the participants. Furthermore, even though data collected by other methods, such as eye tracking, could enable in extracting the specific areas of attention, it would be impossible to analyse which element draws the attention (e.g., colour, form or, for instance, visual tension between these elements).

5 FRAMEWORK OF VISUAL EXPERIENCE IN HTI

Research focused on experiential aspects of HTI shows that scientific explanation of human behaviour is achievable only with a relevant framework, including cognition and emotion (Law et al., 2009; Zhang, 2013). In case of a study that requires solid theoretical foundations, a relevant framework must be theoretical, consisting of theoretical assumptions, concepts, values, and practices that constitute a way of viewing reality (American Heritage Dictionary, 2016). If there is no single existing theory that is appropriately explaining the phenomenon under study, one must build a relevant one that explicitly states the theoretical assumptions, connects the study to existing knowledge, and has enough explanatory power. The framework should also facilitate in intellectual transitions from depicting the phenomenon (empirically) studied to making generalisations about several aspects of the phenomenon.

The framework of visual experience in HTI integrates different dimensions of visual experience with methodological position and functions as a basis for argument-based design as an explanatory framework (Figure 3). Thus, the research questions of this thesis are answered as follows.

RQ1: How the visual dimension of technology is experienced? is explicated with the constituents of visual experience in appraisal process via apperception.

RQ2: How visual experience and its underlying dynamics in HTI can be examined? is answered with the interactionist approach to visual experience in HTI.

RQ3: How to design for visual experiences in technology-interaction? is answered with argument-based visual design in HTI which is based on the framework and, thus, the framework functions as an explanatory framework for argument-based visual design in HTI.

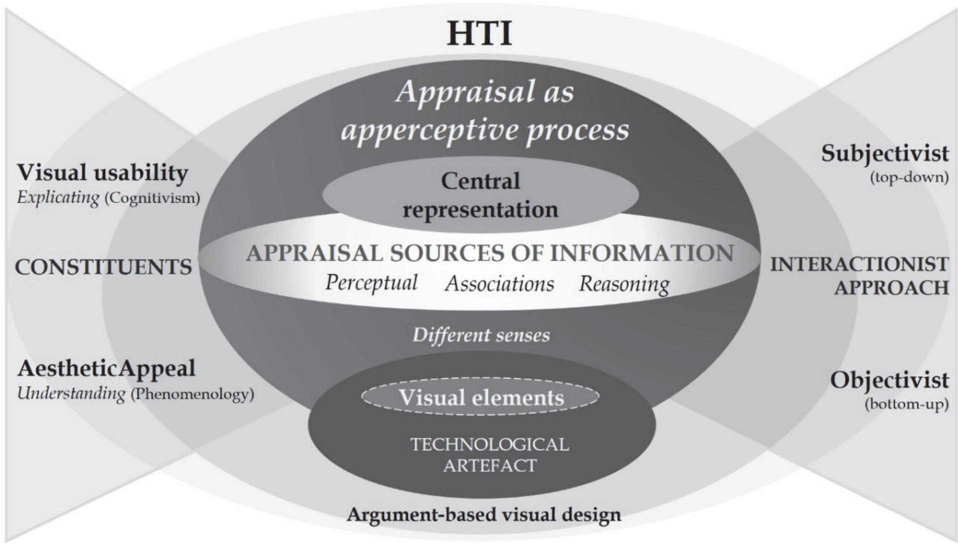


FIGURE 3 Framework of visual experience in HTI.

The integration of the framework of visual experience in HTI is based on the interactionist view, which combines objectivist and subjectivist accounts of visual experience. The constituent dimensions of visual experience are visual usability (functionalist sense-making vehicle) and aesthetic appraisal (experienced quality affects), which are the concepts with which visual experiences can be examined if explicated in detail for operationalisation. Further, the constituents of visual experience are explained in a more theoretical level as mental phenomenon by apperception and appraisal, which posit the fundamental nature of visual experience to be examined with interactionist approach of the operations of the constituent dimensions in experiencing visual elements in HTI. Finally, the framework provides foundations for argument-based visual design in HTI.

In the following sections, first, the constituents of visual experience are explained, which are visual usability (in explicating visual experiences from methodological position of cognitivism) and aesthetic appraisal (in understanding visual experiences from the methodological position of phenomenology). The constituents are further discussed concerning the interplay between them in visual experience. Secondly, apperception and appraisal (including different appraisal sources of information) are described in visual experience as a conscious mental phenomenon in experiencing visual elements of technological artefact. Apperception and appraisal are further discussed in terms of sensory experiences, through which visual experiences can be understood in more detail. Thirdly, the methodological approach undertaken in this thesis is explained. Fourthly, the theoretical framework of visual experience is presented as an explanatory framework for argument-based visual technology-design. The section of argument-based design contributes to the scientific knowledge on how to design visual technological artefacts.

5.1 Visual Usability and Aesthetic Appeal

Visual elements contribute to pragmatic user experience component in terms of visual usability and to hedonic user experience component in terms of subjective preferences of visual aesthetics (*Article I*). Thus, by studying the lowest level elements (as the constructing units of visual representations in technological artefacts) the underlying dynamics of visual experience can be explicated in more detail. The interplay between aesthetic appraisal and evaluations of usability has been explicated with information processing fluency paradigm. Conceptually this paradigm posits in traditional accounts of cognitive science, in focusing on cognitive fluency of information processing without pursuing to understand the mental information contents of visual experiences. Additionally, in HTI research the aesthetic-usability effect research has emerged from this paradigm. However, according to the results of this thesis, in resolving the interplay of the underlying constructs of visual experience in HTI from processing fluency paradigm becomes difficult. Positive aesthetic appraisal is not induced merely due fluency of cognising visual representations, thus, fastness of interpretation does not solely predict aesthetic experiences, but the phenomenon is more complex. For instance, something can be quickly appraised as old-fashioned and unappealing, and thus, is not experienced to possess aesthetic qualities despite the fluency.

The ability of cognitive fluency to increase aesthetic appraisals can be accomplished in focusing on the visual usability aspect of HTI. For, instance in terms of icon interpretation, by designing efficient semantic distances to be interpreted effortlessly, positive aesthetic appraisals are more likely to occur. The difficulty of designing for aesthetic experiences can be conducted in the underlying constructs and the interplay between these is acknowledged. This is in line with Modernistic accounts of design, in which the functional aspects of the pictorial representations communicate meanings (Parsons, 2016). Visual usability functions as a prerequisite for aesthetic appraisals, and contributes to the process of visual experience as the sense-making vehicle, enabling pleasurable visual experiences to take place in HTI. Thus, the framework of visual experience posits the concept of visual usability as a one dynamic involved in visual experiences (*Articles I & VI*). In line with the Vitruvian design constituents, visual usability in visual experience refers to *utilitas* and aesthetic appeal to *venustas*. Thus, the core components of visual design have been long acknowledged, but the ways of examining, explicating, and understanding the experience in light of these constituents not in terms of cognition and affect, for which this framework offers a theoretical vehicle to be utilised in conceptualisation of the studied visual substance, methodological positioning, operationalisation resulting of arguments made on the basis of the first two, and thus, scientific evidence to inform designing for the visual (Figure 4). In addition, the framework functions as discourse tool in outlining the visual in terms of recent advancements in cognitive science.

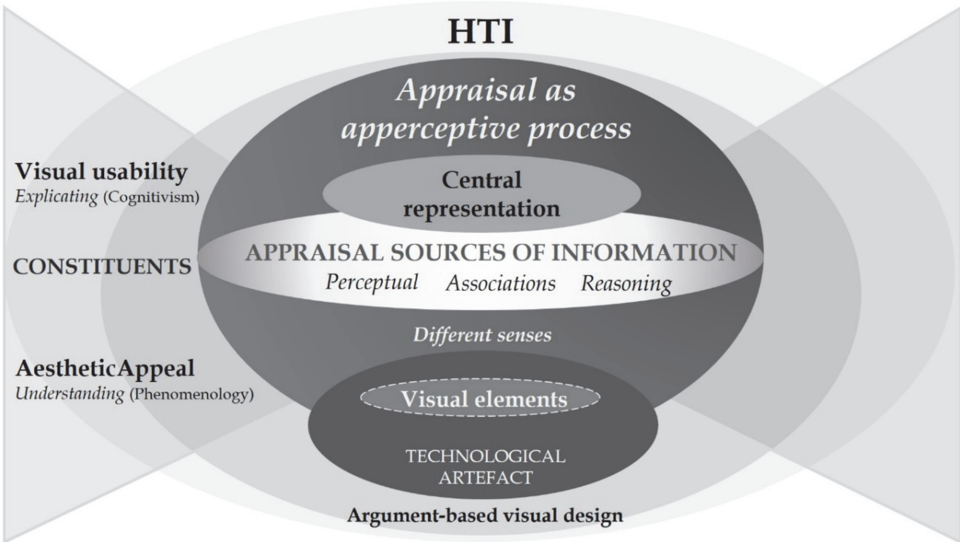


FIGURE 4 Visual usability and aesthetic appeal as constituents of visual experience.

Aesthetic appraisals of technological designs can be examined in terms of philosophy of aesthetics, psychology of aesthetics, and empirical aesthetics according to the framework of visual experience, because aesthetics is not within the object, nor solely in the mind of the perceiver, but occurs in interaction. Thus, aesthetics is not a property of an object per se. If the cognitive-affective approach in visual experience with appraisal process and the concept of apperception are taken into account in methodological position, we could discuss this approach in terms of cognitive aesthetics. This formulation is in line with recent discourse on design objects in philosophy of aesthetics, within the domain of Everyday Aesthetics (Forsey, 2016). Methodological extensions to traditional approaches in philosophy of design have been investigated in the domain of Everyday Aesthetics. However, attempts of broadening the traditional methodologies has not succeeded due to the inconsistency of aesthetics and lack of philosophical rigour (Forsey, 2016). Thus, Everyday Aesthetics lack of foundational analysis of the core concepts; aesthetics, design, and experience.

5.2 Apperception and Appraisal

Appraising visual entities via apperception unifies information from three sources of appraisal; perceptual stimuli, associative information source, and reasoning (Smith & Kirby, 2001). The detection and processing of perceptual stimuli is direct and quick, and thus, does not require complex mental processes. Associative processing is also fast as it depends on spreading activation, which means that retrieving relevant information from long-term memory is dependent on the activation of relevant nodes (Anderson, 2000). The appraisal process from the associative source takes more time than from the source of perceptual stimuli. The third appraisal source of information is reasoning, which occurs under conscious control, is involved in constructing meanings, and is therefore slower than associative processing (Figure 5). All these three appraisal sources of information are important in visual experiences.

Information contents of mental representations are the experiential dimensions through which we make sense and experience of what we perceive (e.g., via touch or vision) and what makes the encountered technological artefacts meaningful to us. By studying apperceptions and appraisals of technology-interaction through information constructed via other sensory modalities (e.g. touch) the logic of apperceiving visual dimensions of technological artefacts can be understood in more detail. Understanding the cognitive-affective process of encountering and experiencing technological artefacts can be explicated in detail with apperception and appraisal theory of emotion.

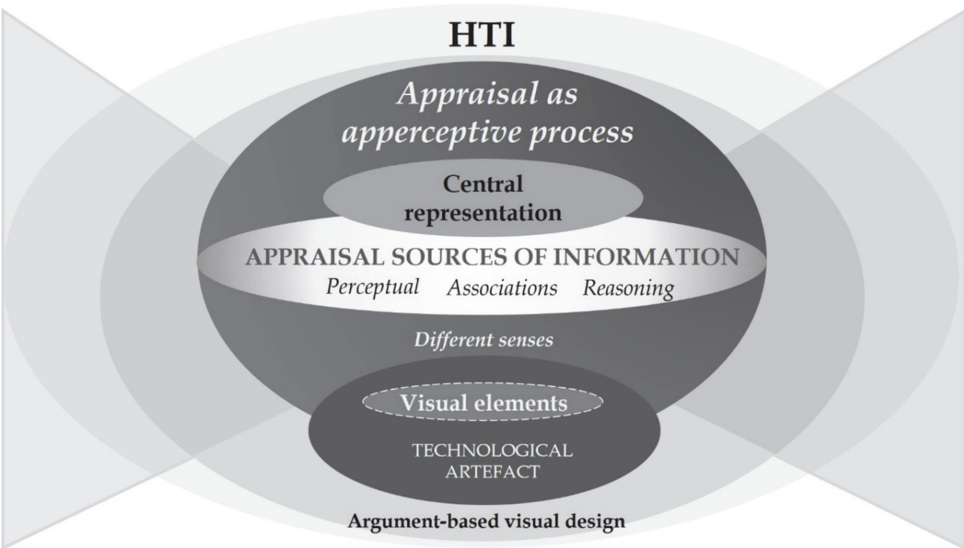


FIGURE 5 Appraisal as apperceptive process in visual experience.

Visual design elements are important factors in experiencing technological products due to their ability to elicit emotions and also to evoke strong emotional responses (Desmet, Overbeeke and Tax, 2001). Emotions elicited by visual product properties inform various sensory modalities, and through examining how information obtained via other senses, than only through the visual modality, enhances the understanding of the underlying dynamics of visual experience. By studying apperceptions and appraisals of technology-interaction through information constructed via other sensory modalities (e.g. touch) the logic of apperceiving visual dimensions of technological artefacts can be understood in more detail. Sensations, perceptions, and apperceptions of multisensorial representations of visual product properties in HTI can be explicated with the cognitive processes through which information contents of mental representations are constructed. Visual representations are capable of eliciting multisensorial mental contents and experiences, in which experience can be understood as the conscious part of a mental representation.

5.3 Interactionist methodology

What visual experience is conceptualised to include (i.e., the foundational grounds of the studied concepts and the theories on which these rely on) determines the methodological position of the research. The explicated methodological position in examining visual experiences functions as a determinator to further research positions, operationalisations, and the chosen methods in investigating the phenomenon. In this thesis, the methodological position was interactionist approach to visual experience was extended from the grounds of processing fluency paradigm with the explication of visual experience as a mental phenomenon. Interactionist approach as a methodological stance in examining visual experiences in HTI combines subjective and objective research paradigms of visual experience, affective and cognitive processes, and experience as a mental phenomenon apperceived in appraisal process. Thus, objectivistic (or formalistic) view cannot function as a sufficient basis for explicating visual experiences. Subjectivists accounts would function as a framework to be applied to everything, thus all things encountered would only be 'seen' as with non-perceivable mental contents without the visual elements influencing the experience outcomes. Thus, objectivist accounts can be referred to operations of perception and subjectivist to apperception, but including explicable cognitive and affective processes. What results of this argumentation, is the interactionist account of examining visual experiences (Figure 6).

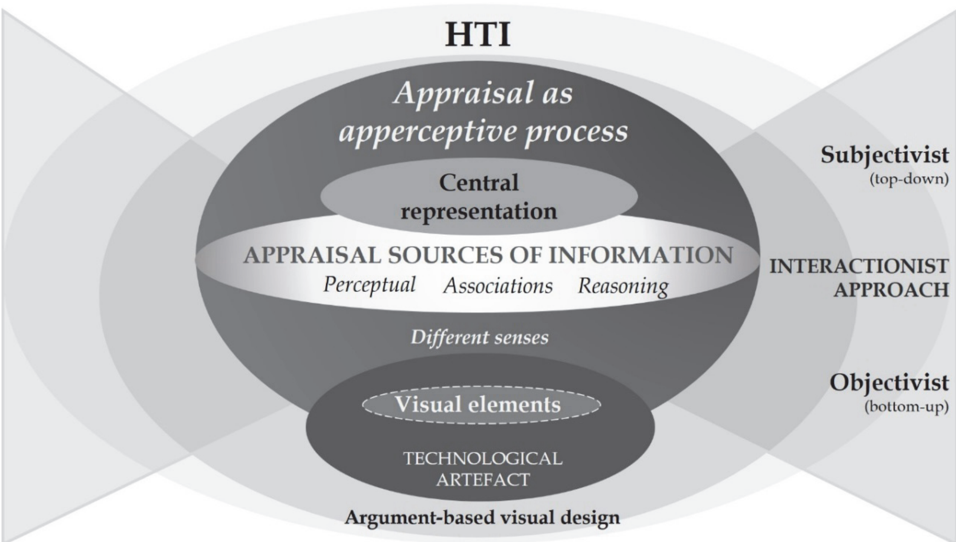


FIGURE 6 Interactionist approach to visual experience research.

However, as shown in the article VI, information processing fluency paradigm as a basis for interactionist approach to visual experience, or aesthetic appraisal (if quality of the encounter is emphasised), is required to be enhanced with foundational analysis of the visual substance and its operations. For instance, if processing fluency predicts an object to be appraised as beautiful, the assumption here stands within the gratitude of the process in terms of cognitive fluency. However, design objects can be quickly appraised for instance as old-fashioned (with negative valence), but apperceived as aesthetic despite of the cognitive fluency of processing the visual stimuli. Thus, the postulates of the visual under investigation requires detailed analysis to produce valid results. Therefore, a theoretical framework for visual experience incorporates foundational analysis of the visual substance as a concept to be examined along with the methodological positions in order to be operationalised, and to provide research knowledge for argument-based visual design of technological artefacts.

The methodological approach, thus, unifies recent advances in cognitive science with a careful analysis of the visual substance, and through this posits reliable grounds for visual experience research. Even though represented mental contents are highly subjective (i.e. meaningful information contents apperceived in technology interaction coloured by already existing information contents), with careful operationalisation of the studied constructs, qualitative dimensions (also non-perceivable, such as timeless and imaginative) attributed to the properties of technological artefacts can be examined, as the visual experience process is informed by the encountered visual entities. The framework can be further explicated by discussing dichotomy between usability and aesthetics or the numerous studies reporting their correlations but complex relationship.

5.4 Argument-based Visual Design

Technology changes constantly with increasing speed, but knowledge of human cognition does not. Thus, argument-based design from the human perspective is more valid basis for technology-design than novel technological solution as the starting point. Argument-based design involves both scientific and design stances, due to the conceptualisation of creativity in the design activity. Creativity is considered as analytical thinking which synthesises user knowledge, research knowledge and innovative thinking, and foundations of design (Saariluoma, 2005). Technological advancements have changed for instance family structures, and the design of nursing homes with hospital concept, in which human mental needs are not in the core of the treatment. In these institutions people are first understood as patients and after that as human beings. The same way technological advancements have enabled new ways of pictorial representations, and it has to be acknowledged that visual representations are a powerful way of communication, and might involve different biases and hidden value structures. For instance, how conventions and standards evolve and are established, according to what criteria the correct way of presenting information content in some visual form is determined? These kinds of choices in technology-design shapes our lives, as these established design decisions informs us of the world, and subtly teaches us correct interaction modes. Thus, research-based design is an influential way towards enhanced equality in HTI.

Changes in HTI (especially in HCI) design and problems that occur when the traditional design-as-engineering approach is utilised can be explained with the changes of defining technology-experience and to design for technology-experiences. HCI design and the concept of user have changed during last few years. The human is seen as someone who has an experience with or through the technology previously people in technology-interaction were conceptualised as just in terms of engaging in dialogue with the system. Previously engineering approach to HCI design was appropriate due to the compatibility with the existing thought structures concerning the human in interacting with technologies. However, the engineering approach to HCI and to HTI lacks many of the key aspects of examining technology-experiences, as it separates form and content, behaviour and emotion, and functionality and aesthetics while the quality of experience emerges from the interplay between them.

If the workings of visual cognition and other cognitive processes in experiencing visual information are acknowledged by technology-designers, the more subtle ways of influencing technology-experiences can be designed. From user psychological perspective this knowledge in designing technological artefacts is one of the cognitive science background areas in explanatory frameworks for argument-based design. In order to accomplish design tasks with the suggested theoretical background, knowledge of visual experience as mental phenomenon with its underlying dimensions, research on visual communication design of visual elements and sensitivity in visual literacy are required.

To design for specific experiences is difficult. Predictability of experience outcomes on the basis of visual design decisions is hard. However, through careful examination of the interplay between dimensions of visual experience design solutions can be suggested. For instance, according to the results of this thesis there's more predictability of designing for semantic distance and touch, which affect the visual experience and quality evaluations. As visual usability and aesthetic appeal affect each other in visual experiences, by focusing on effective and comprehensible visual usability design the likelihood of aesthetic appeal to occur is better. In addition, affective qualities are appraised with different logic, but unified in the experience process via apperception. As appraisals via touch are conducted more unanimously, there's also more predictability for touch experience-design than for visual experience-design. To carefully consider the different senses and the affective qualities the design for certain goals is more manageable. In addition, experiences emerging via the various senses inform each other, as technology-experiences are multisensorial. The framework of visual experience can be utilised as discourse tool and as a basis for argument-based design in HTI.

Emotions elicited by visual product properties inform various sensory modalities, and through examining how information obtained via other senses, than only through the visual modality, enhances the understanding of the underlying dynamics of visual experience. By studying apperceptions and appraisals of technology-interaction through information constructed via other sensory modalities (e.g. touch) the logic of apperceiving visual dimensions of technological artefacts can be understood in more detail (Article VII). Sensations, perceptions, and apperceptions of multisensorial representations of visual product properties in HTI can be explicated with the cognitive processes through which information contents of mental representations are constructed. Visual representations are capable of eliciting multisensorial mental contents and experiences, in which experience can be understood as the conscious part of a mental representation.

6 CONTRIBUTIONS

The main contribution of the thesis is a theoretical framework explicating visual experience in HTI as cognitive-affective process. The framework is built from relevant holistic theory ground and empirical experiments presented in the seven attached articles, which form a whole of the contributed four-fold knowledge claim.

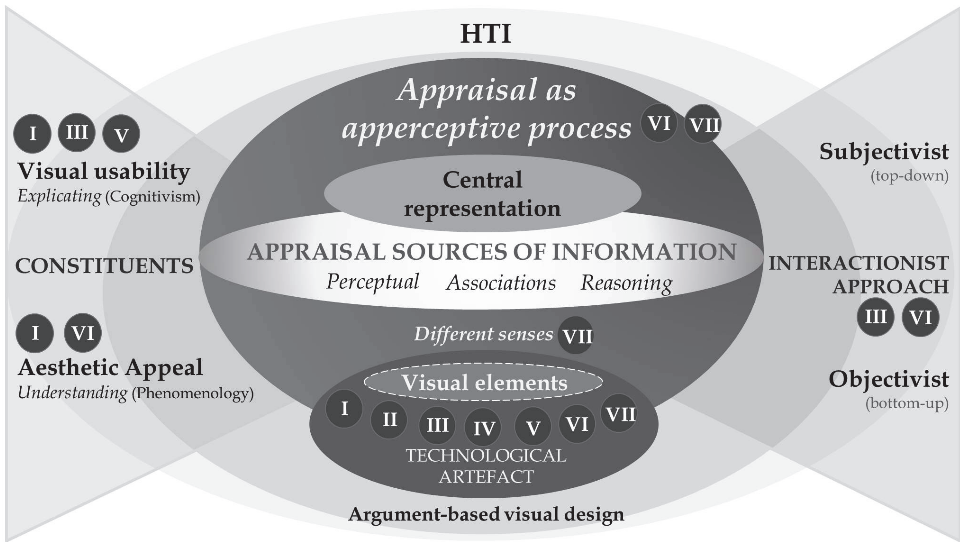


FIGURE 7 The relationships between the articles of the thesis and the theoretical framework

First, theoretical contribution in the form of a framework explicating visual experience in apperceiving visual elements in HTI, and the constituents of visual experience (visual usability and aesthetic appeal). Second, methodological contribution of interactionist approach and the method of primed product comparisons in examining visual experience in HTI. Third, empirical results contributing to the understanding of visual experience in detail in HTI, and providing scientific evidence for the theoretisation of visual experience. Fourth, the design implications for designing visual experiences in HTI for argument-based visual technology-design. In the following the contributions are summarised in relation to the theoretical framework (Figure 7).

In *article I* visual elements contribute to the experiential aspects of visual experience and to experienced visual usability of mobile applications. From the affective viewpoint, color was found as an important visual element, especially in appraising aesthetic al appeal of mobile user interfaces with affects, such as, beautiful, attractive, and in terms of vividness. From a functional viewpoint in terms of visual usability in guiding the interaction, color was seen as an organiser of information and contributor to a clearer overall impression of the user interfaces due to the color contrasts. Black and white color schemes were disliked from both affective and functional viewpoints. Design contribution highlights the ways how user interface design can create a sensation of some specific style with colours and the perceived dimensionality.

In addition, perceived dimensionality influences visual experiences of mobile user interfaces differently depending on the type of mobile application. For task-oriented applications (e.g., local transport system) additional perceived three-dimensional volume had a negative effect on the perceived pragmatic product quality. In terms of visual usability, two-dimensionality of user interface elements was perceived to be clearer, simpler, and easier to grasp than three-dimensional visual elements. Three-dimensionality was also experienced as an unnecessary element, by mainly confusing and complexifying the overall appearance of the user interface without providing added information. From an affective viewpoint, two-dimensionality was appraised as more stylish and authentic than three-dimensionality. This contribution contradicts the findings of previous studies that recommend the usage of perceived three-dimensionality in computer user interfaces (e.g., Ark et al., 1998; Sutcliffe, 2009). Three-dimensionality was not preferred in mobile application user interfaces with a more practical and task-oriented context of use. In entertainment mobile application perceived dimensionality of visual elements did not have a significant influence on liking the user interface design. Therefore, the context has to be taken into account when designing and using specific perceived dimensionalities in mobile applications.

The contributions of *Article I* strengthen the framework of visual experience in HTI by indicating the relationship of visual elements to visual experience in terms of the constituent factors of visual usability and aesthetic appeal. In addition, the ways visual elements are experienced qualitatively in a different manner is described with the constituent factors of visual experience. The differences between visual usability and aesthetic appeal differ, as the intention towards making sense and experiencing visual elements have differing goals. The methods utilised in article I present an empirical approach in examining the role of visual elements (and how these can be experimentally investigated) contributing to constituents of visual experience. Additionally, the way visual elements are experienced depends on the type of a technological artefact. Therefore, apperception plays a significant role in understanding how same visual elements elicit different experience contents in different contexts.

Design contribution of the *Article II* is that designing for surprise via unexpected events should not be utilised as a design strategy regardless of the product context. Designing unexpected events in goal-oriented applications does not seem to have a very distinct effect on users. Although it has been found that surprise has a positive effect on appraising classical product design and in the domain of digital games (e.g., Ludden et al., 2009; Gross & Thüring, 2013), this does not seem apply in experiencing digital goal-oriented applications. Thus, designing for surprise is not beneficial in goal-oriented mobile applications, but designing for appropriate level of unexpected events can elicit positive emotions of the technological artefact. This applies only if the appropriate level of design is achieved in a way that it is experienced as an integral part belonging to the technological artefact. In designing for an appropriate level of unexpectedness the context of the application and the type of technological product regarding design decisions is essential.

These contributions strengthen the framework with a methodological contribution in that the visual elements in the study were operationalised explicitly with the characteristics of visual elements (Mullet & Sano, 1995). This enables detailed analysis on how the characteristics of visual elements are appraised, and thus, connects the visual substance to the appraised emotion dimension. This is necessary in examining visual experiences in HTI in order to detect the influences visual properties have in the whole visual experience. For instance, if the visual substance under investigation has not been operationalised and previous research has not been taken into account, experiments might be conducted in vain. Concerning colour studies in HCI, unnecessary experiments have been conducted due to the lack of visual theory in operationalisations of the visual (Silvennoinen & Isomäki, 2013).

The design contribution of the *Article III* indicates which visual elements are considered as the most salient ones in web page design that affects communicability, visual usability. In addition, from the affective viewpoint, the contribution is to give evidence to what kind of emotions visual elements elicit or were attributed with. Methodological procedures integrate the salient visual elements into an emotional experience. The results indicate programmers' appraisals of salient visual elements in web page design. The emotional emphasis was on centered, symmetrical, and balanced composition, which was experienced as pleasant and calming.

These contributions strengthen the framework of visual experience in HTI by elaborating the relationship of emotional experience and visual elements with appraisal theory of emotion from an interactionist approach. The appraisal process integrates the salient visual elements into an emotional experience. In addition, article III contributes to visual element categorisation by presenting eight hierarchical visual element categories from the lowest level salient visual elements to visual usability. The eight hierarchical visual elements categories are further connected to different emotions, such as boredom, frustration, and calmness, via relational emotion themes, which are explained via appraisal theory of emotion.

The contribution of the *Article IV* is a novel method of primed product comparisons, useful for HTI and HCI research. The method is based on the methodology of studying affective mental contents (Saariluoma & Jokinen, 2014; Saariluoma, Jokinen, Kuuva, & Leikas, 2013), included in appraisal process (Frijda, 1988; Lazarus, 1991; Scherer, 2005; 2009). The method of primed product comparisons is based on reaction times and preference scores and can, therefore, reveal mental processes associated with evaluating design artefacts. With this method, designers can examine appraisals of some detailed design properties or overall appraisals of design concepts in the early design phases. Thus, the stimuli under investigation can be as detailed as needed, as well as the investigated affects, to be outlined according to the desired experience goals. For instance, a designer of a new car can vary one single property of the design, such as the curvature of one of the front headlights, and examine how the design choice influences the overall experience.

The method of primed product comparisons is based on an affective primes and stimuli. A participant is given a prime (e.g., unique or elegant) according to which the participant then makes a preferential match between two stimulus images shown side by side. Preferential matches are asked to be made as quickly as possible, so that the responses can be used in examining the preferences as well as the time it takes to make these preferences. The method strengthens the framework by providing a tool for obtaining additional information relating to the mental processing associated with making affective judgments. In addition, the method enables the examination of visual experience as an appraisal process with different appraisal sources of information in experiencing and evaluating visual properties of technological artefacts. The reaction times indicate that overall, preferential matches are conducted quickly, but the time used select the preferred stimulus for the given prime, depends on the adjective as well as the stimuli. More abstract primes (e.g., timeless or festive) took, on average, more time than the more tangible ones (e.g., durable or light). These differences in appraising different stimuli with different primes are in line with the three distinct appraisal sources; perceptual stimuli, associative processing, and reasoning (Smith & Kirby, 2001).

The contributions of the *Article V* indicate that the primed product comparisons method provides additional information compared to mere preference rankings, and that reaction times and preferences are associated with faster judgment times. This indicates that more preferred visual stimuli are also faster to process visually and mentally (i.e., semantic distance is significantly associated with preference, and therefore efficiently operationalised with preference scores and reaction times). In addition, the primed product comparisons method was elaborated to include two-fold method in indicating the best possible combination of visual stimuli in terms of semantic distance (in that every icon has as short as possible semantic distance to its meaning, but as far as possible to other icons in a same icon set).

This is essential especially in time-and safety critical interaction contexts where visual usability of a visual stimulus should be evident, and meanings of pictorial representations should not be ambiguous and confused to meanings conveyed with other visual representations in the same view. Therefore, the two-fold approach the method of primed product comparisons can be utilised in investigating efficient visual usability among different visual stimuli competing for perceiver's attention in technological artefacts. The contribution strengthens the framework methodologically by providing an efficient tool for analysing the visual usability of visual elements.

The main theoretical and methodological contribution of *Article VI* is the analysis of visual usability and aesthetic appeal as a cognitive process, that is, the clarification of the partly unconscious process, in which people find pictorial representations visually appealing and usable. These contributions strengthen the framework in indicating the necessity of detailed operationalisations of the concepts of studied phenomenon (e.g. the constituents of visual experience) and in providing an in-depth view of the visual experience process by indicating the influence of design eras to aesthetic-usability effect in terms of emotional appraisal. This explication further elaborates the foundational grounds of visual usability and aesthetic appeal as constituents of visual experience.

Moreover, the results indicated, through explicated operationalisation of the concepts, the connection of between cognitive processing fluency, familiarity, and aesthetic appeal with a strong theoretical background strengthening the interactionist approach described in the framework of visual experience in HTI. In addition, the results indicate that more detailed explications of the underlying dynamics between usability and appeal in apperceiving visual elements can be achieved with the method of primed product comparisons, and thus, strengthen the framework of visual experience with conceptual, methodological, and design contributions.

In A*rticle VII* the concept of apperception (i.e. product qualities are not perceived as objective, inherent properties of physical objects, but instead constructed in a mental process of apperception, which makes the products and their properties meaningful to the users) was investigated in material experience. Thus, in HTI, interaction involves different sensory modalities (in which touch plays an essential role) which also include of altering appraisals. These lead to variance in the affective contents that people associate with products in their minds. This knowledge of sensory experiences as mental processes, in appraisal process via apperception, can be utilised in designing interactive products, particularly in increasingly embodied fields, such as, the internet of things (IoTs), soft technologies, and in developing technological artefacts for enabling multisensory experiences. The main conclusion of the study is that material properties which are primarily visual, such as brightness, are encoded tactually through associations with different affects than in visual material experience.

These contributions strengthen the framework in indicating that apperception is not sensory modality dependent, but the logic of appraisal differs between sensory modalities. Thus, by examining visual or, for instance, material elements via different senses, more detailed understanding of visual experience can be obtained. In addition, cognitive-affective process of appraising stimuli via different sense can be experimentally investigated with the different appraisal sources of information, and thus increase knowledge of the cognitive-affective processes of obtaining, processing, and experiencing information with the different senses in HTI.

The overall value of the contributions of this thesis is in that by studying apperceptions and appraisals of technology-interaction through the theoretical framework with information constructed via other sensory modalities (e.g. touch), the logic of appraising visual dimensions of technological artefacts can be understood in more detail. Further, the results of this thesis extend knowledge of performative aspects of visual elements in technological artefacts in terms of visual usability, aesthetic appeal and multisensorial experiences elicited by them. In addition, this thesis enlarges methodological perspectives to the study of visual experience in HTI from interactionist perspective, and conceptual understanding to the underlying cognitive and affective processes of visual experiences.

The core in examining visual experiences is the explication of the experience process as a mental phenomenon in appraising visual entities via apperception with an interactionist approach. The results facilitate understanding the ways visual elements are experienced in HTI and the performative, emotional and multisensorial aspects attached to these. Technology industry could utilise the results in the design of new interactive technologies. The presented framework of visual experience in HTI can be utilised as a discourse tool in understanding, explaining visual experiences of technological artefacts, and thus, forms a basis as an explanatory framework for argument-based visual technology-design.

6.1 Limitations and evaluation of the study

The concept of visual usability presented in this thesis (based on Articles I, III and IV) requires further work in examining the concept in different contexts. This investigation will add more detailed explication of how visual usability functions as a sense-making vehicle in HTI. In addition, visual usability is needed to be enhanced by foundational analysis (Saariluoma, 1997) of the concept. Foundation analysis of visual usability will be conducted by comparing the concept to other concepts of usability (before actual interaction) such as, perceived usability (e.g. Hassenzahl & Monk, 2010 and apparent usability (Kurosu & Kashimura, 1995).

In this thesis, visual experience is examined as mental interaction with design properties, in which the experience is not affected by concrete technology-interaction with the technological designs (besides of Article II), but constructed via sight. Appraisals of design features can change whether the interaction is contemplative or functional (Saariluoma & Jokinen, 2015). Thus, the framework of visual experience is needed to be examined in concrete interaction contexts to investigate the possible changes in the experience dynamics.

In the article VII, the differences in material apperceptions constructed via sight and via touch were analysed separately to explicate the the process of visual appraisal in more detail. The analysis of control group's (material appraisals both via sight and touch) appraisals is required to be analysed to validate the results presented in the article. In addition, in the article VII apperceptions of the lowest –level appraisal information source (i.e. perceptual information source) was examined. Thus, to understand and explicate experiences through the different senses, analyses of higher-level affects of appraisal information sources (e.g. associations and reasoning) are required.

In all the experiments the participants' rights were explained to them in an understandable and clear way. They were also informed on how their privacy and identity will be protected during the research process as well as in the storage of the data, and in the reporting of the results. The participants were also informed that the participation in the experiments was voluntary and they had the right to withdraw from the experiment at any time without any consequences. The organisation and conduct of the ways in which the research and the reporting of its findings was done so that participants' identities were treated as confidential information. No personal data was collected during the experiments.

6.2 Future research

Moving from low-level visual elements in to the apperceptions and appraisals of more complex pictorial representations in technological artefacts, and especially to the experiences affected by information obtained through the different senses are objectives for future research. Experimenting how experience occurs through one sense at a time can reveal underlying cognitive processes in appraising different sensory properties in HTI. Further developments considering the method of primed product comparisons are conducted in order to apply the method in investigating appraisals via different sensory modalities, such as via sound and touch.

In addition, research on multisensory integration, mental sensory transfer, and cross-modal correspondences with detailed experimentation through the different senses and what kinds of attributes are mentally represented are needed, particularly in HTI. For instance, people are more unanimous in appraising tactile stimuli than visual stimuli (Silvennoinen, et al., 2015). Thus, there is more predictability in designing for tactile experiences when assessing the sensory dimensions of the stimuli, than for visual experiences. Future research focuses on how these cognitive and affective processes function in terms of how they influence and activate other sensorial information.

Further, more work is required concerning higher level appraisals in multisensory experience including associations, through which sensory experiences are qualitatively attributed via apperception to non-perceptual contents, such as timelessness, uniqueness, and imaginativeness. The logic of appraisal process in experiencing different sensory properties and the higher-level associations and reasoning attributed to them, calls for interactions approach into multisensory experience in HTI. In addition, the possibilities of enhancing different cognitive processes (e.g., memory, attention, and learning) in technology-interaction with visual and other sensory elements (e.g. tactile semantic distance) will be carried out. Visual usability of multisensorial design properties would enhance different context of HTI, for instance through developing efficient audio semantic distances for time and safety critical interaction contexts.

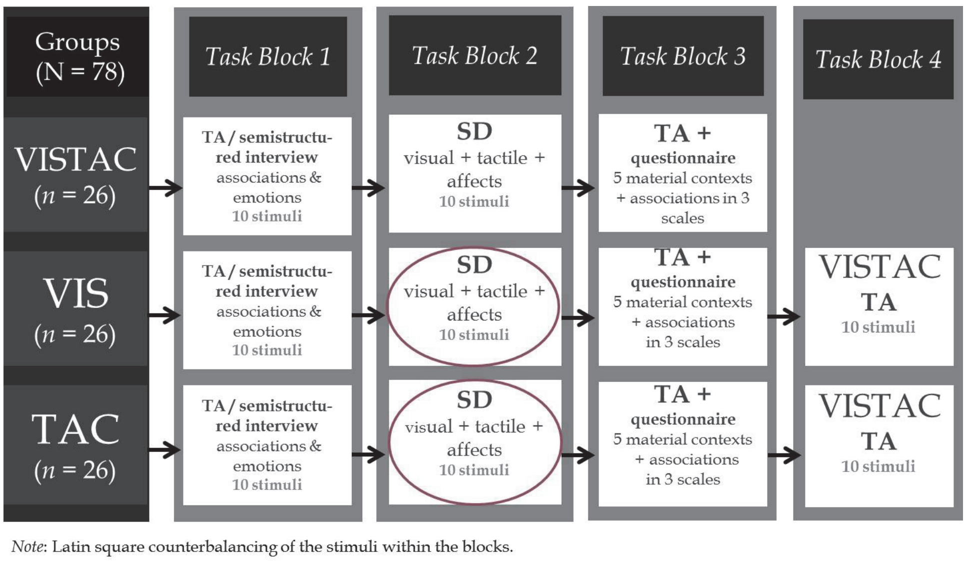


FIGURE 8 Factorial design with task blocks.

Article VII functions as a starting point to further research. In Figure 8, the experimental setup is presented, from which the affects of perceptual information source (Task block 2) were analysed with SDs (Osgood et al., 1975). Participants in the second group (VIS) appraised 10 different materials via sight. The same procedure was conducted in the third group (TAC), but participants were only allowed to appraise the materials via touch. In Figure 9, detailed description of the experiment is presented and the data analysed in article VII is indicated with a red circle.

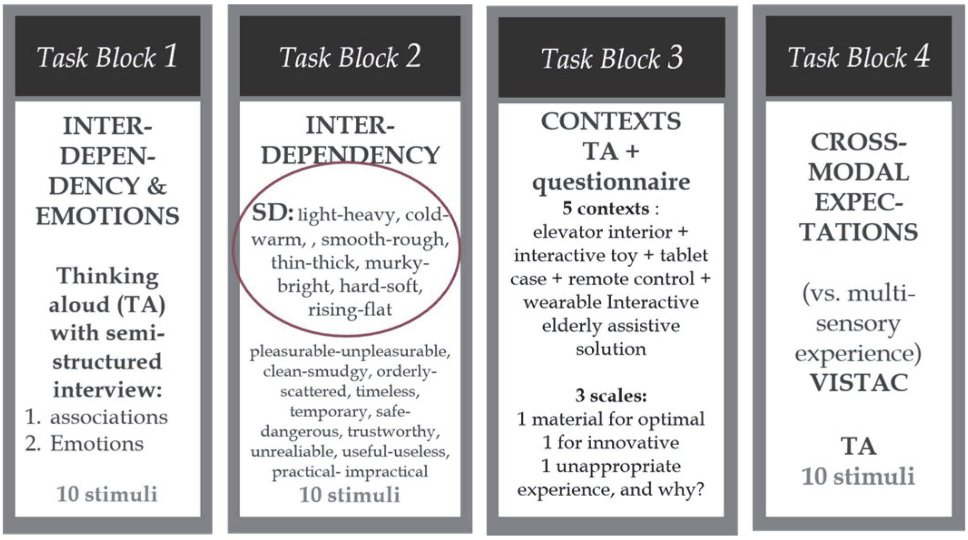


FIGURE 9 Experimental setup.

The data not yet analysed serves as a basis for further research in investigating cognitive and affective processes in obtaining information through touch and vision. The main goal of such research is conducted to construct a framework for multisensory experiences in HTI. This research would also reveal more nuances in understanding the operations of visual experience in HTI.

In addition, different methods will be utilised to examine and explain sensory experiences, especially concerning experiences of touch, sound, and taste in HTI, as these domains lack of established vocabularies in expressing experiences through verbalisation. Obrist, Seah and Subramanian (2013) have started to examine the vocabulary of expressing tactile experiences. As experiencing design artefacts is a multisensorial event, it requires systematical methods in analysing what specific sensory stimuli elicits which kinds of affects. However, abilities in differentiating affects appraised via different sensory modalities can be difficult. Analysing various aspects of design artefacts informing the senses requires perceptual sensory sensitivity and abilities in verbalising the encountered. Vocabularies for multisensorial experiences can also be approached by examining metacognition in multisensory experiences, which stands for individual's ability to monitor one's own decisions and representations, and accuracy and uncertainty in integrating individual sensory signals to integrated percepts (Deroy, Spence, & Noppeney, 2016). These necessities require careful methodical considerations. In addition, multisensorial experiences are dynamic, as for instance, one change in haptic design of an artefact changes the whole experience concerning representations of the artefact pertaining to the other senses than the sense of touch. Therefore, the ways experiences of touch and, for instance, sound are expressed through verbalisation requires understanding of the vocabularies utilised in explaining sensory experiences.

REFERENCES

Altaboli, A., & Lin, Y. (2011). Investigating effects of screen layout elements on interface and screen design aesthetics. *Advances in Human-Computer Interaction,* 5.

American Heritage® Dictionary of the English Language, Fifth Edition. Copyright © 2016 by Houghton Mifflin Harcourt Publishing Company. Published by Houghton Mifflin Harcourt Publishing Company.

Anderson, J. R. (2000). *Cognitive psychology and its implications*, 5th edition. New York: Worth Publishers.

Ark, W., Dryer, C. D., Selker, T., & Zhai, S. (1998). Representation matters: The effect of 3-D objects and spatial metaphor in a graphical user interface. In *Proceedings of HCI ´98, People and Computers XIII,* (pp. 209–219). London: Springer.

Arnheim, R. (1969). *Visual thinking*. California: University of California Press.

Arnheim, R. (1974). *Art and visual perception: t psychology of the creative eye.* Berkeley: University of California.

Bamford, G. (1991). Design, Science and Conceptual Analysis. In J. Plume (ed.) *Architectural Science and Design in Harmony: Proceedings of the Joint ANZAScA/ADTRA Conference, Sydney, July 10-12, 1990*. Australia & New Zealand Architectural Science Association, pp. 229-38.

Bardzell, J. (2012). Commentary on: Tractinsky, Noam (2012): Visual aesthetics: in human–computer interaction and interaction design. *Encyclopedia of Human Computer-Interaction*. Aarhus, Denmark: The InteractionDesign. org Foundation.

Bargas-Avila, J. A., & Hornbæk, K. (2011). Old wine in new bottles or novel challenges: a critical analysis of empirical studies of user experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2689-2698). New York: ACM.

Bauerly, M., & Liu, Y. (2006). Computational modeling and experimental investigation of effects of compositional elements on interface and design aesthetics. *International Journal of Human-Computer Studies, 64*(8), 670-682.

Bell, C. (1958). *Art.* New York: Capricorn Books.

Berkowitz, M. (1987). Product Shape as a Design Innovation Strategy. *Journal of Product Innovation Management, 4*, 274-283.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton-Century-Crofts.

Berlyne, D. E. (1974). *Studies in the new experimental aesthetics: Steps toward an objective psychology of aesthetic appreciation*. Hemisphere.

Bødker, S. (2006). When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles* (pp. 1-8). New York: ACM Press.

Card, S. K., Newell, A., & Moran, T. P. (1983). *The psychology of human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Carroll, N. (2001). *Beyond aesthetics. Philosophical essays.* Cambridge: Cambridge University Press.

Cassell, J., Sullivan, J., Prevost, S., & Churchill, E. (2000). *Embodied conversational agents*. Cambridge, MA: MIT Press.

Chang, D., Dooley, L., & Tuovinen, J. E. (2002). Gestalt theory in visual screen design: a new look at an old subject. In *Proceedings of the Seventh world conference on computers in education conference on Computers in education: Australian topics-Volume 8.* Australian Computer Society, Inc., 5–12.

Changizi, M. A. (2009). *The vision revolution: How the latest research overturns everything we thought we knew about human vision*. Dallas, TX: BenBella Books.

Coursaris, C. K., Swierenga, S. J., & Watrall, E. (2008). An empirical investigation of color temperature and gender effects on web aesthetics. *Journal of Usability Studies, 3*(3), 103-117.

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design studies, 25*(6), 547-577.

Cyr, D. (2013). Emotion and website design. Soegaard, M., & Dam, R. F. (Eds.), *The Encyclopedia of Human-Computer Interaction, 2nd Ed.* Aarhus, Denmark: The Interaction Design Foundation. Available online at http://www.interaction-design.org/encyclopedia/emotion_and_website_design.html

Cyr, D., Head, M., & Larios, H. (2010). Colour appeal in website design within and across cultures: A multi-method evaluation. *International Journal of Human-Computer Studies, 68*(1), 1-21.

Cyr, D., Head, M., Larios, H., & Pan, B. (2009). Exploring human images in website design: a multi-method approach. *MIS quarterly*, 539-566.

Csikszentmihalyi, M. (1991). Design and order in everyday life. *Design issues*, *8*(1), 26-34.

Demir, E., Desmet, P. M. A. & Hekkert, P. (2009). Appraisal patterns of emotions in human-product interaction. *International Journal of Design, 3*(2), 41–51.

Demirbilek, O., & Sener, B. (2003). Product design, semantics and emotional response. *Ergonomics, 46*(13-14), 1346-1360.

Deng, L., & Poole, M. S. (2010). Affect in Web Interfaces: A Study of the Impacts of Web Page Visual Complexity and Order. *MISQuarterly, 34*(4), 711–730.

Deroy, O., Spence, C., & Noppeney, U. (2016). Metacognition in Multisensory Perception. *Trends in Cognitive Sciences, 20*(10), 736-747.

Desmet, P. (2012). Faces of product pleasure: 25 positive emotions in human-product interactions. *International Journal of Design*, *6*(2).

Desmet, P., & Hekkert, P. (2007). Framework of product experience. *International journal of design, 1*(1).

Desmet, P. M. A., Overbeeke, C. J., & Tax, S. J. E. T. (2001). Designing products with added emotional value: development and application of an approach for research through design. *The Design Journal, 4*(1), 32–47.

Desmet, P. M. A., & Pohlmeyer, A. E. (2013). Positive design: An introduction to design for subjective well-being. *International Journal of Design, 7*(3), 5-19.

Dewey, J. (1958). *Art as Experience.* New York: Capricorn Books.

Diefenbach, S., Lenz, E., & Hassenzahl, M. (2013). An interaction vocabulary. describing the how of interaction. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 607-612). New York: ACM Press.

Dickie, G. (1997). *Introduction to aesthetics.* Oxford, England: Oxford University Press.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data* Cambridge, MA: MIT Press.

Eysenck, M. W., & Keane, M. T. (2005). *Cognitive Psychology* (5th ed.). East Sussex: Psychology Press.

Fodor, J. (1985a). Fodor's guide to mental representation. *Mind, 94*(373), 76-100.

Fodor, J. (1985b). Précis of the modularity of mind. *Behavioral and brain sciences*, *8*(01), 1-5.

Fokkinga, S. F., & Desmet, P. M. A. (2013). Ten Ways to Design for Disgust, Sadness, and Other Enjoyments: A Design Approach to Enrich Product Experiences with Negative Emotions. *International Journal of Design, 7*(1), 19-36.

Folkmann, M. N. (2013). *The aesthetics of imagination in design*. Cambridge, MA: MIT Press.

Folkman, S., & Lazarus, R. S. (1985). If it changes it must be a process: study of emotion and coping during three stages of a college examination. *Journal of personality and social psychology, 48*(1), 150–170.

Forlizzi, J., Mutlu, B., & DiSalvo, C. (2004). A study of how products contribute to the emotional aspects of human experience. *Emotion and Experience*, *Proceedings of the Design & Emotion Conference 2004,* Ankara, Turkey.

Forsey, J. (2016). *The aesthetics of design.* Oxford University Press.

Frankish, K., & Ramsey, W. (2012). *The cambridge handbook of cognitive science*. Cambridge: Cambridge University Press.

Frijda, N. H. (1994). Varieties of affect: Emotions and episodes, moods and sentiments, In P. Ekman & R. J. Davidson (Eds.), *The nature of emotion.* New York: Oxford University Press.

Frijda, N. H. (1988). The laws of emotion. *American Psychologist*, *43*(5), 349–358.

Galitz, W. O. (2007). *The essential guide to user interface design: an introduction to GUI design principles and techniques.* John Wiley & Sons.

Gardano, A. C. (1986). Cultural influence on emotional response to color: A research study comparing Hispanics and non-Hispanics. *American Journal of Art Therapy, 23*, 119-124.

Gibson, J. (1979). *The ecological approach to human perception*. Boston: Houghton Mifflin.

Goldstein, B. E. (1999). *Sensation and perception,* 5th edition. Pacific Grove: Brooks/Cole Publishing Company.

Gombrich, E. H. (1959). *Art and illusion: A study in the psychology of pictorial representation.* Oxford: Phaidon.

Gombrich, E. H. (1995). *The story of art* (Vol. 12). London: Phaidon.

Gross, A., & Silvennoinen, J. (2014). Surprise as a design strategy in goal-oriented mobile applications. In *Proceedings of the 5th International Conference on Human Factors and Applied Ergonomics AHFE2014,* Krakow, Poland.

Gross, A., & Thüring, M. (2013). Encountering the Unexpected: Influencing User Experience through Surprise. In Berkovsky, S., Herder, E., Lops, P. & Santos, O.C. (Eds.). *Proceedings of The UMAP Annual Conference*. Rome, Italy: Springer, 3-9.

Hancock, P. A., Pepe, A. A., & Murphy, L. L. (2005). Hedonomics: The power of positive and pleasurable ergonomics. *Ergonomics in Design*, *13*(1), 8-14.

Hassenzahl, M. (2001). The Effect of Perceived Hedonic Quality on Product Appealingness. *International Journal of Human-Computer Interaction, 13*(4), 481–499.

Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction, 19*, 319–349.

Hassenzahl, M. (2008). Aesthetics in interactive products: Correlates and consequences of beauty. In H. N. J. Schifferstein &, P. P. M. Hekkert (Eds.), *Product Experience* (pp. 287-302). Amsterdam: Elsevier.

Hassenzahl, M., & Monk, A. (2010). The inference of perceived usability from beauty. *Human-Computer Interaction, 25*(3), 235-260.

Hassenzahl, M., & Tractinsky, N. (2006). User experience - a research agenda. *Behaviour & Information Technology, 25*(2), 91–97.

Heidegger, M. (1927). *Being and time.* English translation by J. Macquarrie and E. Robinson (1962). Oxford: Basil Blackwell.

Hekkert, P. (2006). Design aesthetics: principles of pleasure in design. *Psychology Science, 48*(2), pp. 157-172.

Hekkert, P., & Leder, H. (2008). Product aesthetics. In H. N. J. Schifferstein, & P. P. M. Hekkert (Eds.), *Product Experience* (pp. 259-286). Amsterdam: Elsevier.

Hekkert, P., & Schifferstein, H. N. (2008). Introducing product experience. In H. N. J. Schifferstein, & P. P. M. Hekkert (Eds.), *Product Experience* (pp. 1-8). Amsterdam: Elsevier.

Hekkert, P., Snelders, D., & Wieringen, P. C. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. British journal of psychology, 94(1), 111-124

Ho, A. G., & Siu, K. W. M. (2012). Emotion Design, Emotional Design, Emotionalize Design: A Review n Their Relationships from a New Perspective. *The Design Journal, 15*(1), 9-32.

Hornbæk, K. (2006). Current practice in measuring usability: Challenges to usability studies and research. *International journal of human-computer studies, 64*(2), 79-102.

Houkes, W., & Vermaas, P. E. (2010). *Technical functions: On the use and design of artefacts* (Vol. 1). Springer Science & Business Media.

Hsiao, K-A., & Chen, L-L. (2006). Fundamental dimensions of affective responses to product shapes. *International Journal of Industrial Ergonomics, 36*, 553-564.

Husserl, E. (1936). *The crisis of european sciences and transcendental phenomenology.* Northwestern University Press, Evanston, IL.

Isherwood, S. (2009). Graphics and semantics: The relationship between what is seen and what is meant in icon design. In *International Conference on Engineering Psychology and Cognitive Ergonomics* (pp. 197-205). Springer Berlin Heidelberg.

Isomäki, H. (2009). The human modes of being in investigating user experience. In P. Saariluoma, & H. Isomäki (Eds.), *Future interaction design II* (pp. 191–207). London: Springer.

Itti, L., Koch, C., & Niebur, E. and others. (1998). A model of saliency-based visual attention for rapid scene analysis. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 20*(11), 1254–1259.

Ivory, M. Y., Sinha, R. R., & Hearst, M. A. (2001). Empirically validated web page design metrics. In *Proceedings of the SIGCHI conference on Human factors in computing systems – CHI'01* (pp. 53–60). New York: ACM Press.

Jankovíc, D., & Markovíc, S. (2009). Implicit semantic features and aesthetic preference. *Journal of Vision*, *9*(8), 942-942.

Johnson, P. (1947). *Mies van der Rohe*. New York, NY: Museum of Modern Art.

Jokinen, J. P. P. (2015a). Emotional user experience: Traits, events, and states. *International Journal of Human Computer Studies, 76*, 67–77.

Jokinen, J. P. P. (2015b). User psychology of emotional user experience. University of Jyväskylä: University Press, Doctoral Dissertation.

Jokinen, J. P. P., Silvennoinen, J. M., Perälä, P. M., & Saariluoma, P. (2015). Quick affective judgments: Validation of a method for primed product comparisons. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems – CHI'15* (pp. 2221-2230). New York: ACM Press.

Jones, J. C. (1970). *Design methods: seeds of human futures*. London and New York: John Wiley.

Jordan, P. 2000. *Designing pleasurable products.* London: Taylor & Francis.

Kant, I. (1787). *Critique of pure reason.* English translation by Paul Guyer and Allen Wood (1998). Cambridge: Cambridge University Press.

Karvonen, K. (2000). The Beauty of Simplicity. In *Proceedings of the 2000 ACM Conference on Universal Usability 2000*, 85-90.

Kepes, G. (1944). *Language of vision*. Chicago: Paul Theobold.

Ketelaar, T., & Ellis, B. J. (2000). Are evolutionary explanations unfalsifiable? Evolutionary psychology and the Lakatosian philosophy of science. *Psychological Inquiry, 11*(1), 1–21.

Kim, J., Lee, J., & Choi, D. (2003). Designing emotionally evocative homepages: an empirical study of the quantitative relations between design factors and emotional dimensions. *International Journal of Human-Computer Studies, 59*(6), 889-940.

Kim, S., & Stoel, L. (2004). Apparel retailers: website quality dimensions and satisfaction. *Journal of Retailing and Consumer Services, 11*(2), 109-117.

Koffka, K. (1935). *Principles of Gestalt psychology*. New York: Harcourt. Brace & World.

Koskinen, I., & Battarbee, K. (2003). Introduction to user experience and empathic design. In I Koskinen, K. Battarbee, & A. Mattelmäki (Eds.), *Empathic design: User experience in product design* p(p. 37-50). Edita Publishing: Finland.

Kress, G. R., & Van Leeuwen, T. (1996). *Reading images: The grammar of visual design.* Psychology Press.

Krippendorff, K. (1989). On the essential contexts of artifacts or on the proposition that" design is making sense (of things)". *Design issues*, *5*(2), 9-39.

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*. Sage.

Krippendorff, K. (2006). *The Semantic turn: A new foundation for design*. Taylor & Francis, CRC Press, Boca Raton, London, New York.

Kurosu, M., & Kashimura, K. (1995). Apparent usability vs. inherent usability: experimental analysis on the determinants of apparent usability. In *Proceedings of CHI95 Conference Companion 1995* (pp. 292–293).

Laudan, L. (1977). *Progress and its problems.* Berkeley, CA: University of California Press.

Lavie, T., Oron-Gilad, T., & Meyer, J. (2011). Aesthetics and usability of in-vehicle navigation displays. *International Journal of Human-Computer Studies*, *69*(1), 80-99.

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

Law, E. L. C., Roto, V., Hassenzahl, M., Vermeeren, A. P., & Kort, J. (2009, April). Understanding, scoping and defining user experience: a survey approach. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems -CHI'09* (pp. 719-728). New York: ACM Press.

Lazarus, R. S. (1991). *Emotion and adaptation.* New York: Oxford University Press.

Lee, S. (2013). Understanding user experience with computer-based applications with different use purposes. *International Journal of Human-Computer Interaction, 29*(11), 689-701.

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

Levy, B. I. (1984). Research into psychological meaning of color. *American Journal of Art Therapy, 23*, 58-62.

Lidwell, W., Holden, K., & Butler, J. (2003). *Universal Principles of Design.* Beverly, MA: Rockport Publishers.

Lin, Y.-C., Yeh, C.-H., & Wei, C.-C. (2013). How will the use of graphics affect visual aesthetics? A user-centered approach for web page design. *International Journal of Human-Computer Studies, 71*(3), 217–227.

Lindgaard, G., & Dudek, C. (2003). What is this evasive beast we call user satisfaction?. *Interacting with computers, 15*(3), 429-452.

Lindgaard, G., Dudek, C., Sen, D., Sumegi, L., & Noonan, P. (2011). An exploration of relations between visual appeal, trustworthiness and perceived usability of homepages. *Topics in Human-Computer Interaction (TOCHI), 18*(1), 1-30.

Lindgaard, G., Fernandes, G., Dudek, C., & Brown, J. (2006). Attention web designers: You have 50 milliseconds to make a good first impression! *Behavior & Information Technology, 25*(2), 115-126.

Liu, Y. (2003). Engineering aesthetics and aesthetic ergonomics: Theoretical foundations and a dual-process research methodology. *Ergonomics, 46*(13-14), 1273-1292.

Liu, Y., Goncalves, J., Ferreira, D., Xiao, B., Hosio, S., & Kostakos, V. (2014). CHI 1994-2013: mapping two decades of intellectual progress through co-word analysis. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems – CHI '14* (pp. 3553-3562). New York: ACM Press.

Ludden, G. D. S., Schifferstein, H. N. J. & Hekkert, P. 2009. Visual-tactual incongruities in products as sources of surprise. *Empirical Studies of the Arts, 27*(1), 61-87.

Marcus, A., & Gould, E. W. (2001). Cultural dimensions and global web design: What? So what? Now what? *Proceedings of the Conference on Human Factors and the Web.*

Marković, S. (2012). Components of aesthetic experience: aesthetic fascination, aesthetic appraisal, and aesthetic emotion. *i-Perception, 3*, 1–17.

Martindale, C., Moore, K., & Borkum, J. (1990). Aesthetic preference: Anomalous findings for Berlyne's psychobiological theory. *The American Journal of Psychology*, 53-80.

McDougall, S., & Isherwood, S. (2009). What's in a name? The role of graphics, functions, and their interrelationships in icon identification. *Behavior research methods, 41*(2), 325-336.

Michailidou, E., Harper, S., & Bechhofer, S. (2008). Visual complexity and aesthetic perception of web pages. In *Proceedings of the 26th annual ACM international conference on Design of communication* (pp. 215–224). New York: ACM Press.

Miniukovich, A., & De Angeli, A. (2015). Computation of Interface Aesthetics. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15* (pp. 1163–1172). New York: ACM Press.

Moshagen, M. & Thielsch, M. T. (2010). Facets of visual aesthetics. *International Journal of Human-Computer Studies, 68*(10), 689–709.

Moshagen, M., Musch, J., & Göritz, A. S. (2009). A blessing, not a curse: Experimental evidence for beneficial effects of visual aesthetics on performance. *Ergonomics*, *52*(10), 1311-1320.

Mullet, K. & Sano, D. (1995*). Designing Visual Interfaces: Communication Oriented Techniques.* Prentice Hall: New Jersey, USA.

Newell, A. & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Ngo, D. & Byrne, J. (2001). Application of an aesthetic evaluation model to data entry screen. *Computers in Human Behavior, 17*, 149-185.

Ngo, D. C. L., Teo, L. S., & Byrne, J. G. (2003). Modelling interface aesthetics. *Information Sciences*, *152*, 25-46.

Nisbett, R. (2003). *The Geography of Thought.* New York: The Free Press.

Norman, D. (1988). *The design of everyday things*. New York: Basic Books.

Norman, D. (2004). *Emotional Design: Why We Love (or Hate) Everyday Things).* New York: Basic Books.

Obrist, M., Seah, S. A., & Subramanian, S. (2013, April). Talking about tactile experiences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1659-1668). New York: ACM Press.

Obrist, M., Velasco, C., Vi, C., Ranasinghe, N., Israr, A., Cheok, A., Spence, S., & Gopalakrishnakone, P. (2016). Sensing the future of HCI: touch, taste, and smell user interfaces. *interactions*, *23*(5), 40-49.

Oron-Gilad, T., & Hancock, P. A. (2009). From ergonomics to hedonomics: Trends in human factors and technology. *Technology and psychological well-being*, 131-147.

Osgood, C. E., May, W. H., & Miron, M. S. (1975). *Cross-cultural universals of affective meaning.* University of Illinois Press.

Pallasmaa, J. (2009). *The thinking hand: Existential and embodied wisdom in architecture*. Chichester: Wiley.

Palmer, S. E., & Schloss, K. B. (2010). An ecological valence theory of human color preference. In *Proceedings of the National Academy of Sciences*, *107*(19), 8877-8882.

Papachristos, E., & Avouris, N. (2013). The influence of website category on aesthetic preferences. In *IFIP Conference on Human-Computer Interaction* (pp. 445–452). Springer.

Parsons, G. (2016). *The philosophy of design*. Cambridge: Polity Press.

Petroski, H. (2006). *Success through failure: The paradox of design*. Princeton University Press.

Post, R. A. G. (2016). The beauty of unity-in-variety: Studies on the multisensory aesthetic appreciation of product designs. Delft University of Technology, Doctoral Dissertation.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2016). 'To preserve unity while almost allowing for chaos': Testing the aesthetic principle of unity-in-variety in product design. *Acta psychologica, 163*, 142–152.

Post, R., Nguyen, T., & Hekkert, P. (2017). Unity in Variety in website aesthetics: A systematic inquiry. *International Journal of Human-Computer Studies*, *103*, 48-62.

Postrel, V. (2003). *The substance of style. Hoe aesthetic value is remaking commerce, culture, and consciousness.* New York: HarperCollins Publishers.

Poulin, R. (2011). *Language of graphic design: an illustrated handbook for understanding fundamental design principles*. Beverly, MA: Rockport Publishers.

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

Ramachandran, V. S. (2004). *A brief tour of human consciousness.* New York: PI Press.

Reber, R., Schwarz, N. & Winkielman, P. (2004). Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver´s Processing Experience? *Personality and Social Psychology Review, 8*(4), 364-382.

Reinecke, K., & Bernstein, A. (2011). Improving performance, perceived usability, and aesthetics with culturally adaptive user interfaces. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *18*(2), 8.

Reinecke, K., Yeh, T., Miratrix, L., Mardiko, R., Zhao, Y., Liu, J., & Gajos, K. Z. (2013). Predicting users' first impressions of website aesthetics with a quantification of perceived visual complexity and colorfulness. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems – CHI'13* (pp. 2049–2058). New York*:* ACM Press.

Reppa, I., & McDougall, S. (2015). When the going gets tough the beautiful get going: aesthetic appeal facilitates task performance. *Psychonomic Bulletin & Review, 21*(6).

Reynolds, G. (2013). *Presentation zen design: simple design principles and techniques to enhance your presentations*. Berkeley, CA: New Riders.

Robins, D., & Holmes, J. (2008). Aesthetics and credibility in web site design. *Information Processing and Management: an International Journal, 44*(1), 386–399.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1281–1288.

Saariluoma, P. (1995). *Chess players' thinking.* London: Routledge.

Saariluoma, P. (1997). *Foundational analysis. Presuppositions in experimental psychology.* London: Routledge.

Saariluoma, P. (2003). Apperception, content based psychology and design. In U. Lindemann (Ed.), *Human behaviour in design* (pp. 72–78). Berlin: Springer.

Saariluoma, P. (2005). Explanatory frameworks for interaction design. In A. Pirhonen, H. Isomäki, C. Roast, & P. Saariluoma (Eds.), *Future interaction design* (pp. 67–83). London: Springer.

Saariluoma, P., & Jokinen, J. P. P. (2014). Emotional dimensions of user experience: a user psychological analysis. *International Journal of Human–Computer Interaction, 30*(4), 303–320.

Saariluoma, P., & Jokinen, J. P. P. (2015). Appraisal and mental contents in human-technology interaction. *International Journal of Technology and Human Interaction, 11*(2), 1–32.

Saariluoma, P., Jokinen, J. P. P., Kuuva, S., & Leikas, J. (2013). User Experience as Mental Contents. In *Proceedings of the 10th European Academy of Design Conference* (pp. 1–15). Goethenburg, Sweden: Chalmers University of Technology.

Saariluoma, P., & Leikas, J. (2010). Life-based design - An approach to design for life. *Global Journal of Management and Business Research, 10*(5), 17–23.

Saariluoma, P., & Oulasvirta, A. (2010). User pschology: Re-assessing the Boundaries of a discipline. *Psychology, 1*(5), 317–328.

Saariluoma, P., Cañas, J. J., & Leikas, J. (2016). *Designing for Life: A Human Perspective on Technology Development*. Springer.

Salgado-Montejo, A., Salgado, C. J., Alvarado, J., & Spence, C. (2016). Simple lines and shapes are associated with, and communicate, distinct emotions. *Cognition and Emotion*, 1-15.

Santayana, G. (1955). *The sense of beauty: Being the outline of aesthetic theory*. New York: Dover. (Original work published in 1896).

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

Scherer, K. R. (1997). Profiles of Emotion-antecedent Appraisal: Testing Theoretical Predictions across Cultures. *Cognition and Emotion, 11*(2), 113-150.

Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information*, *44*(4), 695–729. doi:10.1177/0539018405058216

Scherer, K. R. (2009). The dynamic architecture of emotion: Evidence for the component process model. *Cognition & Emotion*, *23*(7), 1307–1351.

Schirato, T., & Webb, J. (2004). *Understanding the visual*. Sage: London.

Schlatter, T. & Levinson, D. (2013). *Visual usability, principles and practices for designing digital applications.* MA, USA: Morgan Kaufman.

Seckler, M., Opwis, K., & Tuch, A. N. (2015). Linking objective design factors with subjective aesthetics: An experimental study on how structure and color of websites affect the facets of users' visual aesthetic perception. *Computers in Human Behavior, 49*, 375–389.

Shorter Oxford English Dictionary (1972).

Siegel, S. (2006). Subject and object in the contents of visual experience. *The Philosophical Review*, *115*(3), 355-388.

Silvia, P. J. (2005). Cognitive appraisals and interest in visual arts: Exploring an appraisal theory of aesthetic emotions. *Empirical Studies of the Arts, 23*, 119-133.

Silvia, P. J. (2009). "Looking past pleasure: Anger, confusion, disgust, pride, surprise and other unusual aesthetic emotions. *Psychology of Aesthetics, Creativity and the Arts, 3*, 48-51.

Silvia, P. J. & Brown, E. M. (2007). Anger, Disgust, and the Negative Aesthetic Emotions: Expanding an Appraisal Model of Aesthetics Experience. *Psychology of Aesthetics, Creativity, and the Arts, 1*(2), 100-106.

Silvennoinen, J. & Isomäki, H. (2013). The Notion of Colour in Human-Computer Interaction Studies**.** In *Proceedings of the AIC Colour Conference,* Newcastle*, UK.*

Silvennoinen, J. M. & Jokinen, J. P. P. (2016a). Appraisals of salient visual elements in web page design. *Advances in Human-Computer Interaction*, Article ID 3676704, 14 pages.

Silvennoinen, J. M., & Jokinen J. P. P. (2016b). Aesthetic appeal and visual usability in four icon design eras. In *Proceedings of the 2016 Conference on Human Factors in Computing Systems – CHI '16* (pp. 4390-4400). New York: ACM Press.

Silvennoinen, J. M., Rousi, R., Jokinen, J. P. P., & Perälä P. M. H. (2015). Apperception as a multisensory process in material experience. In *Proceedings of the Academic Mindtrek*, 144-151.

Silvennoinen, J., Vogel, M., & Kujala, S. (2014). Experiencing visual usability and aesthetics in two mobile application contexts. *Journal of Usability Studies, 10*(1), 46-62.

Simon, H. A. (1969). *The sciences of the artificial.* Cambridge: Mass.: MIT press.

Skinner, B. F. (1969). *Contingencies of reinforcement: A theoretical analysis.* New York: Appleton-Century-Crofts.

Smith, C. A., & Kirby, L. D. (2001). Toward delivering on the promise of appraisal theory. In *Appraisal Process in Emotion,* K. R. Scherer, A. Schorr, & T. Johnstone (Eds.). Oxford UniversityPress, New York, 121–138.

Smith, C. A. &, Lazarus, R. S. (1993). Appraisal components, core relational themes, and the emotions. Cognition and Emotion, 7(3), 233-269.

Sonderegger, A., & Sauer, J. (2010). The influence of design aesthetics in usability testing: Effects on user performance and perceived usability. *Applied ergonomics 41*(3), 403–410.

Sonderegger, A., Zbinden, G., Uebelbacher, A., & Sauer, J. (2012). The influence of product aesthetics and usability over the course of time: a longitudinal field experiment. *Ergonomics, 55*(7), 713-730.

Sun, H. & Zhang, P. (2006). The role of moderating factors in user technology acceptance. *International Journal of Human-Computer Studies, 64* (2), 53-78.

Sutcliffe, A. (2009). Designing for user engagement: Aesthetic and attractive user interfaces. *Synthesis lectures on human-centered informatics, 2*(1), 1-55.

Tatarkiewicz, W. (2005). *History of Aesthetics, Vol. 1: Ancient Aesthetics*. London: Continuum. Translated by Adam Czerniawski and Ann Czerniawski. Published originally in Polish in 1962-7.

Tinio, P. P. & Smith, J. K. (Eds.). (2014). *The Cambridge handbook of the psychology of aesthetics and the arts*. Cambridge University Press.

Thagard, P. (1996). *Mind: Introduction to cognitive science*, 2nd edition. Cambridge, MA: MIT press.

Thielsch, M. T., & Hirschfeld, G. (2012). Spatial frequencies in aesthetic website evaluations – explaining how ultra-rapid evaluations are formed. *Ergonomics, 55*(7), 731–742.

Thielsch, M. T., Engel, R., & Hirschfeld, G. (2015). Expected usability is not a valid indicator of experienced usability. *PeerJ Comput. Sci 1*, e19.

Thüring, M., & Mahlke, S. (2007). Usability, aesthetics, and emotions in human-technology interaction. *International Journal of Psychology, 42*, 253-264.

Tractinsky, N. (2012). Visual Aesthetics. In: Soegaard, Mads and Dam, Rikke Friis (eds.). *The Encyclopedia of Human-Computer Interaction, 2nd Ed.* Aar-

hus, Denmark: The Interaction Design Foundation. Available online at http://www.interaction-design.org/encyclopedia/visual_aesthetics.html
Tractinsky, N., Cokhavi, A., Kirschenbaum, M. & Sharfi, T. (2006). Evaluating the consistency of immediate aesthetic perceptions of web pages. *International Journal of Human-Computer Studies,* 64 (11) pp. 1071-1083.
Tractinsky, N., & Lowengart, O. (2007). Web-store aesthetics in e-retailing: A conceptual framework and some theoretical implications. *Academy of Marketing Science Review, 11*(1), 1–18.
Tractinsky, N., Katz, A. S. & Ikar, D. (2000). What is Beautiful is Usable. *Interacting with Computers, 13* (2), 127-145.
Tsonos, D., & Kouroupetroglou, G. (2011). Modeling reader's emotional state response on document's typographic elements. *Advances in Human-Computer Interaction*, *2011*, 2.
Tuch, A. N., Presslaber, E. E., Stöcklin, M., Opwis, K., & Bargas-Avila, J. A. (2012). The role of visual complexity and prototypicality regarding first impression of websites: Working towards understanding aesthetic judgments. *International Journal of Human-Computer Studies, 70(*11), 794–811.
Tähti, M., & Niemelä, M. (2006). 3E-Expressing Emotions and Experiences. *Proceedings of WP9 Workshop on Innovative Approaches for Evaluating Affective Systems,* Stockholm, Sweden. HUMAINE (Human-Machine Interaction Network on Emotion) (2006), 15 - 19.
Udsen, L. E., & Jørgensen, A. H. (2005). The aesthetic turn: unravelling recent aesthetic approaches to human-computer interaction. *Digital creativity*, *16*(04), 205-216.
Valkola, J. (2004). *Cognition and visuality*. Jyväskylä: University of Jyväskylä.
Van Leeuwen, T. (2004). Semiotics and iconography. In T. van Leeuwen, & C. Jewitt (Eds.), *Handbook of visual analysis,* 4th edition (pp. 92-118). London: Sage.
Van Schaik, P., & Ling, J. (2008). Modelling user experience with web sites: Usability, hedonic value, beauty and goodness. *Interacting with computers*, *20*(3), 419-432.
Verbeek, P. P. (2005). *What things do: Philosophical reflections on technology, agency, and design*. University Park, PA: Pennsylvania State University Press. Translated by Robert P. Crease.
Veryzer, R. W., & Hutchinson, J. W. (1998). The influence of unity and prototypicality on aesthetic responses to new product designs. *Journal of consumer research, 24*(4), 374-394.
Ware, C. (2010). *Visual thinking: For design*. Morgan Kaufmann.
Ware, C. (2012). *Information visualization: perception for design*. Elsevier.
Wei-Ken, H., & Lin-Lin, C. (2012). Effects of novelty and its dimensions on aesthetic preference in product design. *International Journal of Design, 6*(2).
Wertheimer, M. (1938). *Laws of organization in perceptual forms.*
Wilde, J. & Wilde R. (2000). *Visual literacy: A conceptual approach to graphic problem solving.* New York, NY: Watson-Guptill Publications.

Williams, R. (2009). *The non-designer's presentation book*. Berkeley, CA: Peachpit Press.

Zettl, H. (1973). *Sight, sound, motion: Applied media aesthetics*. Cengage Learning.

Zhang, P. (2013). The affective response model: A theoretical framework of affective concepts and their relationships in the ICT context. *MIS Quarterly, 37*(1), 247-274.

Zimmerman, J. & Forlizzi, J. (2008). The Role of Design Artifacts in Design Theory Construction. *Human-Computer Interaction Institute*, paper 37.

ORIGINAL ARTICLES

I

EXPERIENCING VISUAL USABILITY AND AESTHETICS IN TWO MOBILE APPLICATION CONTEXTS

by

Silvennoinen, Johanna, Vogel, Marlene, & Kujala, Sari. 2014

Journal of Usability Studies, 10(1), 46-62.

JUS
JOURNAL OF USABILITY STUDIES
Vol. 10, Issue 1, November 2014 pp. 46-62

Experiencing Visual Usability and Aesthetics in Two Mobile Application Contexts

Johanna Silvennoinen
PhD Candidate
University of Jyväskylä
Department of Computer Science and Information Technology
P.O. Box 35
40014 University of Jyväskylä
Finland
johanna.silvennoinen@jyu.fi

Marlene Vogel
PhD Candidate
Dräger Safety AG & Co KGaA
Moislinger Allee 53/55
23558 Lübeck
Germany
marlene.vogel@draeger.com

Sari Kujala
Research Fellow, PhD
Aalto University
Department of Computer Science and Engineering
P.O. Box 15400
FI-00076 Aalto
Finland
sari.kujala@aalto.fi

Abstract

Visual attractiveness is increasingly seen as an essential factor in perceived usability, interaction, and overall appraisal of user interfaces. Visual elements in technological products are capable of evoking emotions and affective responses in users. In this paper, we focus on the role of visual usability and visual aesthetics in an experimental research setup. This study examined user experiences and preferences in relation to the visual elements of color and perceived dimensionality of two different mobile application contexts. Quantitative and qualitative data were collected using two online questionnaires in order to gain insights to user preferences of visual elements in the two different mobile applications. The results imply that colors highly improve hedonic and pragmatic qualities of an application with a task-oriented functionality, as well as an application for entertainment purposes. We found that two-dimensionality (2-D) was generally preferred by the participants. The impression of three-dimensionality (3-D) was seen as a confusing and unnecessary element in the task-oriented mobile application context. The results of this study enhance understanding of the role and the influence of visual elements on user experience. Visual elements contribute to pragmatic user experience component in terms of visual usability and to hedonic user experience component in terms of subjective preferences of visual aesthetics. In addition, the methodological approach can be utilized to study the role of visual elements in pragmatic and hedonic user experience components with different visual elements and regarding different types of user interfaces.

Keywords

visual user interface design, mobile application, color, perceived dimensionality, user experience, attractiveness, user preference, visual usability, visual aesthetics

Introduction

People prefer products not only for usefulness and usability, but also for a good user experience (Thüring & Mahlke, 2007). Besides the traditional view regarding the importance of functionality and usability, the importance of the visual design of user interfaces (UIs), often referred as visual aesthetics in HCI, is taken into consideration in many studies (e.g., Desmet & Hekkert, 2007; Hassenzahl, 2001; Hassenzahl, 2003; Hassenzahl & Monk, 2010; Thüring & Mahlke, 2007; Tractinsky, 2012). Existing studies have shown that product aesthetics, for instance regarding visual appearance of UIs, plays a significant role when people are choosing between different technological products before interacting, for example, the pre-use phase (Crilly, Moultrie, & Clarkson, 2004). Because aesthetic information is evaluated immediately, it is largely responsible for the users' first impressions (Tractinsky, Cokhavi, Kirschenbaum, & Sharifi, 2006). Immediate assessments of attractiveness (Tractinsky et al., 2006) and, for instance, trustworthiness (Cyr, Head, & Larios, 2010) are made based on visual appearance of UIs.

Research results show that visual attractiveness and perceived usability are related (Thüring & Mahlke, 2007; Tractinsky et al., 2006; Sonderegger, Zbinden, Uebelbacher, & Sauer, 2012; Tractinsky, 2012). It has claimed that what is beautiful is also usable (Tractinsky, Katz, & Ikar, 2000). However, Lindgaard and Dudek (2003) showed that visual attractiveness does not always lead to good usability ratings. One possible explanation for the conflicting results was that users focused on different aspects of use depending on whether their goal was to have fun or to accomplish tasks. It is known that perceived usability is more important when people accomplish tasks, and hedonic, pleasure-oriented aspects are more important when they intend to have fun (Hassenzahl, 2008).

Studies concerning visual aesthetics in HCI have mainly focused on high-level attributes (Tractinsky, 2012), such as unity and prototypicality (Veryzer, & Hutchinson, 1998), typicality and/or novelty (Hekkert, Snelders, & Wieringen, 2010; Hung & Chen, 2012). Therefore, the available study literature lacks information for HCI visual aesthetics, such as low-level attributes (Tractinsky, 2012), also defined as visual elements (Mullet & Sano, 1995) or psychophysical properties (Hekkert & Leder, 2008). In addition, previous studies have shown that product type and usage situation influence user experience (e.g., Gross & Bongartz, 2012; Lee, 2013). The context in which the visual elements appear highly influences the aesthetic effects (Hekkert & Leder, 2008). User experience is a highly dynamic, subjective, and complex phenomenon (e.g., Law, Roto, Hassenzahl, Vermeeren, & Kort, 2009) and can be subdivided in different phases of use: pre-use, use, post-use, repetitive use, past use, and re-use (Pohlmeyer, 2011).

The role of visual elements in different mobile application contexts has not been investigated. Therefore, the goal of this paper is to understand how visual elements influence user experience in two different mobile application contexts. The focus is on the perception-based evaluation of user experience in an anticipated use situation, that is, pre-use phase. Do user experience and preferences change in relation to visual elements in two different mobile application contexts? The first mobile application is for task-oriented and more practical context of use, a mobile transport system application, whereas the second is an application for entertainment purposes.

The visual elements studied in this paper are color and perceived dimensionality. Perceived dimensionality means creating an impression of three-dimensionality (3-D) of UI objects in a two-dimensional (2-D) surface (Poulin, 2011). Perceived dimensionality can be achieved through highlighting and shadowing that stimulates the sensation of a raised surface.

The scope of this study is presented in Figure 1. The colorful area of the figure represents the scope of our study. The aim of this study is to find out how color and perceived dimensionality are preferred in different types of mobile applications and how color and perceived dimensionality are related to different aspects of user experience (overall appraisal, hedonic, and pragmatic product qualities) in an anticipated use-phase. The results provide insights into user preferences of perceived dimensionality of UI elements and color in mobile application UIs, as well as whether people change their preferences of color and perceived dimensionality of UI elements according to the type of application. Designers could utilize the results in designing mobile applications according to user preferences and the specific mobile application types. The methodological approach could be utilized to study visual elements in different mobile application types.

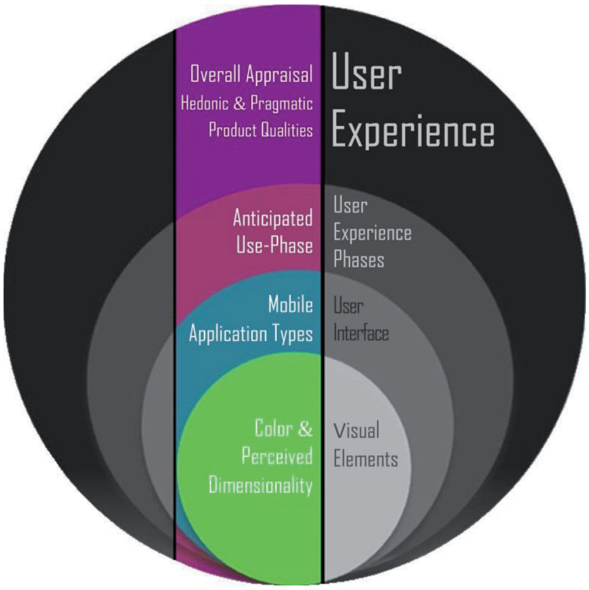


Figure 1. The scope of the study.

Visual Elements in User Interface Design

When users experience products, they perceive numerous visual elements (Zettl, 1999). Visual elements are essential in UI design due to the communicative ability inherent in them (Galitz, 2007; Mullet & Sano, 1995; Schlatter & Levinson, 2013). However, there is no Holy Grail for a universal design language to be applied to all contexts involved in visual design (Tractinsky, 2012). Therefore, it is important to study visual elements in specific UI contexts. In addition, many design principles have been presented (e.g., Lidwell, Holden, & Butler, 2003), but user preferences and experiences of visual elements in mobile application UIs have not been taken into account. Perceived dimensionality is widely used in visual representations, and it is seen as visually dynamic and engaging in graphic design (Poulin, 2011). Knowledge of user preferences of perceived dimensionality in mobile UIs is important due to the visual effectiveness of perceived dimensionality. The 2-D and 3-D impressions of UI objects have different effects on how the objects are perceived. For UI objects in 3-D, this includes perceived height, width, and depth, which make the objects stand out from the background surface. This perceived 3-D impression of visual volume can be conveyed with several design principles, such as shading the receding surfaces and with overlapping elements (e.g., Frutiger, 1997). On the contrary, 2-D objects lack perceived visual volume. Therefore, they are not perceived to stand out from the background surface. They are rather seen as flat objects belonging to the background surface. Perceived 3-D elements in UIs can be, for instance, buttons, icons, and boxes. In HCI, 3-D can also refer to 3-D virtual environments and 3-D displays, with a sensation of 3-D space. In this study the focus is on the perception of UI objects in 3-D and 2-D.

HCI studies have mainly focused on virtual environments with the sensation of 3-D space, for instance, designing interactive systems with perceived 3-D spaces is supposed to enhance user engagement (Sutcliffe, 2009). Ark, Dryer, Selker, and Zhai (1998) suggested that a realistic representation of 3-D objects contributed positively to task performance, and the usage of 3-D ecological, realistic interfaces was recommended rather than 2-D iconic UIs. Kim, Proctor, and Salvendy (2011) studied cell phone menus as perceived 3-D elements. Their study concluded that more information can be included to 3-D menus than 2-D menus, and 3-D menus may also enhance the usability of the limited screen space in mobile devices. Besides the perceived dimensionality, color design is also an important aspect of experiencing and designing mobile UIs. In graphic design, color is one of the most communicative and powerful visual element. Color is often seen as a primary visual element that can add visual interest in any visual compositions (e.g., Poulin, 2011). However, in HCI, color has been studied mostly in relation to web pages (e.g., Kim, Lee & Choi, 2003). Coursaris, Swierenga, and Watrall (2008) studied the effects of color temperature and gender on perceptions of web page aesthetics. They found out that gender had no effects, but cool color combinations (blue to light blue) were preferred more than warm color combinations (red to orange). Cyr et al. (2010) studied color appeal in website design across cultures. Their results revealed that color appeal in websites has significant value for trust and satisfaction, and there were differences in reactions to website colors between cultures, concluding that color can be used in website design to influence users' emotions, perceptions, and reactions.

Research Objective

The objective of our research is to investigate the relation of visual elements, color and perceived dimensionality of UI elements, in mobile applications according to user preferences and liking in an anticipated use situation (pre-use phase). We also investigated the perception-based evaluation of user experience components, for example, pragmatic and hedonic product qualities and attractiveness (Hassenzahl, 2003), in relation to different visual elements.

The following are our research questions:

1. Do color and perceived dimensionality of UI elements influence user experience and user preferences of mobile applications?
2. Do user experience and user preferences of visual elements change in relation to different types of mobile applications?

Analysis of qualitative data will provide insight to the reasons behind user preferences of visual elements and possible changes of preferences according to the different types of mobile applications.

Hypothesis

We assume that color and perceived dimensionality of UI elements have significant influences on the perception and evaluation of hedonic and pragmatic product qualities as well as liking and preferences. This assumption is based on the essential role of visual elements in UI design and the communicative ability inherent in them (e.g., Galitz, 2007; Mullet & Sano, 1995; Schlatter & Levinson, 2013).

Additionally, we hypothesize that the influences of color and perceived dimensionality on user experience components, preferences, and liking differ in relation to the type of the mobile application, because aesthetic effects of visual elements are dependent of the context in which they appear (e.g., Hekkert & Leder, 2008).

Method

This study followed a mixed methods sequential explanatory design (Creswell & Plano Clark, 2007) by explaining quantitative results with qualitative data. Quantitative and qualitative data were collected from two different mobile application contexts with two separate online questionnaires utilizing a between-subject design. The two mobile applications used in this study were a local transport application and an entertainment application. A UI with black and white color scheme served as a control condition to investigate the influence of color on user experience components and the appeal of those components. The UI design elements "color" (black and white or colored) and "perceived dimensionality" (2-D or 3-D) were tested as within-subject factors. Therefore, each questionnaire presented four versions of the specific application: one black and white 2-D, one color 2-D, one black and white 3-D, and one color 3-D. (see Figures 2, 3, 4, and 5).

Qualitative content analysis (Krippendorff, 2004) was conducted in order to understand reasons behind user preferences of visual elements. Users' written descriptions were first categorized thematically to sections in relation to numerical ratings accompanied with the amount of participants given the rating. Second, the rating categories were analyzed and categorized thematically regarding descriptions of preferences: what were the reasons behind liking or disliking the UI version. The analysis consisted of familiarization, organization, and categorization of the data, followed by the analysis process with interpretation and conversation with the data.

Stimulus Material

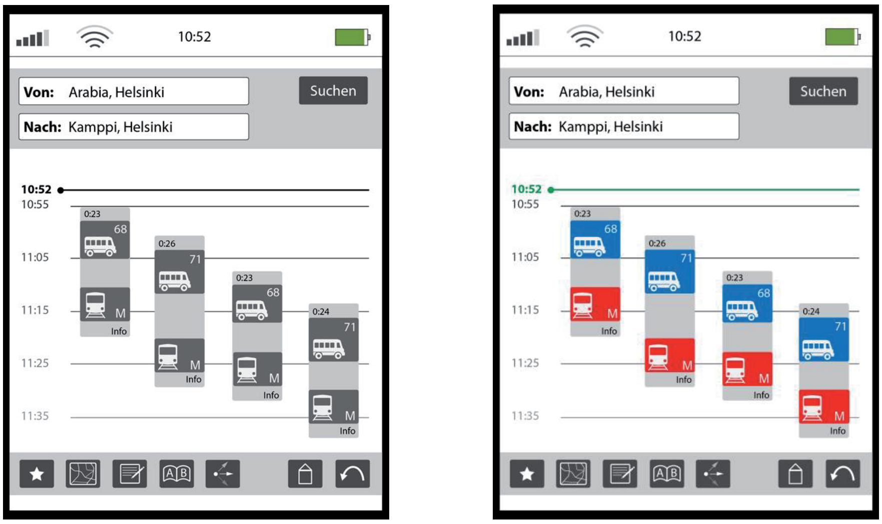
The preparation of the stimulus material followed a 2 × 2 experimental design with the independent factors of "color" (black and white, color) and "perceived dimensionality" of UI elements (2-D and 3-D). The stimulus material consisted of UI screen captures assuming an anticipated use (pre-use phase) of two mobile applications.

Preferences between different alternatives employ us on a daily basis. Judgments and evaluations of appeal are more easily carried out when possibilities of comparing alternative options are provided (e.g., Peevers, Douglas, & Jack, 2008). In designing the stimulus material this possibility was taken into account by using a within-subject design for the color and perceived dimensionality factors. In addition, all four designs were shown at the same time to provide the participants with the ability to compare and evaluate the designs together.

The first UIs of the mobile application for a local transport system represent the task-oriented functionality for a practical context of use (Figures 2 and 3). This mobile application is for searching public transport routes and connections from different locations. The application's UI screen capture displays search results from one location to another and gives different connections for users to compare and select the most suitable option. The second application is an application for entertainment purposes (Figures 4 and 5). This mobile application is for voice recording, where the animal that was selected by the participant repeated the participant's recorded voice using a funny voice, facial expression, and body gesture.

Color

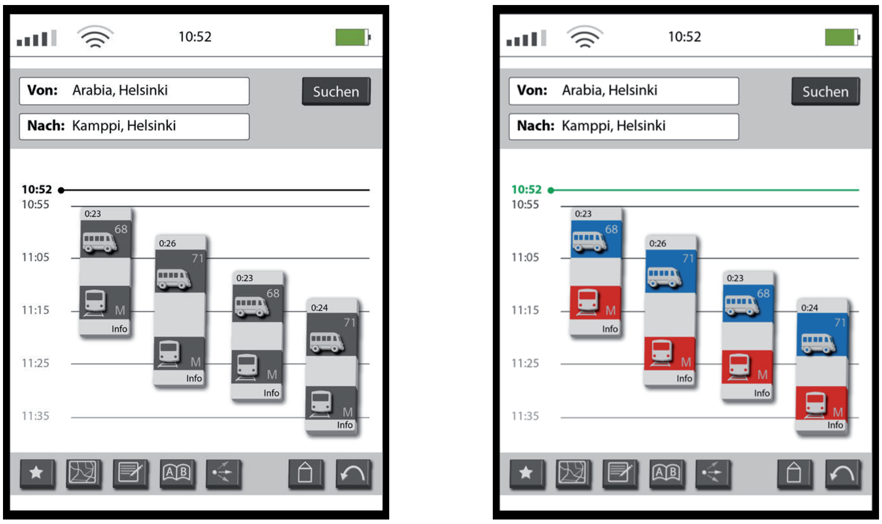
Investigating the visual element "color" in a different context of use, we prepared two UI versions using two different color schemes: a black and white color scheme served as a control condition in relation to a UI with color (Figures 2 and 3). The colored version consisted of two primary hues, red and blue in the most central functional elements, and a secondary hue of green. In the colored UIs of the mobile transport system application, the blue and red colors were added to the bus and metro signs to resemble the colors of these vehicles in Helsinki's local transport system. The green color was added to the horizontal line that represented the actual time. Although the data collection was conducted among German participants, they got instructions that the UI screen captures displayed local transport information from Helsinki, Finland.



A

B

Figure 2. Transport application: *A* is black and white 2-D, and *B* is the color 2-D.

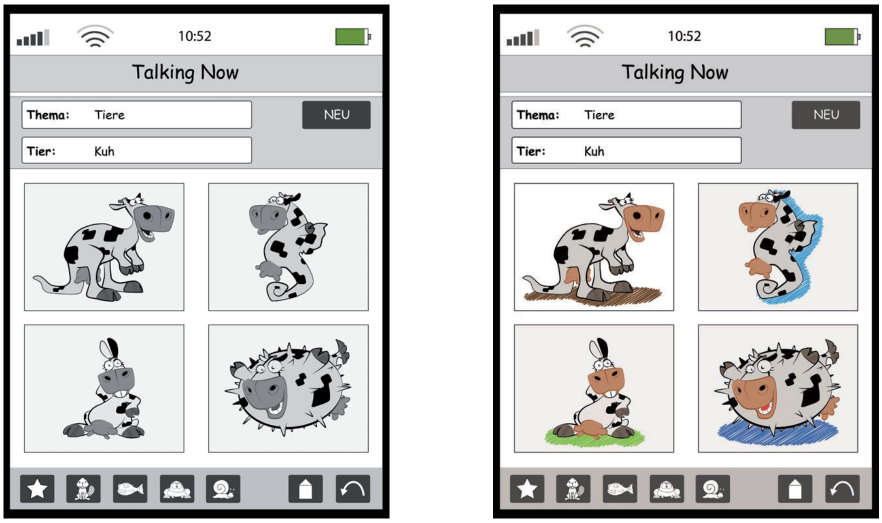


A

B

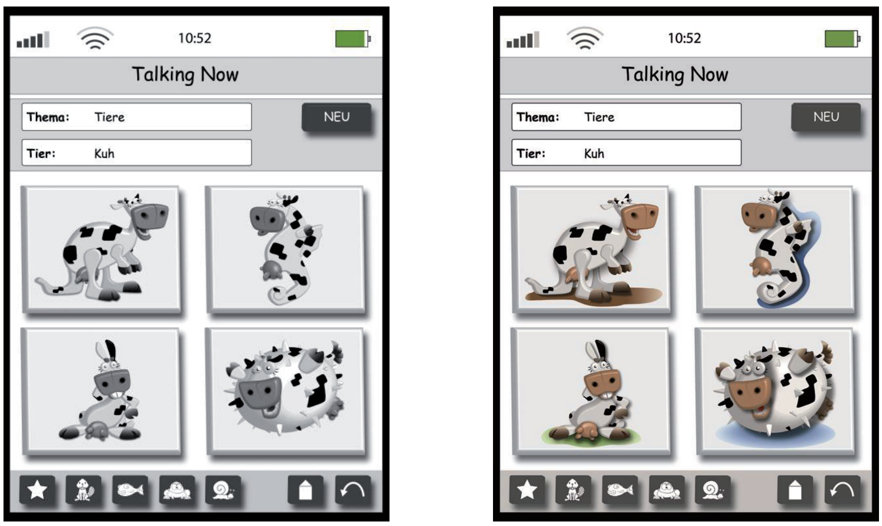
Figure 3. Transport application: *A* is black and white 3-D, and *B* is the color 3-D.

In the colorful version of the mobile application for entertainment purpose, we included a secondary hue of orange and brown, which was the combination of all three primary colors: red, blue, and yellow (e.g., Itten, 1973).



A B

Figure 4. Entertainment application: *A* is black and white 2-D, and *B* is the color 2-D.



A B

Figure 5. Entertainment application: *A* is black and white 3-D, and *B* is the color 3-D.

Perceived dimensionality

Two different perceived dimensionalities of UI objects were investigated (2-D and 3-D). The perceived 3-D volume of the objects was created by adding interposition, texture gradient, and shading to 2-D elements. Interposition means that overlapping shapes create a sense of 3-D depth in 2-D surface (e.g., Arnheim, 1974; Costache, 2012). Texture gradient was applied when the texture of a surface varied in density. Areas with more density are perceived to be further away. The same idea applies to shading and shadows (e.g., Lidwell et al., 2003). The perceived three-dimensionality was added to the UI elements that included functionalities, which also increased the affordances of these objects. The overall impression of UIs did not highlight a sensation of 3-D space, but rather an impression of volume in the UI components. Pictures on the buttons (bus, metro, and cows) as well as the buttons themselves included added dimensionality with perceived depth (Figures 3 and 5). The amount of objects manipulated by color and perceived dimensionality were equal in both applications.

Participants

Based on the experimental design, two groups of participants were involved in the study. A total of 37 participants (24 female, 13 male; age: M = 25.68, SD = 4.28) completed the online questionnaire in the first portion of this study that tested the four versions of the local transport application. These participants were mostly students of bachelor (37.8%) and master (59.5%) degree programs in different subjects of study (e.g., cognitive science, mathematics, informatics, biology, human factors, engineering, neurology science, psychology, and philosophy).

For the second portion of the study, evaluating the four versions of the entertainment application, 25 participants (17 female, 8 male; age: M = 29.16, SD =3 .34) completed the second online questionnaire. For this online questionnaire 88% of the participants had a bachelor's degree in similar subjects as participants who participated in the first online questionnaire. Only 8% (two people) had no university degree.

Participants were recruited by email lists and were German speaking. They participated voluntarily and did not receive any reward. The online questionnaires were conducted online using LimeSurvey®, which is a free open source survey application. All the participants used their own desktop computer or laptop for viewing the stimulus mobile application pictures and answering the questionnaire. The survey application showed the pictures of each application approximately in the size of 320 x 430 pixels, and the four versions of each application were shown at the same time. Regarding the display of the colors on different mobile devices, the designs were tested in a natural context as people will always have different mobile devices when they use the application. Thus, the test was done in the actual usage context and a variation on screen quality.

Research Procedure

The procedures for both online questionnaires for each application were equivalent. Each questionnaire had three sections for each application: an AttrakDiff-mini section, a 7-point Likert-type scale measuring how well participants liked each application, and an open-ended question section. The presentation order of UI versions was counterbalanced. The four different UI versions of each application were displayed next to each other so that the participants were able to see all the versions at the same time.

Participants evaluated the four UI versions of the application using a version of the AttrakDiff-mini questionnaire developed by Hassenzahl and Monk (2010). This questionnaire was conducted using a semantic differential ranging from ugly (1) to beautiful (7).Using the modified AttrakDiff-mini questionnaire, participants evaluated each UI based on items such as pragmatic product qualities, identification, stimulation, and attractiveness. The mean value from these four subscales of the AttrakDiff-mini questionnaire resulted in an "overall UX" score.

After completing the AttrakDiff section of the questionnaire, participants rated how well they liked each UI version. We measured "liking" as a single item using a 7-point Likert scale with anchors for extremes (I like it: 1= not at all, 7 = totally). Then, participants selected the best and worst UI from the four versions of each application.

Finally, participants answered eight open-ended questions. Follow up questions were asked in relation to each four screen capture versions of each application: What do you like or dislike about this version? What do you think about 2-D and 3-D visual design and why? How do you feel about the choice of color for the different versions and why? Which version do you like the most and why? Which version do you dislike the most and why?

Results

The focus of this study was to investigate how color and perceived dimensionality of UI components influence user preferences and the anticipated experience in two different mobile application contexts. Participants did not interact with the applications; they only viewed four screen captures of the application.

User Preferences—Local Transport Application

Participants were asked to select one UI as the best version and one UI as the worst version from the four UI options of local transport application screen captures. The same procedure applied for the evaluating the entertainment application. They did not rank the four UIs into preferential order.

Best UI

Twenty-four participants (64.9%) named the 2-D colored UI version as the best option. Seven participants (18.9%) preferred the 3-D colored UI, and only three (8.1%) preferred the black and white 2-D version as well as the black and white 3-D version. The 2-D colored UI version was preferred for several reasons. One participant said, "clear, color contrasts are well designed, design is functional orientated and not unnecessarily confusing." The overall impression of the UI was seen as clear, legible, and functional, which was achieved by color contrasts. Colors were also seen as organizers of the content. This UI was also valued because no unnecessary elements or effects, such as shadows, were included. The combination of the colors and 2-D was seen as the best degree of simplicity. Colors were also seen as vivid, beautiful, and attractive. Some of the participants commented that "with color it looks fresher and livelier" and "the colors are beautiful."

Worst UI

Twenty-six participants (70.3%) did not prefer the black and white 3-D version, whereas only six participants (16.2%) did not favor the black and white 2-D version. Four participants (10.8%) did not prefer the 3-D colored UI. Only one participant (2.7%) rated the 2-D colored version as the worst option. The 3-D black and white UI version was not preferred; participants said that it was "dark, unclear and lacking of color contrast." Participants described their preferences, for instance, with the following words: "content is barely distinguishable from the rest because of non-colored and even dark shadows." The shadows creating the perceived 3-D volume were seen as unnecessary effects. As described by one participant, the black and white color scheme was "all shades of gray, looks dull and confusing."

Analysis

We used a multiple analysis of variance (MANOVA) with repeated measurements. The analysis included "color" and "perceived dimensionality" as independent variables, and "liking," as well as user experience components (pragmatic product quality, identification, stimulation, attractiveness, overall user experience) as dependent variables. Overall, regarding these dimensions, the colored version was evaluated better than the black and white version (see Figure 6). The following effects revealed a significant main influence of color:

- pragmatic product qualities: $F(1,35) = 4.41$, $p = 0.04$, $\eta^2_{PART} = 0.1$
- identification: $F(1,35) = 15.36$, $p < 0.001$, $\eta^2_{PART} = 0.30$
- stimulation: $F(1,35) = 29.84$, $p < 0.001$, $\eta^2_{PART} = 0.46$
- attractiveness: $F(1,35) = 15.22$, $p < 0.001$, $\eta^2_{PART} = 0.30$
- liking: $F(1,35) = 8.20$, $p < 0.001$, $\eta^2_{PART} = 0.19$
- overall user experience: $F(1,35) = 20.05$, $p < 0.001$, $\eta^2_{PART} = 0.40$

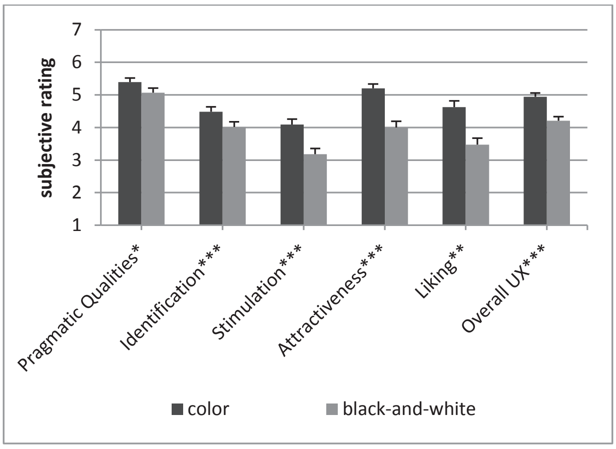


Figure 6. Transport application: main effect of color on UX components (*p < 0.05, **p < 0.01, ***p < 0.001). Semantic differential with 1 = negative and 7 = positive evaluation for subjective rating scales (pragmatic qualities, identification, stimulation, attractiveness, and overall UX) utilizing the AttrakDiff-mini questionnaire. Liking measured by single-item 7-point scale ranging from 1 (not at all) to 7 (totally). Error bars represent standard deviation (*SD*).

Overall, the 2-D version was evaluated as better than the 3-D version. The perceived dimensionality had significant main influences on the following (see Figure 7):

- pragmatic product qualities: $F(1,35) = 4.63$, $p = 0.04$, $\eta^2_{PART} = 0.12$
- attractiveness: $F(1,35) = 5.01$, $p = 0.03$, $\eta^2_{PART} = 0.13$
- liking: $F(1,35)=10.15$, $p=0.01$, $\eta^2_{PART}=0.23$
- overall UX (only a marginal significant effect): $F(1,35) = 3.21$, $p = 0.08$, $\eta^2_{PART} = 0.08$

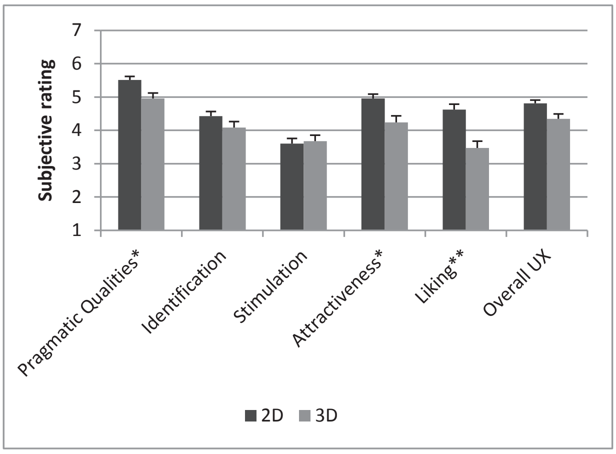


Figure 7. Transport application: main effect of dimensionality on UX components (*p < 0.05, **p < 0.01). Semantic differential with 1= negative and 7 =positive evaluation for subjective rating scales (pragmatic qualities, identification, stimulation, attractiveness, and overall UX)

utilizing the AttrakDiff-mini questionnaire. Liking measured by single-item 7-point scale ranging from 1 (not at all) to 7 (totally). Error bars represent standard deviation (*SD*).

User Preferences—Application for Entertainment Purpose

Prior experience with other gaming applications was asked and entered to MANOVA as co-variable. No significant interaction with any dependent variable occurred.

Best UI

Fifteen participants (60%) preferred the colored 2-D version (Figure 4B) the most. Ten participants (40%) preferred the colored 3-D version (Figure 5B) over all others. Some participants justified their preferences for the 2-D colored UI version by stating the following: “because colorful and clearly structured” and “colors are strongest, sketching seems relaxed and playful.” This 2-D version was seen as the clearest, funniest, and most creative. The style of the color design in the figures was considered important. The figures were seen as comic-like figures. The second most preferred UI version was the 3-D colored UI version. In this version the colors were also highlighted, but the way the colors were rendered in 3-D figures was not preferred as much as in the 2-D version.

Worst UI

Sixteen participants (64%) evaluated the 3-D black and white version as the worst (Figure 5A). Eight participants (32%) rated the 2-D black and white version (Figure 4A) the worst, and only one person (4%) thought the 3-D colored version (Figure 5B) was the worst option. The 3-D black and white UI was seen as too dark, unclear, and “difficult to distinguish between elements” due to the lack of colors. In addition, the perceived three-dimensionality without colors was seen as an unusual combination.

Analysis

For analyzing, a MANOVA with repeated measurements was performed. It included color and perceived dimensionality as independent variables, and liking as well as user experience components (pragmatic product quality, identification, stimulation, attractiveness, overall user experience) as dependent variables. The following effects revealed a significant main influence of color:

- attractiveness: $F(1, 22) = 13.63$, $p = 0.001$, $\eta^2_{PART} = 0.38$
- liking: $F(1,22) = 10.15$, $p = 0.003$, $\eta^2_{PART} = 0.23$
- overall user experience: $F(1, 22) = 7.61$, $p = 0.01$, $\eta^2_{PART} = 0.26$
- pragmatic product qualities (only a marginal significant effect on color): $F(1,35) = 3.49$, $p = 0.08$, $\eta^2_{PART} = 0.14$.

Within Bonferroni adjusted post-hoc tests, significant main effects of color on pragmatic product qualities ($p = 0.008$), identification ($p < 0.001$), stimulation ($p < 0.001$), attractiveness ($p = 0.001$), liking ($p < 0.001$), and overall UX ($p < 0.001$) have been detected (Figure 8).

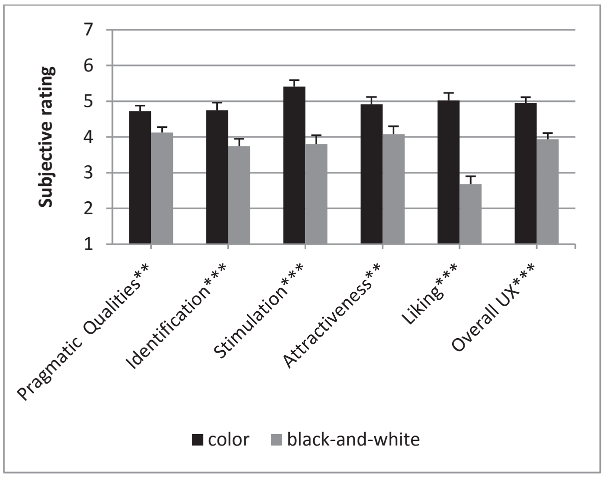


Figure 8. Entertainment application: main effect of color on UX components, liking, and overall UX using pairwise comparison. Bonferroni adjusted post-hoc test (*p < 0.05, **p < 0.01, ***p < 0.001). Semantic differential with 1 = negative and 7 = positive evaluation for subjective rating scales (pragmatic qualities, identification, stimulation, attractiveness, and overall UX) utilizing the AttrakDiff-mini questionnaire. Liking measured by single-item 7-point scale ranging from 1 (not at all) to 7 (totally). Error bars represent standard deviation (*SD*).

Perceived dimensionality did not have any main effects on any dependent variable. No significant interaction occurred for color and perceived dimensionality on any dependent variable either.

Conclusion

In this paper, user experiences and preferences in relation to visual elements in two different mobile application contexts were studied. The results show that visual elements contribute to experiential aspects of mobile applications. Color was highlighted as an important visual factor in both mobile applications. The participants reported that color is an important element regarding personal affective preferences, such as beauty, attractiveness, and vividness. From a functional viewpoint color was seen, for instance, as an organizer of information and contributor to a clearer overall impression of the UI due to the color contrasts. Therefore, these results emphasize the importance of color design for effective visual usability. The colors in the entertainment application were also preferred because of the style of the figures. Participants described the style of the figures as comic-like and reminded them of children's books, and that the sketching of the figures made them more charming (these descriptions only occurred for the colored 2-D version, not for the colored 3-D version). Therefore, the ways by which colors and the perceived dimensionality are included into a UI design can create a sensation of some specific style and should be taken into account in a design process. These subtle stylistic impressions can be acknowledged by studying user preferences of visual elements in specific mobile application contexts.

The black and white color scheme was disliked from affective and functional viewpoints. Black and white color schemes are used in various design objects as a unifying style. However, in the mobile application UI design, the black and white color scheme was described, for example, as boring and too gray. From a functional viewpoint, different actions and functionalities were considered difficult to be distinguished from each other. It can be concluded, that the color in a UI has a higher influence on a variation of different user experience components than perceived dimensionality of UI elements. Colored UIs are perceived as more a pragmatic and hedonic valuable, which can be verified by the increased attractiveness and liking by the participants.

Colorful UIs are generally preferred over black and white UIs, independent from the type of the mobile application.

However, perceived dimensionality has different influences depending on the type of mobile application used. For task-oriented applications (e.g., local transport system) additional perceived 3-D volume had a negative effect on the perceived pragmatic product qualities: attractiveness and liking. From a functional point of view the two-dimensionality of UI elements was perceived to be clearer, simpler, and easier to grasp than UI elements in 3-D. From an affective viewpoint, two-dimensionality appeared to the participants as more stylish and authentic. In addition, the overall appearance with two-dimensionality was seen from a positive perspective, which was mainly achieved by simplicity. From a functional viewpoint, three-dimensionality was seen as an unnecessary element, which mainly confuses and makes the overall appearance of the UI more complex without including more information. In contrast to these findings, previous studies recommended the usage of perceived three-dimensionality in computer UIs (Ark et al., 1998; Sutcliffe, 2009). However, according to our results three-dimensionality was not preferred in mobile application UIs with a more practical and task-oriented context. Nevertheless, perceived dimensionality did not have a significant influence on user experience and liking regarding the entertainment application. Therefore, the context has to be taken into account when designing and using specific perceived dimensionalities in mobile applications.

Limitations of the Study

Visual design is not universally understood similarly in different cultures. For instance, in some cultures, different meanings are attached to dimensions of visual space and can be strongly influenced by a culture’s style of writing and reading direction (e.g., van Leeuwen & Kress, 2006). Moreover, colors carry lots of cultural design traditions and symbolic meanings (e.g., Cyr et al., 2010). Therefore, the results of this study can be extended to be applied in many Western countries. In addition, the results of the present study may not be directly generalized to all kinds of mobile applications and usage situations. For example, using colors in mobile applications, the intended style and color combinations need to be considered according to the specific context.

Future Research

In this study, user preferences of visual elements, color and perceived dimensionality, in different mobile applications were studied focusing on the anticipated use-phase in a user experience life cycle (Pohlmeyer, 2011). Therefore, users viewed screen captures of the UI versions and did not interact with the applications. Interaction with technological products often occurs by first gaining perceptual knowledge and experiences of a product, after which information gained by other sensory modalities supplements the interaction (Ludden, Schifferstein, & Hekkert, 2009).

Therefore, the results presented in this paper could be further examined and elaborated on. User preferences could be studied in relation to real interaction (use-phase) with a mobile application. In addition, future research could take into account experiences conveyed through other sensory modalities than just perceptual modality. Further research could, therefore, focus on the role of visual elements in a more holistic understanding of a user’s experience in interacting with technological products. Future research steps could also focus on resolving what kind of impact different use-phases (pre-use, use, post-use, repetitive use, past use, and re-use) has on interacting with mobile applications constructed from visual elements and other design features. Moreover, user preferences of visual elements could be studied in relation to different kinds of mobile applications.

Tips for Usability Practitioners

The following findings, based on the results of this study, have practical value for usability, user experience, and design practitioners:

- Consider visual elements such as color and perceived dimensionality as they influence both user preferences and perceived usability when testing the appeal of a mobile application.
- Pay attention to visual elements as the constructing units of UIs because they influence hedonic and pragmatic user experience components and, therefore, are strong determinants of the success of technological products.
- Use colors for organizing information, creating continuity and consistency, and enhancing visual usability and influence on users' emotions. Select colors in relation to the type and style of the mobile application and user expectations.
- Consider that black and white color schemes can function as a basis for carefully considered stylistic impressions; however, black and white color schemes in mobile applications were not generally preferred and therefore require consideration.
- Consider, carefully, the role of perceived three-dimensionality in designing mobile applications. Perceived three-dimensionality in mobile applications was not preferred in the task-oriented or entertainment application.
- Use a mixed methods approach. We highlight that it is essential to effectively analyze the quantitative and qualitative data in a dialogue and select the mixed methods approach that supports the study design and the research problem.

Acknowledgements

This work was supported by Deutsche Forschungsgemeinschaft (DFG) and Deutscher Akademischer Austauschdienst (DAAD).

References

Ark, W., Dryer, C. D., Selker, T., & Zhai, S. (1998). Representation matters: The effect of 3-D objects and spatial metaphor in a graphical user interface. *Proceedings of HCI ´98*, *People and Computers XIII,* (pp. 209–219). London: Springer.

Arnheim, R. (1974). *Art and visual perception: A psychology of the creative eye.* Berkeley and Los Angeles: University of California Press.

Coursaris, C. K., Sweirenga, S. J., & Watrall, E. (2008). An empirical investigation of color temperature and gender effects on web aesthetics. *Journal of Usability Studies, 3*(3), 103–117.

Costache, I. D. (2012). *The art of understanding art.* Oxford, UK: Blackwell Publishing Ltd.

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, CA: Sage.

Crilly, D., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: Consumer response to the visual domain in product design. *Design Studies, 2,* 547–577.

Cyr, D., Head, M., & Larios, H. (2010). Colour appeal in website design within and across cultures: A multi-method evaluation. *International Journal of Human–Computer Studies*, *68*, 1–21.

Desmet, P. M. A., & Hekkert, P. (2007). Framework of product experience. *International Journal of Design, 1*(1), 57–66.

Frutiger, A. (1997). *Signs and symbols. Their design and meaning* (2nd ed.). Cham, Switzerland: Syndor Press GmbH.

Galitz, W. O. (2007). *The essential guide to user interface design: An introduction to GUI design principles and techniques* (3rd ed.). Indianapolis, IN: Wiley Publishing, Inc.

Gross, A., & Bongartz, S. (2012). Why do I like it? Investigating the product-specificity of user experience. *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design* (pp. 322-330). New York: ACM.

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

Hassenzahl, M. (2003). The thing and I: Understanding the relationship between user and product. In M. A. Blythe, A. F. Monk, K. Overbeeke & P. C. Wright (Eds.), *Funology: From usability to enjoyment* (pp. 1–12). Dordrecht: Kluwer Academic Publishers.

Hassenzahl, M. (2008). Aesthetics in interactive products: Correlates and consequences of beauty. In H. N. J. Schifferstein, & P. P. M. Hekkert (Eds.), *Product experience* (pp. 287–302). Amsterdam: Elsevier.

Hassenzahl, M., & Monk, A. (2010). The inference of perceived usability from beauty. *Human-Computer Interaction, 25*(3), 235–260.

Hekkert, P., & Leder, H. (2008). Product aesthetics. In H. N. J. Schifferstein & P. P. M. Hekkert (Eds.), *Product experience* (pp. 259–286). Amsterdam: Elsevier.

Hekkert, P., Snelders, D., & Wieringen, P. C. W. (2010). "Most advanced, yet acceptable": Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology, 94*(1), 111–124.

Hung, W. –K., & Chen, L. L. (2012). Effects of novelty and its dimensions on aesthetic preference in product design. *International Journal of Design, 6*(2), 81–90.

Itten, J. (1973). *The art of color: The subjective experience and objective rationale of color.* New York: Van Nostrand Reinhold.

Kim, J., Lee, J., & Choi, D. (2003). Designing emotionally evocative homepages: An empirical study of the quantitative relations between design factors and emotional dimensions. *International Journal of Human-Computer Studies, 59*, 899–940

Kim, K., Proctor, R. W., & Salvendy, G. (2011). Comparison of 3-D and 2-D menus for cell phones. *Computer in Human Behavior, 27*, 2056–2066.

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology* (2nd ed.). Thousand Oaks, CA: Sage.

Law, E. L. C., Roto, V., Hassenzahl, M., Vermeeren, A. P. O. S., & Kort, J. (2009). Understanding, scoping and defining user experience: A survey approach. *Proceedings of the 27th International Conference on Human Factors in Computing Systems, CHI 2009* (pp. 719–728). New York: ACM.

Lee, S. (2013). Understanding user experience with computer-based applications with different use purposes. *International Journal of Human-Computer Interaction, 29*(11), 689–701.

Lidwell, W., Holden, K., & Butler, J. (2003). *Universal principles of design*. Beverly, MA: Rockport Publishers.

Lindgaard, G., & Dudek, C. (2003). What is this evasive beast we call user satisfaction? *Interacting with Computers*, *15*(3), 429–452.

Ludden, G. D. S., Schifferstein, H. N. J., & Hekkert, P. (2009). Visual-tactual incongruities in products as sources of surprise. *Empirical Studies of the Arts, 27*(1), 3–89.

Mullet, K., & Sano, D. (1995). *Designing visual user interfaces: Communication oriented techniques.* Upper Saddle River, NJ: Prentice Hall.

Peevers, G., Douglas, G., & Jack, M. A. (2008). A usability comparison of three alternative message formats for an SMS banking service. *International Journal of Human-Computer Studies, 66*, 113–123.

Pohlmeyer, A. E. (2011). *Identifying attribute importance in early product development*. Ph.D. thesis, Technische Universität Berlin, Germany.

Poulin, R. (2011). *The language of graphic design: An illustrated handbook for understanding fundamental design principles*. Beverly, MA: Rockport Publishers.

Schlatter, T., & Levinson, D. (2013). *Visual usability, principles and practices for designing digital applications.* MA: Morgan Kaufman.

Sonderegger, A., Zbinden, G., Uebelbacher, A., & Sauer, J. (2012). The influence of product aesthetics and usability over the course of time: A longitudinal field experiment. *Ergonomics, 55*(7), 713–730.

Sutcliffe, A. (2009). Designing for user engagement: Aesthetics and attractive user interfaces. *Synthesis Lectures of Human-Centered Informatics, 2*(1), 1–55.

Thüring, M., & Mahlke, S. (2007). Usability, aesthetics, and emotions in human-technology interaction. *International Journal of Psychology, 42,* 253–264.

Tractinsky, N. (2012). Visual aesthetics. In M. Soegaard & R. F. Dam, (Eds.). *The encyclopedia of human-computer interaction* (2nd ed.). Aarhus, Denmark: The Interaction Design Foundation.

Tractinsky, N., Cokhavi, A., Kirschenbaum, M., & Sharifi, T. (2006). Evaluating the consistency of immediate aesthetic perceptions of web pages. *International Journal of Human-Computer Studies, 64*(11), 1071–1083.

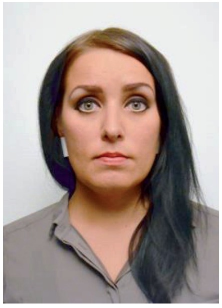
Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers, 13*, 127–145.

van Leeuwen, T., & Kress, G. (2006). *Reading images. The grammar of visual design* (2nd ed.). Taylor & Francis e-Library.

Veryzer, R. W., & Hutchinson, J. W. (1998). The influence of unity and prototypicality on aesthetic responses to new product designs. *Journal of Consumer Research, 24*(4), 374–385.

Zettl, H. (1999). *Sight, sound, motion: Applied media aesthetics.* Boston: Wadsworth Publishing Company.

About the Authors



Johanna Silvennoinen
Ms. Silvennoinen is a PhD Candidate of Cognitive Science at the University of Jyväskylä, Finland. She has conducted research in the field of visual aesthetics in human-technology interaction, especially regarding visual elements and emotions elicited by them. Her research interest also expands to cover multi-modal experiences in interacting with technological products.

Marlene Vogel
Ms. Vogel is a PhD Candidate at the Department of Psychology at the Technische Universität Berlin and working as a usability and user researcher at Dräger in Lübeck, Germany. She has conducted research in the field of user experience (UX) and its dynamics over the course of time.

Sari Kujala, PhD
Dr. Kujala is a Research Fellow in the Department of Computer Science and Engineering, Aalto University, Finland. Her background is in psychology and her research interests include user-centered design, user involvement, and user experience.

II

SURPRISE AS A DESIGN STRATEGY IN GOAL-ORIENTED MOBILE APPLICATIONS

by

Gross, Alice & Silvennoinen, Johanna. 2014

In *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics* (pp. 4716-4726).

III

APPRAISALS OF SALIENT VISUAL ELEMENTS IN WEB PAGE DESIGN

by

Silvennoinen, Johanna M. & Jokinen, Jussi. P. P. 2016.

Advances in Human-Computer Interaction, Article ID 3676704, 14 pages.

Hindawi Publishing Corporation
Advances in Human-Computer Interaction
Volume 2016, Article ID 3676704, 14 pages
http://dx.doi.org/10.1155/2016/3676704

Research Article

Appraisals of Salient Visual Elements in Web Page Design

Johanna M. Silvennoinen and Jussi P. P. Jokinen

Department of Computer Science and Information Systems, University of Jyvaskyla, Mattilanniemi 2, 40100 Jyväskylä, Finland

Correspondence should be addressed to Johanna M. Silvennoinen; johanna.silvennoinen@jyu.fi

Received 29 November 2015; Revised 9 March 2016; Accepted 16 March 2016

Academic Editor: Thomas Mandl

Visual elements in user interfaces elicit emotions in users and are, therefore, essential to users interacting with different software. Although there is research on the relationship between emotional experience and visual user interface design, the focus has been on the overall visual impression and not on visual elements. Additionally, often in a software development process, programming and general usability guidelines are considered as the most important parts of the process. Therefore, knowledge of programmers' appraisals of visual elements can be utilized to understand the web page designs we interact with. In this study, appraisal theory of emotion is utilized to elaborate the relationship of emotional experience and visual elements from programmers' perspective. Participants ($N = 50$) used 3E-templates to express their visual and emotional experiences of web page designs. Content analysis of textual data illustrates how emotional experiences are elicited by salient visual elements. Eight hierarchical visual element categories were found and connected to various emotions, such as frustration, boredom, and calmness, via relational emotion themes. The emotional emphasis was on centered, symmetrical, and balanced composition, which was experienced as pleasant and calming. The results benefit user-centered visual interface design and researchers of visual aesthetics in human-computer interaction.

1. Introduction

Visual design of user interfaces is significant to users interacting with different software. Through visual user interfaces, constructed of visual elements (i.e., color, size, and shape), interfaces communicate to the users and are expected to be both visually and emotionally appealing. However, visual user interface design is rather complex, because there is no universal formula of visual design to be applied in all user interface design contexts to elicit positive emotional experiences. Visual elements can be designed in countless different combinations and therefore, the same information content can be designed to appear in numerous visual forms which affect the users in different ways. For instance, different user interface genres, such as online banking web pages, are expected to visually represent the context in an appropriate way. If users' expectations and visual design solutions are not considered in the design process, interaction can lead to negative emotional outcomes, such as frustration. Thus, numerous perspectives are required to be considered when designing visual user interfaces. One approach is to empirically examine how visual elements are emotionally experienced and how this knowledge informs user interface design decisions. This information is especially important when considering programmers' appraisals of visual elements. This is because often in a software development process programming and general usability guidelines are considered as the most important parts of the process, while neglecting experiential aspects of the interaction conveyed with visual user interfaces.

Therefore, in addition to the traditional efforts in human-computer interaction, current and future user interfaces need to be developed in a novel way to match the potentials offered by the newest computing technologies and the users' requirements based on their visual and emotional experiences. From a user-centered perspective, the rapid development of user interface technologies demands clarification of how visual elements should be utilized in user interface design to promote positive user experience. The improvement of visual aesthetics in user interface design enhances understandability of the product, by improving visual organization, clarity, and conciseness of user interfaces [1], and more profound understanding of how visual elements are experienced contributes to enhanced visual usability of user interfaces [2, 3], that is, how people represent visual elements and how the visual aspects of objects relate to the functions afforded by them. Moreover, in the current era of visual user interfaces, usable designs need to highlight aesthetic expression as meaningful presence for users instead of just providing designs as functional tools [4].

However, the snowballing research of user interface design has, until now, largely left aside the study of how visual elements in user interface design elicit emotional experiences. Current research of experiencing visual user interface designs, in the research area of visual aesthetics in human-computer interaction, has mainly focused on the overall impression of visual user interfaces (e.g., [5–7]), as a means of enhancing user experience with aesthetic pleasantness (e.g., [8]). In addition, more detailed approaches have focused, for example, on typography [9] and on high-level attributes (e.g., [10]). These high-level attributes include, for example, unity and prototypicality [11], novelty [12], and typicality and novelty [13]. Therefore, research of visual aesthetics in human-computer interaction lacks knowledge of emotional responses in experiencing low-level attributes, that is, visual elements (e.g., [14]), such as color, size, and balance [15]. In this paper, appraisal theory of emotion [16–18] is utilized to elaborate the relationship of emotional user experience and visual elements. Therefore, this study adopts an interactionist approach to human-technology experience; that is, it does not merely focus on either user interface design properties or users' impressions and preferences of visual user interface designs, but analyses screen-based visual elements and their appraised dimensions together. Screen-design based approach focuses on detecting the visual properties of design components and their spatial organization in user interfaces [19], which affect user experience. How these identified visual elements are appraised is the key to understanding their role in human-computer interaction and in web page design.

According to Tractinsky [10], usability experts and designers have come to the conclusion that these two aspects of design, visual aesthetics and usability, could and should coexist in the same context of use. Before this shift in the first decade of the 21st century, visual aesthetics and usability were often seen as having a contradictory relation in that when one was emphasized, the other one was automatically omitted. The shift has emerged mostly because recent research corroborates a positive correlation between aesthetic and usability principles (e.g., [5, 6, 19–22]). Due to this shift, aesthetic qualities are currently emphasized in designing software for human-computer interaction. In addition, advancements in computer graphics have opened a variety of new design possibilities, which have increased the importance of aesthetic design of user interfaces providing emotional experiences. Yet, often in software development process, only the implementation of software (e.g., programming) and the traditional, general usability design [23] are considered as the most important parts [24]. In reality, users' experiential needs are not taken into account in the software development process [25]. The essential deficit in user interface design lies in the absence of visual user interface design specialists in the process. Therefore, in this study, appraisals of salient visual elements are addressed from the point of view of future programmers and engineers. Focusing on programmers' emotional experiences of visual elements in web page designs provides information on the visual elements that are considered essential and the way they are appraised. Understanding the appraisal process of the most salient visual elements among future programmers enriches the visual user interface design practice in software development and provides insights into visual design solutions applied in current user interface designs that we interact with.

The rest of the paper is organized as follows. First, the background concerning the visual elements and their capability in eliciting emotions in human-computer interaction is described with the appraisal theory of emotion. This is then concluded with presenting the research questions of the study. Second, the method is described including participant information, research procedure, stimuli, and data analysis. Third, the results are presented and discussed. Finally, the conclusions are presented with future research and limitations of the study.

2. Visual Elements and the Emotion Process

Establishing the connection between visual elements and the emotion response is one of the key elements in developing theory for describing visual elements in human-computer interaction. Visual elements in user interfaces are important factors in experiencing technological products due to their potential of eliciting attributed emotions and the ability to elicit actually felt emotions [26]. Additionally, visual elements are capable of evoking strong emotional responses in technology interaction and thus affect the overall experience [27]. While the psychological research on emotion has already posited the cognitive process, which connects an external event to emotional experience [16–18], this process has not yet received a satisfactorily discussion in user experience literature. However, research connecting the psychological theory of appraisal with emotional experience in human-technology interaction has started to produce promising examples concerning this [28–30].

Visual elements as the constructing units in user interfaces are the components through which the emotional process of experiencing visual user interfaces can be understood and approached in detail. By exploring users' emotional experiences of visual elements, an in-depth view on visual aesthetics in human-computer interaction can be approached. Emotional aspects of visual user interface design have been studied in relation to trust. For instance, beauty of simplicity [31], visual appeal [32], and color appeal [33] have been stated to affect feelings of trust in interacting with user interfaces. However, more profound and detailed knowledge is needed in order to understand how and which visual elements in user interfaces elicit emotions and in which contexts.

In this study, visual representations that draw on the theories of two-dimensional pictorial elements are utilized as theoretical vehicles to create novel insight into experiencing visual user interface design. The dispensation of visual theory is in that it provides knowledge of exact visual elements, such as size, value, hue, orientation, contrast, texture [34], shape, proportion, and position [1] and, for instance, form and expression [35], which are seen as visual elements inherent in contemporary user interfaces. Mullet and Sano [1] refer to visual language in designing visual user interfaces. Through visual language, based on visual elements, user interfaces communicate to the users. Visual language of user interface design is divided into visual design factors which are visual characteristics (shape, color, position, texture, size, orientation, etc.) in a specific set of design elements (point, line, volume, plane, etc.) and the factors by which they relate to each other, such as balance, structure, proportion, and rhythm. These elements facilitate exploring the salient visual elements that draw attention to website design, elicit emotions in users, and affect the interaction between users and user interfaces. Further, visual theory serves as a starting point in the study because aesthetic impressions conveyed by visual representations influence users' experiences of user interface qualities [6] that may promote positive feelings on user interfaces [36] due to the emotional nature of visual experience [37–39].

The cognitive process in which emotion episodes occur is called appraisal [16–18]. Appraisal is the evaluation of the personal significance of an event and its consequences and consists of multiple levels, such as motivational changes, physiological responses, and subjectively categorized emotions [18, 39]. There are various models of appraisal, which differ in the details of the emotion process, but most agree that the event is appraised at least from the following dimensions: implications to personal goals, pleasantness, causality, coping, and conformity [18, 28, 40]. Each is discussed here briefly, and their relation to visual user interface design is considered.

Events which satisfy one's personal goals are usually appraised as positive, while goal-incongruent events are appraised as negative [16]. The appraisal dimension of goal-relevance is understandably very salient in human-computer interaction research and design: usability problems, including visual usability problems, are usually taken to cause goal-incongruent events, which elicit negative emotions. Obstructions to efficient, goal-congruent use of systems result in frustration and anger, while successful mediation of the goal-oriented action results in feeling of competence [29, 30, 41]. However, pleasantness of an event is also appraised independently of the personal goals and current motivations, especially with the so-called aesthetic emotions, which can be contrasted with utilitarian emotions [39]. This notion is central in user experience research, where the focus is more on the noninstrumental side of interaction [42]. Positive experience of a user interface is not necessarily related to the immediate goals of the user.

The causality dimension of the appraisal process considers responsibility, that is, who caused the event and what was the motive behind these actions [18]. The agency can be attributed to oneself, such as when a user feels competent after being successful in demanding tasks [29, 41], or to other actors, for example, when evaluating visual user interface design choices made by designers. It is also possible to attribute the cause of the event to nonhuman agent. An example of this appraisal would be the aggression towards an inanimate object, such as a computer, when the goals of the actor are obstructed [43].

The coping dimension refers to the potential of the subject to manage the event or the emotion which results from the event. Coping is an individual's adaptation effort to events and as such is not associated only with negative events [44, 45]. Therefore, a response to a goal-incongruent computing event may result in either enthusiasm or anxiety, depending on how much the individual expects to be able to exert control over the event. There are two main coping strategies, problem-centered and emotion-centered. For example, in human-computer interaction, individual differences in how people are able to solve interaction problems and how well they are able to cope with their emotions play a significant role in the user experience process [29]. The conformity dimension of appraisal refers to the compatibility of the event in relation to self-concept and social norms and values [18]. Anger, for example, is the result of an event in which causality is attributed to someone who is appraised to act in a deliberate norm violation. In user interface design, violating the norms of established design practices may, therefore, cause negative emotions even if the norm-violating aspects do not cause goal-incongruent use events.

Of the all possible appraisal dimensions, perhaps the most frequently used scheme for describing emotion is the combination of valence and arousal [40]. Valence refers to the pleasantness of the experience and arousal to how much the emotion is associated with activation. For example, feeling calm is pleasant but not an active emotion, while feeling energetic is a pleasant and active emotion. Sadness is a negative and deactivating emotion, and anger is a negative and arousing emotion. While these two are not the only relevant dimensions of emotional experience, they are often the most salient and can be used for rich descriptions of emotion in human-computer interaction [41]. Regarding emotional experiences of pictorial representations, for instance, works of art can differ in their potential to cause arousal. Works of art which possess ability to evoke high arousal are most likely perceived as dramatic and dynamic, and works of art with low potential on eliciting arousal are generally perceived as static and harmonious [46].

This paper focuses on studying the most salient visual elements in user interfaces and their relation to emotions attributed and elicited by them from the perspective of future programmers, in order to provide usable insight for the evaluation and design of visual elements in user interfaces that promote user experience and thus to benefit user-centered visual user interface design. This study focuses on the following research questions: What are the most salient visual elements in web pages from programmers' point of view? What kind of emotions do the salient visual elements elicit? How are the salient visual elements evaluated in the appraisal process?

3. Method

3.1. Participants. Participants ($N = 50$) expressed their impressions and emotions regarding visual website designs with 3E-templates. Of the participants, 17.5% were female and 82.5% male. The average age of the participants was 25.4 years (SD = 5.4 and range 20–46). The participants were allowed to return the templates anonymously without information that could be used to identify them, because the data collection was organized as a part of a university course. Thus, the reported age and gender information is from 40 participants, while ten participants answered without identification information. However, the average age of the 40 participants did not differ much from the average age of the participants in the course: the average age of the participants in the course was 25.0 years (SD = 5.8 and range 19–50).

All the participants were university students, mainly from the Faculty of Information Technology. 67.5% of the participants who returned the templates with identification information were students of computer science, 27.5% were students of information systems, and 5% of the students were from other majors. From the students in the course, 66.7% had a major in computer science, 26% were students of information systems, and 7.3% were from other majors. The circumstances of the data collection were designed similarly for all the respondents. The stimuli of the study and the data collection template were presented to the participants at the same time with the same advice in an auditorium, and the participants were allotted the same amount of time for answering the template.

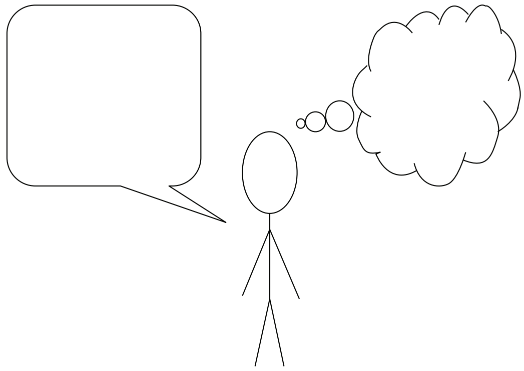


Figure 1: The 3E-tempalate.

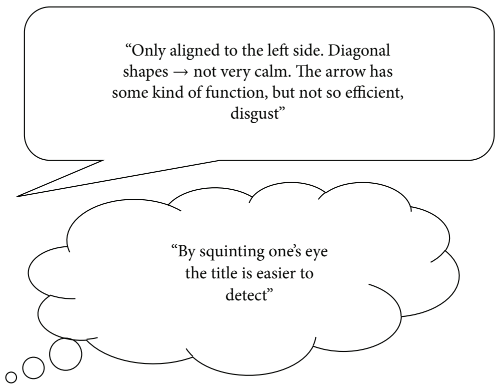


Figure 2: Examples of written expressions from one template.

3.2. Research Procedure. The data collection was conducted as a part of a University course about user-centered design. The data was collected from the lecture dealing with layout design. The lecture introduced the participants with relevant terms to describe the user interfaces. From the beginning of the lecture, the participants were familiarized with the design process in general, the evaluation methods of visual user interfaces, and visual elements, such as visual rhythm, dynamics, balance, tension, symmetry, contrast, Gestalt laws, and other various different design principles. People who are experienced in creating visual representations are more capable of analyzing them and more aware of their responses to visual phenomena [47]. Therefore, the introduction of the visual design terminology was conducted to provide the participants a starting point for utilizing verbal vocabulary to express their visual experiences. The numerous terms were equally emphasized and the participants were not forbidden to use other terms to express their impressions. If the data would have been collected with questionnaires, with predetermined concepts of visual elements and emotion terms, the data would have been a result of a conception of the researchers' understanding of emotions attributed to visual elements.

Therefore, the data was collected with the 3E- (expressing emotions and experiences) template [48, 49]. The 3E-template was selected as a data collection method to allow respondents to express their thoughts both verbally and nonverbally: by writing and drawing (Figure 1).

After the introductory part of the lecture, participants were introduced to the 3E-template and asked to write and draw their thoughts and impressions of two still pictures of web pages, with a focus on the compositional elements of the web pages. The participants were not aware during the introductory part of the lecture that they would need to report their impressions of user interface designs with visual design terminology. In the templates, participants did not describe their impressions only with the concepts presented in the lecture, and they did not mention some of the presented concepts at all.

The participants took approximately 20 minutes in answering the two templates. The research data is comprised of the written and drawn reflections and interpretations on the compositional aspects of the example web pages. A total of 100 templates were returned, as each participant evaluated two web pages. One template was returned without any written or drawn reflections and was therefore excluded from the analysis. The templates that comprise the data were mainly used by the participants to express their impressions of the UIs in written form. Examples of written expressions in the speech and think bubbles are presented in Figure 2.

3.3. Stimuli. The objects for the compositional reflection were two web pages (Figures 3 and 4) from the CSS Zen Garden web page gallery, web pages created with CSS-based design [50]. All the gallery web pages have the exact same content but altering visual appearances. The web pages were

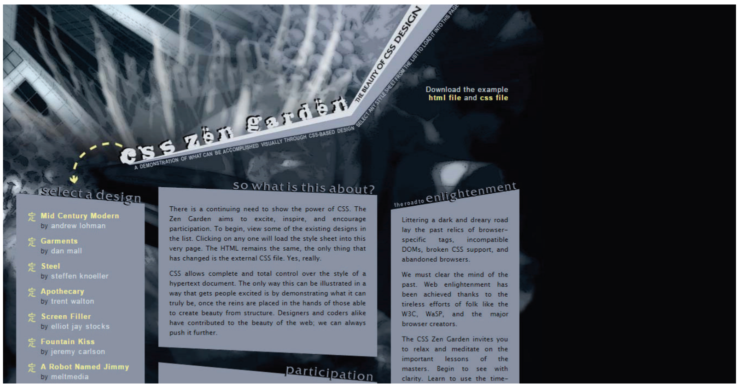


Figure 3: The first user interface used in data collection.

Figure 4: The second user interface used in data collection.

selected to serve as stimuli, because the altering visual designs with the same content enable reflecting on the visual elements of the designs without concentrating on the content. In addition, the CSS Zen Garden web pages were selected as the stimuli in order not to bias the respondents with product expectations [51], such as brand experience.

The CSS Zen Garden web pages were surveyed for two example layouts that would differ from each other, especially with regard to the amount of elements that divide the surface such as lines, shapes, and the overall use of space. The web pages were first divided into two categories and then compared step by step, finally resulting in two example web pages.

Emphasis on a choice of web pages according to their differentiating elements was made in order to provoke participants towards a comparative analysis between web page layouts. Bell [52] also emphasizes that evaluations with content analysis are often comparative. The web pages were, therefore, selected with a comparative setting, regarding the pages' differences in constructing visual elements. This was achieved in the study by using two different web pages with similar content but differing visual appearances. In addition, these two web pages were asked to be reflected in detail. Therefore, the two selected web pages were considered sufficient for the present study with a comparative setting, since all pictorial representations are constructed with visual elements. A broader sample of stimuli could be studied in future research. But first, it is essential to understand in detail which elements are considered important and what kind of emotions is attributed to them.

3.4. Data Analysis. When people experience pictorial representations, such as visual user interfaces, numerous visual elements are encountered [53]. People may experience visual elements as both explicit and simple but also as elements involving interpretation. Therefore, the research method should facilitate the combination of the analysis of qualitative and quantified issues. As Collier [54] points out, a studied phenomenon must first be examined without premature analyses of the data, maintaining a focus on preexistent structures and points of interest. First, a data-driven content analysis was conducted to detect and describe the user interface elements depicted by the informants after having looked at the selected user interfaces. Second, the elements found and defined were quantified in order to identify the visual elements that are considered most salient in visual user interface design, particularly in layout design from the programmers' perspective. The aim was to find the visual elements that have drawn the most attention and can be seen to have importance due their frequent emergence and significance of the content. The quantification of the explicitly written words representing specific objects is important, but it also relates to the qualitative procedures. Krippendorf [55] emphasizes the meaning of context in content analysis. Texts and images are always produced in some specific cultural context and they also refer to wider cultural context. This aspect was considered by first deploying the interpretative viewpoint as an independent phase before quantifying the found elements.

The methodological decisions for the study are influenced by the nature of the visual viewpoint: instead of directly analyzing visual user interfaces, the data is comprised of participants' descriptions of the two example web pages. Therefore, many methods, for example, semiotics and iconography [56], as well as social semiotic visual analysis [57], are not applicable because they assume that the data along with the object of analysis are visual images. Furthermore, even though the data collected by other methods (such as eye tracking) could enable the extraction of specific points of attention, it would be impossible to analyze which particular element draws attention, color, form or, for instance, a visual tension between the elements. The analysis of the visual elements was conducted with these two procedures, which supported the analysis from two different viewpoints. The emotions elicited by salient visual elements were analyzed with same procedure.

The data analysis proceeded as follows. First, the data was observed as a whole by reading the templates. The purpose was to first focus on the visual elements in a neutral context in order to gain an understanding of the visual elements that are seen as important in visual user interface design despite the emotions they might evoke. The second phase was to create categories of relations and then to critically combine several different categories of relations between elements into main categories. For instance, from the example illustrated in Figure 2, the first observation about left side alignment is related to the spatial organization as is the second notion of diagonal lines. Stability refers to symmetry and the role of the arrow is related to perceived functionality. The human figure in the templates was only used in a few templates to illustrate emotions by drawing facial expressions. Almost none of the drawings emphasized the written content or the facial emotions of the figure but brought to attention something without a clear connection to the written content. Due to these characteristics of data, the focus of the analysis was on the written texts describing the visual elements and emotions attached to them. After the researchers had acquainted themselves with the data, an interpretation framework was developed and used to assist in the analysis. The interpretation framework included the items, which directed the focus on a conceptual level during the data analysis, in interpreting and comparing interesting insights within the data. The interpretation framework consisted of compositional interpretation [58] and visual elements in user interface design [1].

Compositional interpretation refers to describing the appearance of images with a detailed terminology. This form of visual analysis requires contextual knowledge of pictorial representations and a particular way of looking at images ("the good eye"), which is not methodologically explicit but functions as visual connoisseurship and is a specific way of describing images. Compositional interpretation focuses on the image itself by trying to comprehend its significance mostly by focusing on its compositionality. Interpretation does not focus on "external factors" such as the kind of messages the image sends and whether it has some functional meaning. The terminology of compositional interpretation includes several components. The first component is the content, that is, what the image actually shows. The second component is color, which is more specifically defined with concepts of hue, saturation value, and the harmony of color combinations. The third component is spatial organization, which includes volume, lines, static and dynamic rhythm, geometrical perspective, logic of figuration (how the elements of a picture offer particular viewing position outside the photo), and focalisers (the visual organization of looks and gazes inside the picture and in relation to the viewer's gaze). The fourth is light: the type of light that is represented and its sources. The last component is expressive content, which describes the "feel" of the image combining the effect of the subject matter and visual form. Compositional interpretation approach is established in Art History and is usually used in studying paintings [58]. Visual user interfaces can be comprehended as paintings or, in a more general viewpoint, as any two-dimensional pictorial representation that is constructed with visual elements, such as lines and shapes. Compositional interpretation can, therefore, also be extended to analyzing visual user interfaces.

Mullet and Sano [1] present visual user interface design factors, which are shape, color, position, texture, size, orientation, point, line, volume, balance, symmetry, scale, contrast, structure, proportion, rhythm, and position. The emphasis on visual factors in user interface design is to provide insight into designing good visual usability and effective visual communication. They also point out that negative space (i.e., empty or white space between visual elements and objects, opposite to active space) and grouping are important components in visual user interface design. The interpretation framework combined the discussed visual elements and guided the detection of the concepts related to visual elements in the coding phase of the analysis. The elements were derived from the two approaches described above and created the content of the interpretation framework. The interpretation framework included, but was not restricted to, the following components: color (hue, saturation, value, and harmony of color combinations), spatial organization, geometrical perspective, volume, lines, points, size, texture, shape, static and dynamic rhythm, orientation, balance, symmetry, scale, structure, proportion, negative space, grouping, position, figuration logic, focalisers, contrast, and light. From a compositional interpretation, the expressive content component was excluded from the interpretation framework in the analysis of salient visual elements, because of its emphasis on subject matter evoking emotionality which was not in focus in the first analysis phase of this study. The interpretation framework functioned as a "theoretical lens" in the analysis. The analysis required accuracy and concentration in detecting tiny nuances in finding the relations between the different visual elements, which required close attention in detecting how many altering ways there are, for instance, to describe the use of space in user interfaces. The goal was to create a model that illustrates the hierarchical order of visual elements. The structure of the model is data-driven but the logic is validated using theoretical framework of visual language.

The analysis of the emotions elicited by visual elements followed a procedure similar to the analysis of the salient visual elements. First, all templates were regarded as a whole with the focus on finding the emotions that had been expressed constantly and drawn most attention in relation to the salient visual elements. The construction of the interpretation framework for emotions was based on the appraisal theory of emotion, in which the appraisal of the subjective significance of an event results in subjective emotional experience. Overall, the participants used emotion words or categories clearly less often than visual elements: in total, 26 emotion words or categories in relation to visual elements were observed. Here, the interest was especially in the relationship between the visual elements of a user interface and the subjective emotional experience, that is, the feelings which arise as a response to visual elements. The interpretation framework for analyzing the emotion responses was derived from the appraisal dimensions described above. For the observed emotions, a relational theme which refers to the narrative explanation of the emotion was constructed [17]. The narrative can be constructed with the appraisal dimensions. For example, frustration is an unpleasant (valence) and activating (arousal) emotion, but this is not enough to understand frustration. Frustration results when there is an obstruction preventing the subject from reaching her goals, and the subject still feels some power over the situation [18, 29]. Therefore, in order to understand an emotional response, such as when a user is frustrated at a computer program, a thematic explanation relating the goals of the user to the events of the use, as well as a reference to the coping possibilities of the user, is required [29].

A template was included into the emotion analysis if it contained a common emotion word that is included in lists of emotions, (e.g., [18]) or was an appraisal dimension, for example, *pleasant* [40]. The following words relating to emotions were expressed: frustration, anxiety, calmness, apprehension, boredom, disgust, energetic, pleasant, disturbing, threatening, and confusing. From these, five thematic groups were created: frustration (including "frustration" and "disturbing" as the latter is part of the appraisal profile for frustration), calmness (which included "calmness," "apprehension," and "energetic" because they belong to the same appraisal dimension), "confusion," "boredom," and "pleasantness." Other words were discarded from the analysis, because they were mentioned in connection with the visual elements, which were not analyzed here due to their low frequency. Each thematic group was given a relational theme and was then connected to the visual elements in order to establish the explanatory logic between the user interface design and the emotional response. Examples of expressed emotions in relation to visual elements are presented in Figure 5.

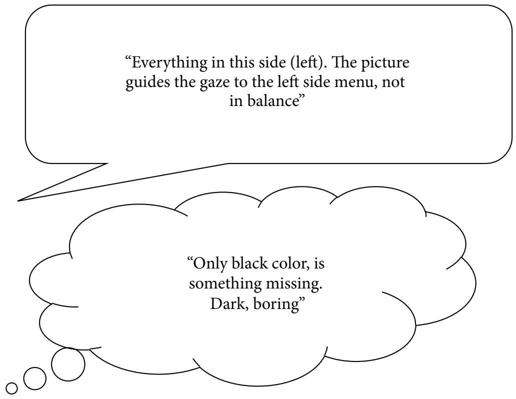


Figure 5: Examples of written emotional expressions from one template.

4. Results

All the 100 templates were analyzed by writing down all the described elements in the templates and by counting the frequency of their occurrence. The number of times each visual element was mentioned in a template and the number of participants who at least once mentioned the visual element are presented in Table 1. The table illustrates the second level classification of visual elements. Different utterances were used to describe, for instance, guiding the gaze, such as *"the picture directs the gaze to the left side menu," "the gaze moves from up right to left down along with the title, and in addition, the gaze is guided with a separate arrow,"* and "*. . .directs the gaze outside of the user interface."* All these different notions were coded in the first phase of the analysis and were classified to the group of guiding the gaze in the second phase of the analysis. Visual elements that had been mentioned only three times or less were excluded from the analysis due to the low frequency.

The interpretation framework guided the detection of written reflections of the described elements. For instance, the interpretation framework did not include usability, which emerged from the data as a connective factor between relations of different elements, especially in terms of visual usability of the user interfaces. In many templates, think bubbles were used to express additional reflections, mostly about the supposed functionality of the user interface. The results of the study are data-driven; the most salient visual

Table 1: Notions of visual elements by participants.

Visual elements	Notions/participants
Guiding the gaze	21/17
Composition in general	15
Grouping	8/7
Grouping with similar contents & functions	10
Grouping with colors	1
Clarity	23/22
Symmetry	7
Asymmetry	8
Balance	14
Imbalance	20/19
Negative space	21/20
Active space	1
Impression of overall use of space	9
Alignment	13
Centering	12
Diagonal lines	15
Horizontal lines	9/8
Vertical lines	7
Lines in general	2
Understandability	5
Legibility	8
Font size & area	12
Font color	8
Background picture	9
Background color	9
Color contrast	22
Font contrast	3
Contrast in general	6
Layers	3
Colors in general	18
UI as a whole	8/7
Square	2
Golden ratio	1
Horizontal composition	2
Straight corners	1
Square	3
Visual tension	3
Color composition	1
Impression of 3-dimensionality	2

elements emerged from the data through content analysis, in which the theoretical framework was used to assist in detecting the utterances describing different elements. Therefore, the background theory of the visual language [1] and compositional interpretation [58] aided the analysis as a theoretical lens in detecting the visual elements as well as organizing the categories to hierarchical relations. For instance, the classification of the two main categories of visual elements, spatial organization and color and contrast, was conducted by reflecting on the background theory.

The salient visual elements are presented in Figure 6. The hierarchical structure of the results illustrates the different levels of visual elements from the lowest-level elements (e.g., diagonal lines) through the visual elements of organizing the lowest-level elements (e.g., alignment and asymmetry) to the main design dimensions (e.g., spatial organization), resulting as positioning of the viewer in appraising the most salient visual elements. Positioning of the viewer gathers all the results under one definition and functions as the main process outcome in experiencing visual user interfaces. Positioning of the viewer (including figuration logic and focalisers) was seen as a visual strategy that guides the viewer's gaze in the user interface, which functions through visual elements guiding the gaze. Overall, positioning of the viewer refers to the user interface's ability to communicate the whole content in a visual manner that is quick and easy to grasp.

Positioning the viewer was discussed in relation to visual elements contributing to spatial organization and color and contrast. Spatial organization and color and contrast were seen to apply both to communicability and to visual usability and interaction. Spatial organization and color and contrast are the main dimensions in visual user interface design language (e.g., [1]), which can be further described in detail with lower-level visual elements contributing to these higher level design dimensions. Spatial organization was emphasized by focusing on grouping and negative space. Imbalance, balance, asymmetry, and symmetry were seen as the primary visual elements affecting grouping and the use of negative space. In addition, grouping and the use of negative space through imbalance, balance, symmetry, and asymmetry were seen as contributing to the spatial organization of visual user interface elements in creating an impression of the user interface as a consistent totality, in which visual elements contribute to the impression of the user interface as a whole. Grouping of similar contents and functions were seen as substantive factors creating clarity. Spatial organization through balance and symmetry was seen as important regarding the overall use of space. Grouping and negative space were further discussed in terms of aligning or centering the content. In the data, spatial organization was reflected in detail and visual elements referring to this category were often mentioned.

Grouping with similar content and functions and negative space were seen in relation to the composition of the user interface in general and impression of overall use of space. Observations of balance and imbalance were seen in relation to symmetry and asymmetry. Alignment to the left or right and centering the content were seen to affect impressions of balance, imbalance, symmetry, and asymmetry. An important relation was often found between diagonal, horizontal, and vertical lines in creating impression of overall use of space and guiding the gaze. Diagonal, horizontal, and vertical lines were especially emphasized and seen as visual elements that guide the gaze forward. A strong emphasis was placed on describing how the visual elements function and how they support visual usability and interaction, especially the ways by which visual elements direct attention in the user interface towards the most important areas.

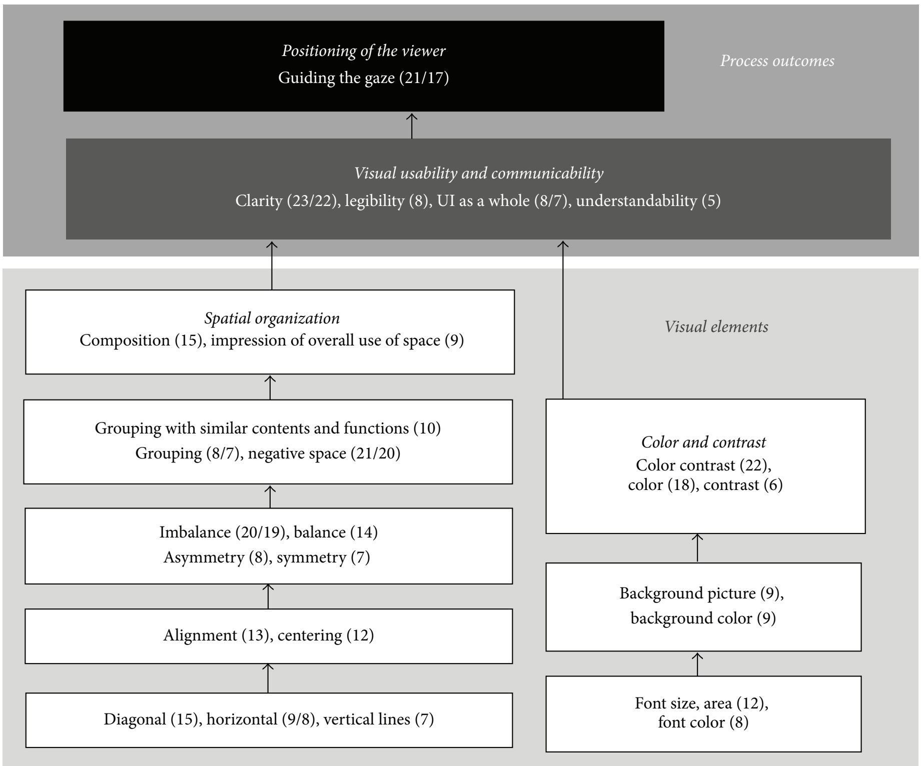


Figure 6: Salient visual elements contributing to positioning of the viewer.

Even though the participants were instructed to only use the template for reflecting the impressions of the compositional elements of the layout, attention was paid towards contrasting colors and their role in visual usability. In relation to contrast, most of the remarks were about color contrasts, especially between the colors of the texts and background colors, which were, moreover, attached to legibility. Size was only discussed in the context of the font size.

The relations of the five thematic groups to the salient visual elements are presented in Figure 7. The figure is based on the first phase of the analysis concerning salient visual elements. The structure of the figure has not been affected by the second part of the analysis due to the order of the analysis phases. The salient visual elements in all categories elicited and were attributed with emotion responses. However, emotions with negative valence were expressed more frequently than positive emotions, and emotions with higher activation, such as frustration, were more frequently expressed than emotions with lower activation, such as boredom.

Frustration was reflected regarding legibility, spatial organization, imbalance, asymmetry, diagonal lines, color and contrast, background picture, and font. Emotional utterances relating to calmness or unease were frequently expressed in reference to spatial organization, grouping, negative space, horizontal and diagonal lines, color, and user interface as a whole. Confusion was reported in relation to how colors in the user interface design were experienced. Boredom was connected to spatial organization, color, and background color. Pleasantness was reflected regarding the user interface as a whole, spatial organization, and centering the content.

5. Discussion

Positioning of the viewer functions as the main appraisal process outcome, in which the interactionist view combining the salient visual elements' ability to guide the interaction and the appraisals of these events is experienced. Positioning of the viewer functions through evaluations and experiences of communicability and visual usability. Visual usability includes the ways of how different visual elements guide the interaction and usability. User interfaces that fluently communicate the content in an understandable visual form are appreciated. Clarity, legibility, impression of the user interface as a whole, and understandability were considered as the most important factors in contributing to communicability and visual usability of the user interface. Thus, in designing visual

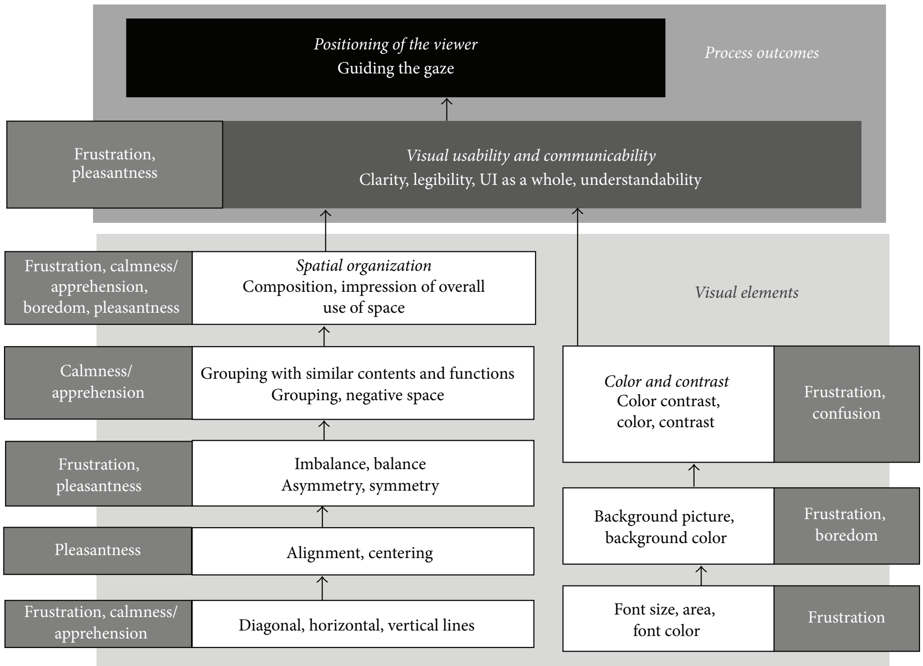


Figure 7: Salient visual elements eliciting emotions.

user interfaces, the power of the visual elements to guide users' attention needs to be taken into account. Besides visual usability, the communicative ability of the visual elements [1], in relation to the content suitability of the visual user interface design, affects positioning of the viewer. The overall visual impression of the user interface's appearance should be suitable for the context for which it is designed.

Alignment and centering the content were considered as constitutive factors influencing grouping, balance, and symmetry. Diagonal, horizontal, and vertical lines were highly emphasized as visual elements that strongly affect the positioning of the viewer and lead the interaction as the main low-level elements. In addition to spatial organization, color and contrast were seen as influential design dimensions. Functional and communicative impressions of the visual elements were implicated in terms of understandability and legibility of the content. Contrast between figures, fonts, and background picture and color was conveyed through different font sizes and color combinations. These ways of creating contrast between visual elements in user interfaces were often expressed, especially the contrast between background color and the size and the font colors. Designing contrast between these elements contributes to efficient visual usability, which promotes fluent user experience in interacting with visual user interfaces.

The visual elements are appraised with attributed potential for creating different emotions and eliciting emotional states. Frustration was expressed in connection with legibility, spatial organization, imbalance, asymmetry, diagonal lines, color and contrast, background picture, and font. Frustration is the response to a goal-incongruent event, that is, an event that frustrates, disturbs, or obstructs the subject [41, 43]. In particular, if the disturbing event is appraised as goal-incongruent and unfair and resulting from a deliberate norm violation, the feeling of frustration is strong and may result in anger or even aggression [18, 43]. When interacting with computers, the user may often appraise that an obstruction to her goals is the result of bad user interface design, which results in frustration response with an implicit causal attribution: *"It's disturbing that [the UI] is not fitted to the browser. This creates an impression of imbalance."* Likewise, poor readability of font obstructs grasping the user interface and frustrates the user, as expressed by one participant: *"The composition is frustrating, grey fonts disappear to the background."*

Emotion words relating to calmness or unease were common in the data and referred to spatial organization, grouping, negative space, horizontal/diagonal lines, color, and user interface as a whole. Being calm (or, on the opposite, apprehended) is dependent on the appraisal of the amount of control and power that the subject has over the event [18, 40]. The appraisal process evaluates certain visual elements in relation to the coping dimension, which results in feeling of control or loss of control. If the user of a user interface feels that she is not in control of the situation, she becomes uneasy, and if the situation is incongruent to the goals of the user and she would need to exert control to remedy this, the user may even feel anxious or threatened [41]. Participants emphasized calm, centered, and balanced composition: *"Only aligned to the left side. Diagonal shapes → not very calm."* Diagonal lines were considered apprehensive and horizontal calming: *"Diagonal lines cause apprehension." and "Text boxes [. . .] are horizontal, reading them is calming."*

It is noteworthy that not all visual elements that are related to coping and feeling of control are necessarily related to the actual control functions of the system; that is, they do not signify affordances, but they are nevertheless associated with coping. This means that the appraisal process integrates low-level visual elements into a complete experience of the user interface, and some connections between the emotional experience and the details of the interface may not be explicitly clear. Further exploration of this issue could, for example, reveal that shapes and lines are associated with emotional coping, whereas the problem-focused coping would be connected to different visual elements.

Confusion was connected to colors in the participants' responses. Confusion is related to not being in control of the situation and is, therefore, closely related to both frustration and apprehension [41]. Avoiding confusion is critical in the context of human-computer interaction, where the user interface does not necessary reveal the inner logic of the software. Often, the user has norm-based expectations concerning the composition and functionality of the user interface, and deviations from this norm are confusing. However, conventional design is not necessarily good design. The explication of the connection between visual elements and emotional responses, such as confusion, should help the formulation of research-based design principles.

Boredom was expressed in relation to spatial organization, color, and background color. Boredom is an unpleasant feeling, which is associated with low effort and decreased attentional activity [40]. It is distinguished from other emotions in that a person feeling bored ignores what is happening; this often happens in a situation where the situation itself is uninteresting and there is nothing to occupy and stimulate the subject. If the composition of the user interface, for example, is not judged as interesting, the user may feel bored: *"The page is just a layer of things. Boring."*

Pleasantness was related to the user interface as a whole, spatial organization, and centering the content. As discussed above, pleasantness-related appraisals have two dimensions: satisfaction of goals and intrinsic pleasantness [18]. Pleasantness associated with the former dimension reflects the visual usability of the user interface, relating to goal-congruence in possible use cases, and the latter dimension is associated with subjective aesthetic preferences, relating to the intrinsic pleasantness appraisal dimension: *"[. . .] More pleasant to watch, and probably also to use. Everything is nicely centered."*

In general, negative emotions were used more frequently when evaluating the user interfaces. This observation is explainable by hedonic asymmetry, which means that adaptation to pleasant emotions happens more quickly than adaptation to unpleasant ones [16]. The participants were, therefore, hastier to report negative than positive emotions. Although negative emotions were more salient in the participants' appraisals, there were also salient visual elements that elicited positive emotions. These were restricted to the spatial organization elements. Color and contrast did not provoke positive emotions. In addition to imbalance with valence, emotions with higher activation in the arousal dimension, such as frustration, were more frequently expressed than emotions with lower activation, such as boredom. It seems that the threshold for expressing emotions with higher activation is lower than expressing emotions with lower activation. However, unlike with valance, the arousal dimension was not observed to be distributed unevenly between different visual elements.

While all of the salient visual element categories were associated with some emotion words or dimensions, spatial organization clearly evoked emotions most frequently and the expressed emotions were also the most diverse. This is understandable as spatial organization is an umbrella term for lower-level elements constructing the user interface composition, and the visual elements belonging to spatial organization were the most frequently observed content in the analysis of salient visual elements.

Grouping with similar contents and functions was reflected to be calming and contributing to grasping the user interface as a whole and to understandability. Also, appropriate amount of negative space was experienced as calming. Both observations are in line with the narrative of calmness, especially, as understood with the help of the coping dimension of appraisal: the listed visual elements helped the participants maintain overall control over the user interfaces, which was reflected as calmness. Imbalance and asymmetry were experienced as frustrating. On the contrary, balance and symmetry were connected to pleasantness. In addition, centering the content was considered pleasant. As the lowest-level visual elements, diagonal lines were emphasized in general and in relation to emotions evoked by them. Diagonal lines were seen as important as constructing elements of the overall impression of the layout. However, the emotions attributed to diagonal lines were controversial. They were experienced as frustrating and apprehensive but also as contributing to elegant impression with dynamic tension.

Color and contrast were discussed frequently, but they were seldom connected to emotions. When color and contrast were discussed in relation to emotions, the connotation was negative (frustration, confusion, and boredom). This is explicable with color's essential role among visual elements. Color is considered as a primary visual element evoking aesthetic preferences [59] and strongly influencing legibility and content understandability.

6. Conclusion

The focus of the study was on future programmers and engineers appraisals of salient visual elements. The results of this study indicate which visual elements are considered as the most salient ones in web page design that contribute to communicability and visual usability and what kind of emotions they elicit or were attributed with. The appraisal process integrates the salient visual elements into an emotional experience. This results in positioning of the viewer, in which the user's experience of the user interface can be explained in terms of how the subjective relevance of the user interface is appraised. This connects salient visual elements with the pleasantness or unpleasantness of the experience, as well as to how well the user is able to cope during the interaction.

Spatial organization and color and contrast, with the lower-level elements which they are based on, such as diagonal lines and colors contrasts, are essential to users in web page designs that promote fluent interaction and visual usability. Characteristics of lines have an important role in emphasizing visual usability and interaction with user interfaces. Spatial organization through grouping with similar content and functions, appropriate use of negative space, and balance and symmetry contribute to the overall impression of the user interface as a clear and understandable totality. Contrast between figures, texts, and backgrounds enhances visual usability and interaction with the user interface. In addition, through contrast, user interfaces can be designed to communicate the content in an effortless manner by grasping the content with one glance. Communicability of the user interface also refers to the content's suitability in relation to the context. Without contrast between visual elements, user interfaces could not communicate the content to the users interacting with them. This notion emphasizes the essence of visual elements contributing to fluent human-computer interaction. User interfaces' ability to position the viewer through visual elements and emotions elicited by them is essential in interacting with different user interfaces.

The emotional responses to user interfaces were analyzed with relational themes created from appraisal dimensions [18, 40]. Connecting these themes to the salient visual elements created a coherent narrative of the process in which emotional experience occurs as a response to visual elements in web page design. Using this framework, future studies should focus on detailing the preliminary findings made here. For example, are all typical emotions encountered in human-computer interaction observed in a connection to all of the salient visual elements so that only the theme of the emotion is different between them? These findings are critical in design, which sets certain experiences as design goals and operationalizes concepts from the explanations which connect designable elements with the user's emotions.

Overall, the emotional emphasis was on centered, symmetrical, and balanced composition, which was experienced as pleasant and calming. Diagonal lines received controversial emotional expressions, as frustrating salient visual element, but also an element which creates a subtle dynamic tension. According to the results, it can be stated that if the goal of the design, from a programmers' perspective, is a pleasurable and controllable experience, the overall composition needs to provide an impression of static balance and symmetry by grouping, centering content, and appropriate use of negative space. This finding emphasizes how attaining feeling of control, another important design goal, is attained by focusing on these elements [28]. Designing with contrasting colors and diagonal lines needs to be considered in relation to the content the user interface is designed to communicate and to whom.

The salient visual elements experienced as pleasant and calming are appraisals of programming students. Visual elements in web page design might gain differing appraisals in different user groups. For example, coping with more various and dynamic combinations of visual elements can be influenced by the level of design expertise and visual literacy abilities [47]. Therefore, future research focuses on resolving differences between different user groups with varying design backgrounds. For more culturally varied results, future research should also be conducted with participants of different backgrounds: information on the cultural variation in the importance of different visual elements would be significant in today's user interface design.

Proceeding from specific contexts towards the discussion of a more general understanding of the studied phenomena is another suggested line for future research. For example, color's powerful position among other visual elements raises questions of its status in emotional interaction. Participants were asked to express their impressions regarding composition and layout design of the web pages, yet color design was frequently discussed in the templates. Therefore, future research should focus on studying the impact of color in user interface design and the emotions elicited by them in order to provide more profound insights into visual elements eliciting emotions in user interface design. Here, the color elements were mostly associated with frustration, which is connected to the goals of the user [41], but the relation of such appraisal dimensions as intrinsic pleasantness should also be investigated. In addition, the emotions triggered by visual elements could be approached in studying symbolist and abstract characteristics attached to the elements and how these meaning making processes influence emotional responses.

In addition, the validity of 3E-templates should be tested by triangulating data with various methods, such as emotion questionnaires, and with various stimuli. It is possible, for example, that with open-ended questions, not all emotions actually elicited by the user interfaces were recorded. Standardized emotion questionnaire would force the participants to rate their emotional experiences, and these results could then be correlated with similar ratings of the visual elements. Moreover, visual design of user interfaces is not universally understood and appreciated similarly in different cultures. Different meanings attached to, for instance, dimensions of visual space are highly influenced by the writing and reading direction [60]. Therefore, due to the context of this study, the results can be applied to Western culture. In addition, this study was conducted in relation to visual web site design and, therefore, might not be applicable to other visual user interface design contexts, such as mobile user interface design. Visual elements as the construction elements of visual mobile user interfaces might be appraised differently, for instance, due to the size and shape of the screen.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

The research has been supported by COMAS (Doctoral School of the Faculty of Information Technology, University of Jyväskylä).

References

[1] K. Mullet and D. Sano, *Designing Visual Interfaces: Communication Oriented Techniques*, Prentice Hall, Upper Saddle River, NJ, USA, 1995.

[2] T. Schlatter and D. Levinson, *Visual Usability, Principles and Practices for Designing Digital Applications*, Morgan Kaufmann, Boston, Mass, USA, 2013.

[3] J. Silvennoinen, M. Vogel, and S. Kujala, "Experiencing visual usability and aesthetics in two mobile application contexts," *Journal of Usability Studies*, vol. 10, no. 1, pp. 46–62, 2014.

[4] L. Hallnäs and J. Redström, "From use to presence: on the expressions and aesthetics of everyday computational things," *ACM Transactions on Computer-Human Interaction*, vol. 9, no. 2, pp. 106–124, 2002.

[5] M. Hassenzahl and A. Monk, "The inference of perceived usability from beauty," *Human-Computer Interaction*, vol. 25, no. 3, pp. 235–260, 2010.

[6] N. Tractinsky, A. S. Katz, and D. Ikar, "What is beautiful is usable," *Interacting with Computers*, vol. 13, no. 2, pp. 127–145, 2000.

[7] P. van Schaik and J. Ling, "Modelling user experience with web sites: usability, hedonic value, beauty and goodness," *Interacting with Computers*, vol. 20, no. 3, pp. 419–432, 2008.

[8] M. Moshagen and M. T. Thielsch, "Facets of visual aesthetics," *International Journal of Human-Computer Studies*, vol. 68, no. 10, pp. 689–709, 2010.

[9] D. Tsonos and G. Kouroupetroglou, "Modeling reader's emotional state response on document's typographic elements," *Advances in Human-Computer Interaction*, vol. 2011, Article ID 206983, 18 pages, 2011.

[10] N. Tractinsky, "Visual aesthetics: in human-computer interaction and interaction design," in *Encyclopedia of Human-Computer Interaction*, M. Soegaard and D. Rikke Friis, Eds., The Interaction Design Foundation, Aarhus, Denmark, 2012, http://www.interaction-design.org/encyclopedia/visual_aesthetics.html.

[11] R. W. Veryzer Jr. and J. W. Hutchinson, "The influence of unity and prototypicality on aesthetic responses to new product designs," *Journal of Consumer Research*, vol. 24, no. 4, pp. 374–394, 1998.

[12] W.-K. Hung and L.-L. Chen, "Effects of novelty and its dimensions on aesthetic preference in product design," *International Journal of Design*, vol. 6, no. 2, pp. 81–90, 2012.

[13] P. Hekkert, D. Snelders, and P. C. W. Van Wieringen, "'Most advanced, yet acceptable': typicality and novelty as joint predictors of aesthetic preference in industrial design," *British Journal of Psychology*, vol. 94, no. 1, pp. 111–124, 2003.

[14] I. Reppa and S. McDougall, "When the going gets tough the beautiful get going: aesthetic appeal facilitates task performance," *Psychonomic Bulletin & Review*, vol. 22, no. 5, pp. 1243–1254, 2015.

[15] J. Silvennoinen, "Towards essential visual variables in user interface design," in *Proceedings of the 7th International Conference on Advances in Human-Computer Interactions*, pp. 229–234, Barcelona, Spain, March 2014.

[16] N. H. Frijda, "The laws of emotion," *American Psychologist*, vol. 43, no. 5, pp. 349–358, 1988.

[17] R. S. Lazarus, "Relational meaning and discrete emotions," in *Appraisal Processes in Emotion*, K. L. Scherer, A. Schorr, and T. Johnstone, Eds., pp. 37–67, Oxford University Press, New York, NY, USA, 2001.

[18] K. R. Scherer, "The dynamic architecture of emotion: evidence for the component process model," *Cognition & Emotion*, vol. 23, no. 7, pp. 1307–1351, 2009.

[19] N. Tractinsky, A. Cokhavi, M. Kirschenbaum, and T. Sharfi, "Evaluating the consistency of immediate aesthetic perceptions of web pages," *International Journal of Human Computer Studies*, vol. 64, no. 11, pp. 1071–1083, 2006.

[20] K.-C. Hamborg, J. Hülsmann, and K. Kaspar, "The interplay between usability and aesthetics: more evidence for the 'what is usable is beautiful' notion," *Advances in Human-Computer Interaction*, vol. 2014, Article ID 946239, 13 pages, 2014.

[21] A. Sonderegger, G. Zbinden, A. Uebelbacher, and J. Sauer, "The influence of product aesthetics and usability over the course of time: a longitudinal field experiment," *Ergonomics*, vol. 55, no. 7, pp. 713–730, 2012.

[22] M. Thüring and S. Mahlke, "Usability, aesthetics and emotions in human-technology interaction," *International Journal of Psychology*, vol. 42, no. 4, pp. 253–264, 2007.

[23] J. Nielsen, *Usability Engineering*, Morgan Kaufman, San Francisco, Calif, USA, 1993.

[24] J. Iivari, H. Isomäki, and S. Pekkola, "The user-the great unknown of systems development: reasons, forms, challenges, experiences and intellectual contributions of user involvement," *Information Systems Journal*, vol. 20, no. 2, pp. 109–117, 2010.

[25] B. Bygstad, G. Ghinea, and E. Brevik, "Software development methods and usability: perspectives from a survey in the software industry in Norway," *Interacting with Computers*, vol. 20, no. 3, pp. 375–385, 2008.

[26] D. Cyr, "Emotion and website design," in *Encyclopedia of Human-Computer Interaction*, M. Soegaard and D. Rikke Friis, Eds., The Interaction-Design Foundation, Aarhus, Denmark, 2013, http://www.interaction-design.org/encyclopedia/emotion_and_website_design.html.

[27] P. Desmet, K. Overbeeke, and S. Tax, "Designing products with added emotional value: development and appllcation of an approach for research through design," *The Design Journal*, vol. 4, no. 1, pp. 32–47, 2001.

[28] E. Demir, P. M. A. Desmet, and P. Hekkert, "Appraisal patterns of emotions in human-product interaction," *International Journal of Design*, vol. 3, no. 2, pp. 41–51, 2009.

[29] J. P. P. Jokinen, "Emotional user experience: traits, events, and states," *International Journal of Human Computer Studies*, vol. 76, pp. 67–77, 2015.

[30] P. Saariluoma and J. P. P. Jokinen, "Appraisal and mental contents in human-technology interaction," *International Journal of Technology and Human Interaction*, vol. 11, no. 2, pp. 1–32, 2015.

[31] K. Karvonen, "The beauty of simplicity," in *Proceedings of the ACM Conference on Universal Usability (CUU '00)*, pp. 85–90, Washington, DC, USA, November 2000.

[32] G. Lindgaard, C. Dudek, D. Sen, L. Sumegi, and P. Noonan, "An exploration of relations between visual appeal, trustworthiness and perceived usability of homepages," *ACM Transactions on Computer-Human Interaction*, vol. 18, no. 1, article 1, 30 pages, 2011.

[33] D. Cyr, M. Head, and H. Larios, "Colour appeal in website design within and across cultures: a multi-method evaluation," *International Journal of Human Computer Studies*, vol. 68, no. 1-2, pp. 1–21, 2010.

[34] M. Wiberg and E. Robles, "Computational compositions: aesthetics, materials, and interaction design," *International Journal of Design*, vol. 4, no. 2, pp. 65–76, 2010.

[35] L. Hallnäs, "On the foundations of interaction design aesthetics: revisiting the notions of form and expression," *International Journal of Design*, vol. 5, no. 1, pp. 73–84, 2011.

[36] D. Norman, *Emotional Design*, Basic Books, New York, NY, USA, 2004.

[37] J. Dewey, *Art as Experience*, Capricorn Books, New York, NY, USA, 1958.

[38] P. Hekkert, "Design aesthetics: principles of pleasure in design," *Psychology Science*, vol. 48, no. 2, pp. 157–172, 2006.

[39] K. R. Scherer, "What are emotions? And how can they be measured?" *Social Science Information*, vol. 44, no. 4, pp. 695–729, 2005.

[40] C. A. Smith and P. C. Ellsworth, "Patterns of cognitive appraisal in emotion," *Journal of Personality and Social Psychology*, vol. 48, no. 4, pp. 813–838, 1985.

[41] P. Saariluomaand and J. P. P. Jokinen, "Emotional dimensions of user experience: a user psychological analysis," *International Journal of Human-Computer Interaction*, vol. 30, no. 4, pp. 303–320, 2014.

[42] M. Hassenzahl, "User experience (UX): towards an experiential perspective on product quality," in *Proceedings of the 20th Conference on l'Interaction Homme-Machine (IHM '08)*, pp. 11–15, ACM, Metz, France, September 2008.

[43] L. Berkowitz, "Frustration-aggression hypothesis: examination and reformulation," *Psychological Bulletin*, vol. 106, no. 1, pp. 59–73, 1989.

[44] S. Folkman and R. S. Lazarus, "If it changes it must be a process: study of emotion and coping during three stages of a college examination," *Journal of Personality and Social Psychology*, vol. 48, no. 1, pp. 150–170, 1985.

[45] R. S. Lazarus and B. N. Lazarus, *Passion and Reason*, Oxford University Press, New York, NY, USA, 1994.

[46] D. E. Berlyne, *Aesthetics and Psychobiology*, Appleton-Century-Crofts, New York, NY, USA, 1971.

[47] D. Curtiss, *Introduction to Visual Literacy: A Guide to the Visual Arts and Communication*, Prentice Hall, Englewood Cliffs, NJ, USA, 1987.

[48] M. Tähti and L. Arhippainen, "A proposal of collecting emotions and experiences," in *Interactive Experiences in HCI*, vol. 2, pp. 195–198, 2004.

[49] M. Tähti and M. Niemelä, "3E—expressing emotions and experiences," in *Proceedings of the WP9 Workshop on Innovative Approaches for Evaluating Affective Systems. HUMAINE (Human-Machine Interaction Network on Emotion)*, Stockholm, Sweden, February 2006.

[50] CSS Zen Garden Gallery, http://www.csszengarden.com.

[51] E. Raita and A. Oulasvirta, "Too good to be bad: favorable product expectations boost subjective usability ratings," *Interacting with Computers*, vol. 23, no. 4, pp. 363–371, 2011.

[52] P. Bell, "Content analysis of visual images," in *Handbook of Visual Analysis*, T. van Leeuwen and C. Jewitt, Eds., Sage, London, UK, 4th edition, 2004.

[53] H. Zettl, *Sight, Sound, Motion: Applied Media Aesthetics*, Wadsworth Publishing Company, Boston, Mass, USA, 1999.

[54] M. Collier, "Approaches to analysis in visual anthropology," in *Handbook of Visual Analysis*, T. van Leeuwen and C. Jewitt, Eds., Sage, London, UK, 4th edition, 2004.

[55] K. Krippendorf, *Content Analysis: An Introduction to Its Methodologies*, Sage, London, UK, 1980.

[56] T. van Leeuwen, "Semiotics and iconography," in *Handbook of Visual Analysis*, T. van Leeuwen and C. Jewitt, Eds., Sage, London, UK, 4th edition, 2004.

[57] C. Jewitt and R. Oyama, "Visual meaning: a social semiotic approach," in *Handbook of Visual Analysis*, T. van Leeuwen and C. Jewitt, Eds., Sage, London, UK, 4th edition, 2004.

[58] G. Rose, *Visual Methodologies: An Introduction to the Interpretation of Visual Materials*, Sage, London, UK, 2005.

[59] R. Poulin, *The Language of Graphic Design: An Illustrated Handbook of Understanding Fundamental Design Principles*, Rockport Publishers, Beverly, Mass, USA, 2011.

[60] T. van Leeuwen and G. Kress, *Reading Images. The Grammar of Visual Design*, Taylor & Francis, 2nd edition, 2006.

IV

QUICK AFFECTIVE JUDGMENTS: VALIDATION OF A METHOD FOR PRIMED PRODUCT COMPARISONS

by

Jokinen, Jussi. P. P., Silvennoinen, Johanna, Perälä, Piia & Saariluoma, Pertti.
2015

In *Proceedings of the 2015 Conference on Human Factors in Computing Systems – CHI '15* (pp. 2221-2230). New York: ACM.

Quick Affective Judgments: Validation of a Method for Primed Product Comparisons

Jussi P. P. Jokinen
University of Jyväskylä
Box 35, Fi-40014 University of Jyväskylä, Finland
jussi.p.p.jokinen@jyu.fi

Johanna Silvennoinen
University of Jyväskylä
Box 35, Fi-40014 University of Jyväskylä, Finland
johanna.silvennoinen@jyu.fi

Piia Perälä
University of Jyväskylä
Box 35, Fi-40014 University of Jyväskylä, Finland
piia.m.h.perala@student.jyu.fi

Pertti Saariluoma
University of Jyväskylä
Box 35, Fi-40014 University of Jyväskylä, Finland
pertti.saariluoma@jyu.fi

ABSTRACT
A method for primed product comparisons was developed, based on the methodological considerations of emotional appraisal process and affective mental contents. The method was implemented as a computer tool, which was utilised in two experiments (N = 18 for both). Ten adjectives served as primes, and five drinking glass pictures as stimuli. Participants' task was to choose a preference between two glasses, given the priming adjective. The results validate the method by providing test-retest reliability measures and showing convergence with questionnaires. Further, different evaluation times between the primes and the stimuli reveal the existence of different mental processes associated with various aspects of product experience, as predicted by appraisal theory. The results have various implications for experience research and development in HCI, as they demonstrate how the method can be used for product evaluation and the analysis of the mental processes, which users use to evaluate the products.

Author Keywords
product experience; affective mental contents; primed product comparisons

ACM Classification Keywords
H.5.2. User Interfaces: Evaluation/ methodology, User-centered design.

CHI 2015, April 18–23, 2015, Seoul, Republic of Korea.
Copyright 2015 © ACM 978-1-4503-3145-6/15/04...$15.00.
http://dx.doi.org/10.1145/2702123.2702422

INTRODUCTION

Experience in human-computer interaction
Human-computer interaction (HCI) researchers and designers are increasingly interested in what people experience when they interact with technology, as demonstrated by such currently popular concepts as *user experience* and *product experience* [10, 11, 14, 15, 16]. The number of different methods for studying experience in HCI has increased, which has improved our understanding of what experience is and how it occurs when we interact with technology [2, 48]. The work is, however, far from complete, and for example, the operationalisation of emotional and aesthetic experience is lacking [2]. Further psychologically valid theorisation, conceptualisation, and operationalisation of experience in HCI is still therefore necessary for justifying experience research and experience-driven design solutions [34, 36].

Psychologically, *experience* can be understood as the conscious part of a mental representation [8, 34]. The essential nature of a *mental representation* is that it is always about something [22]. In HCI, a mental representation can be about the technology [35], the interaction itself [17], or the states of the user [15]. A mental representation has a neural substrate, but it is often more meaningful to investigate its information contents [33, 34]. *Mental content* is the meaningful and subjective information part of the representation: it makes sense to the subject, and is therefore closer to how experience is understood in HCI [22, 34]. Because our thoughts influence our actions, explanations of the behaviour of the user need to refer to the contents of the mental representations of the user [33].

Although experience is subjective and private, it can be explicated by verbalisation and therefore elicited with interviews or protocol analysis [20], or with more standardised ways, such as with questionnaires [2]. However, while the use of self-reports are an important part of HCI research, the self-report itself allows only a limited access to the largely unconscious experience process. It is, of course, possible to analyse latent experience structures via statistical analysis of questionnaire data [34, 35], but clever experimentation should also be used to explore the unconscious cognitive processes behind experience in HCI. While the subjective self-report is necessary for understanding the meaning of the experience, more objective measures of this experience process are required to postulate and test general mechanisms of experience.

Experience has many dimensions, but one of the most important is emotion [2, 34]. There are different psychological theories of emotion, such as basic emotions [19], core affect [3], and appraisal theory [39]; here the interest is in the appraisal theory, because of its ability to elaborate between the emotion process and emotional experience. *Appraisal* is a cognitive analysis of an event, which establishes the personal significance of the event [23, 25, 38, 39]. This analysis proceeds as a process, which involves multiple component levels [39], different sources [41], distinct dimensions [40], and complex interactions between these elements [39, 41].

While all five components of appraisal (cognitive, neurophysiological, motivational, motor expression, and subjective feeling) are relevant in HCI research [44], here the focus is on the cognitive and the subjective feeling components. The *cognitive component* integrates information about the appraised event from different sources, and proceeds mostly non-consciously. *Subjective feeling* is the mentally represented, consciously experienced part of the emotion process, analysable as the affective contents of mental representation [33, 39]. *Affective mental content* refers therefore to the information, which users have about their feelings in their conscious mental representations. In the method developed below, the connection between conscious product experience and the non-conscious cognitive processing is explored.

The information sources for the appraisal process are perceptual stimuli, associative processing, and reasoning [41]. *Perceptual stimuli* are directly detected and quickly processed events, such as pain sensations, and do not involve mentally complex processes. *Associative processing* is fast and automatic, but involves memory to associate meanings with events. *Reasoning* is slow and consciously controlled, and constructs linguistically encoded meanings. This threefold ranking of appraisal sources is similar to Norman's [28] three-level *visceral-behavioural-reflective* framework of product experience, where the physical dimensions of the products are appraised on the visceral level, while the appraisals using more culturally interpreted criteria happen on reflective level.

Because the three sources of appraisal have different computational demands [41], it is possible to study experimentally how these levels are involved in product experience. The processing time from a stimulus event to conscious experience should be dependent on how linguistically and culturally complex elements the evaluation involves. Further, as the memory-based associative processing depends on spreading activation and priming [41], experiments utilising priming as an intervention should be able to posit and test causal hypotheses concerning the formation of product experience.

In previous experimentations in HCI, users have been shown to be capable of reliably judging the appeal of stimulus even after exposures as short as 50 milliseconds (ms) [26]. The subjective ratings of visual appeal are highly consistent between exposures of 500 ms and 10 seconds [45]. It seems that this phenomenon extends to various forms of evaluation, not only liking or disliking the object under evaluation [29], and suggests that a mental representation with various possible affective contents results quickly after the stimulus onset, hinting at fast non-conscious processes. However, these studies have not discussed the computational demands between different product evaluations, as implied by the three sources of appraisal.

Appraisal theory has been used to articulate theories of user or product experience [e.g., 16, 44], but the possibilities of this psychologically well-established and richly modelled theory have not yet been fully realised in HCI research. For example, the implications of the relationship between the cognitive information processing and the subjective feeling components of appraisal have not been investigated. Grounding the research of experience in HCI on appraisal theory would help to clarify the various conceptualisations and models in user and product experience research. At best, this could lead to testable causal models concerning the formation of experience in HCI.

Primed product comparisons

Perception influences subjective experience via conscious and unconscious processes [27]. This distinction can be demonstrated with a *priming effect*. Primes can be presented above the threshold of conscious awareness (*supraliminal priming*), or below it (*subliminal priming*; but note that this 'threshold' is not static). Both levels produce observable changes in the mental process [18]. In addition to the theoretical plausibility (explicated above), priming has empirically been shown to influence assessments of various dimensions of HCI, such as perceived aesthetics, quality, and usability [8, 31]. It is therefore a promising experimental technique for investigating the conscious and unconscious parts of product experience. However, the framework for using priming in user and product experience research is still in development (for progress on the framework, see e.g., [8, 50]).

The method for *primed product comparisons* stems from the notion that people are able to make conscious aesthetic preferences between products. The user is presented a prime, which is used to make a judgment between two similar products. The use of a prime as the criterion for comparison allows investigating the relationship between conscious and unconscious product experience, as the prime can be presented either supra- or subliminally. In this study, the focus is on creating and validating the method, and primes over the conscious threshold are used; further studies will focus on subliminal priming. If the method produces valid evaluations of products, the results should correlate with other methods of product evaluation; this serves as the basis for the first hypothesis of the study.

H1. There is a strong positive correlation in the evaluation of stimuli between primed product comparison and questionnaire responses.

H1 serves to validate the method, but does not argue why questionnaires should be replaced with primed product comparisons. In primed product comparisons, the participants are asked to make their judgment as fast as possible: this allows the study of processing times associated with different aesthetic judgments. This kind of information is useful in HCI, as it allows researchers and designers to better understand how different product properties are mentally processed. The notion that the three sources of appraisal involve different processing times should be visible in longer judgment times with such appraisals, which have more linguistically and cultural complex associations. For example, visceral judgments such as 'This object is heavy', should be processed faster than evaluations of beauty or modernity of an object. We therefore propose that the method of primed product comparisons should produce differences between the primes, depending on how computationally demanding the subsequent evaluation task is. Further, while the evaluation time is affected by the prime, it should also be affected by the product pair.

H2. In primed product comparisons, mean reaction times are different between the primes.

H3. In primed product comparisons, mean reaction times are different between the products.

In addition, the effects of the second and the third hypotheses are also expected to interact, because for certain pairs, certain primed evaluations should be easier to process than for others. For example, the weight of two objects of clearly different size should be easier to appraise than of two very similar objects.

H4. In primed product comparisons, mean reaction times of a same prime are different depending on the product pair.

These hypotheses are tested in a laboratory environment with software developed for primed product comparisons. The use of computer software for assessing product or user experience is not a new idea, and many experience metrics have been computerised. Tools for assessing user experience or usability in interactive environments, such as web sites, are examples of this (e.g., UserTesting [47], Usabilityhub [21]). However, the methods for acquiring and analysing data used by these tools are not always based on rigorous scientific theories and operationalisation. Further, often such tools provide data via user feedback (e.g., communicative feedback, success rate of tasks or questionnaires), and the results focus on improvements of specific websites. Therefore, their use in studying the cognitive experience process is limited and new tools for this purpose are needed.

There are also computerised evaluation tools, which are developed based on scientific theory and operationalisation. Generally, these tools fall into two categories: tools that utilise self-report experience metrics for product and service evaluation, and tools that collect objective, such as psychophysiological data. Some tools serve as web-based research environments, and include data collection, data analysis, and result reporting (e.g., LEMtool [13], PrEmo [30], optimalSort [42], or AttrakDiff [1, 10]). Other tools have implemented the traditional 'pen and paper' -method in software environment (e.g., UEQ [46]).

One prospect of software-aided user research is that it makes collecting data and producing results faster and easier than the more traditional methods. Such tools are hence often emphasised when the focus is in fast results, and not necessarily in scientific analysis (e.g., in e-commerce environments with tools such as Google Analytics [24]). However, when considering software tools in the context of basic scientific research, it is vital to be aware of their methodological assumptions and evaluate the circumstances in which these tools are suitable for providing answers to the research problems. Here, the methodological assumptions have been made clear.

METHOD

Equipment & Procedure

The equipment for primed product comparisons consisted of a computer, a computer screen, and a reaction time (RT) switch with two buttons. A computer application (*tool* henceforth), was programmed for presenting the primes and the stimuli. Given a number of product pictures (*stimuli*) and words (*primes*), the tool iterated through all possible combinations of pairs of stimuli and primes. Primes and the stimulus pairs were presented on a computer screen.

In the two experiments reported here, one task consisted of one prime (one of ten adjectives) and one stimulus pair (two of five product pictures). A prime was first presented on the screen for two seconds, which is well enough for conscious recognition, making the prime supraliminal [27]. Then the prime was replaced with a stimulus pair, side to side in a randomised arrangement. The task of the participant was to press the RT button on the side of the stimulus, which more corresponded to the prime. For example, if the prime was *festive*, the task was to choose which one of the pair of stimulus pictures is more festive. This choice is called here *preferential match* or just *preference*, which is used instead of plain 'match' to emphasise the subjective nature of appraisal process.

Two experiments were conducted with small differences, and are reported here together. In the first experiment, after the priming adjective had been displayed for two seconds, the pair of stimuli was presented for three seconds, after which the screen was cleared and the prime presented again. The participant had to indicate preference by pressing the RT switch as quickly as possible (the participants were asked to keep their index fingers at the buttons at all times). In the second experiment, the pair of stimuli was not cleared, and the participant was asked to indicate preference as soon as possible after having been presented the stimulus pair. In both experiments, after the preference, a message 'OK' was shown for two seconds, after which a new task was presented starting with the prime. The order of the tasks was randomised at the start of each trial. The participants were given two rest periods, the first after completing one third, and the second after completing two thirds of the tasks. The rest duration was up to the participant, but the rests were short, usually less than 15 seconds.

After conducting the tasks, the participants were shown each stimulus picture, one at a time in a randomised order, and asked to appraise the stimuli with semantic differential (SD) questionnaires. The questionnaire consisted of ten adjective pairs so that one adjective of each pair corresponded to an adjective used as a prime in the first part of the experiment. The scale of the questionnaire was from one to nine, one indicating close resemblance of the left-hand adjective, and nine indicating close resemblance to the right-hand adjective. Therefore, the participants rated each stimuli first using the primed product comparisons method, and then with a traditional SD questionnaire. This procedure allowed for testing H1.

Participants & Stimuli

For both experiments, N = 18 participants were recruited using a mailing list for those interested in participating in user psychological experiments. For the first experiment, the mean age of the participants was 21.8 years (SD = 2.6, age range 19–28). Fourteen participants were men, and four women. For the second, the mean age was 24.3 years (SD = 3.0, age range 20–31). Seven participants were men, and eleven women. There were no common subjects between the experiments.

The priming adjectives for the experiments were chosen from a study of drinking glass user experience [35]. From the 31 candidates, ten adjective pairs were chosen to represent various important drinking glass characteristics and to involve different sources of appraisal (H2), while keeping the amount of primes limited. The adjectives were also named important by professional glass designers. From each pair, one adjective was used as a prime, resulting in ten priming adjectives. The adjective pairs were following (boldface indicates the chosen prime): **festive** – mundane, light – **heavy**, modern – **traditional**, durable – **fragile**, **practical** – impractical, fleeting – **timeless**, **angular** – curvy, **general-purpose** – specific-purpose, **decorated** – undecorated, and **grabbable** – ungrabbable. Both adjectives were present in the SD questionnaire.

In both experiments, five pictures of drinking glasses were used as stimuli. The glasses were 'Essence Plus', 'Essence', 'Tapio', 'Ultima Thule', and 'Senta' (displayed below in the results section). Drinking glasses were chosen, because they are familiar, everyday products. To influence processing times associated with similarity (H3), some of the glasses were similar to each other, and some very different from each other, for instance regarding the shape of the product. The pictures were scaled so that on the screen, their size was close to their real-life size. The number of all possible pairwise comparisons of the five glasses was ten.

Data analysis

The primed product comparison data of one participant consisted of 100 preferential matches: ten stimulus pairs multiplied by ten priming adjectives. To prepare the data for analysis, comparative *preference percentages* for each glass were calculated. Ranging from zero to one, the preference percentage compares the stimulus against any other stimulus on a given prime. For example, in the first experiment, 15 participants out of 18 preferred 'Essence' to 'Essence Plus' on *timeless*. Hence, the preference percentage of 'Essence' to 'Essence Plus' on *timeless* was $15 / 18 \approx 0.83$ (83% preferred 'Essence'), and the preference percentage of 'Essence Plus' to 'Essence' on *timeless* was $3 / 18 = 1 - 15/18 \approx 0.17$ (17% preferred 'Essence Plus').

The preference percentage provides a standardised quantitative way for describing the overall comparative stimulus preferences, and its scale (0–1) does not depend on the number of participants. By averaging all preference percentages of a stimulus, a *preference score* (PS) can be calculated. For 'Essence Plus' the PS of *timeless* in the first experiment was 0.61, meaning that, on average, 'Essence Plus' was preferred about 61% of time when compared to other glasses on *timeless*. The closer the PS is to 1.00, the more there was preference for the glass on a given adjective. Conversely, a PS of 0.00 would equate to the glass being never chosen on a given adjective. Table 1 presents example PSs.

To test H1 (a strong positive correlation in the tool and questionnaire responses), the PS and the mean SD questionnaire score were correlated for each glass on all adjectives. First, Pearson correlation coefficients were calculated to indicate the amount of agreement between the product evaluations made using the tool and using the questionnaire. Next, the stimuli were ranked within the primes on their PS and mean SD values, and these ranks correlated. Coefficients close to 1.00 indicate strong agreement, and close to 0.00 little agreement between the tool and the SD questionnaire. Coefficients over .50 were expected for the correlation to be strong [7]. Further, test-retest reliability of the method was assessed by correlating the PSs between the experiments. As in testing H1, both Pearson correlation and correlation of ranks within a prime were calculated. High correlations (over .50) indicate that the stimuli were evaluated similarly in the two experiments, which means that the tool provides repeatable results.

In the second experiment, in addition to preference data, RTs from the stimulus onset to the preference were recorded. In order to test H2 (different mean RTs between the primes), H3 (different mean RTs between the pairs), and H4 (different mean RTs for a given prime between the stimulus pairings), a multilevel model predicting RT was constructed [12]. Main effects in the model were the prime (H1) and the stimulus pair (H2), and a two-way interaction effect between these two was added as a third term (H4). The procedure corresponds to testing the main effects of the prime and the stimulus pair using one-way analyses of variance (ANOVA), and testing the interaction with a two-way ANOVA. However, a multilevel model was used instead of repeated measures ANOVA, because it better handles violations of sphericity [12], often associated with RT data, and works better with testing interaction effects within nested data. In all tests reported here, the level of statistical significance was α = .05 (Sidak adjusted in multiple comparisons). All tests were two-tailed.

While the focus of the study is in the affective process of product experience, the method of primed product comparisons provides also means for product evaluation. In order to demonstrate this, qualitative conclusions about the stimuli are presented at the end of the results. High (> 0.7) and low (< 0.3) PSs (averaged between the two experiments) were highlighted to characterise the stimuli. These product descriptions are not associated with the hypotheses of the study, but they demonstrate how the method can be used in product experience evaluation.

	Timeless		Durable	
	Exp1	**Exp2**	**Exp1**	**Exp2**
Essence Plus	.61 (2)	.61 (2)	.10 (5)	.14 (5)
Essence	.40 (3)	.58 (3)	.44 (3)	.43 (3)
Senta	.82 (1)	.72 (1)	.28 (4)	.32 (4)
Tapio	.40 (3)	.39 (4)	.83 (2)	.86 (1)
Ultima Thule	.26 (5)	.19 (5)	.85 (1)	.75 (2)

Table 1. Example PSs of the drinking glasses on *timeless* and *durable*. The glass rank is in parenthesis.

RESULTS

The participants were able to conduct the tasks without problems. On average, completing all 100 tasks in the first experiment (excluding the rest periods) took 13.3 minutes. The participants of the second experiment completed the tasks, on average, in 11.3 minutes (excluding the rest periods). The second experiment was faster on average, because the participants were asked to indicate their preference as quickly as possible, while the participants in the first task waited for three seconds before this.

Example PSs and rankings of the five drinking glasses on *timeless* and *durable* are presented in Table 1. Space limitation permits printing all PSs, but these values were only of instrumental interest, not the end result of the study. 'Senta' is clearly a timeless glass, while 'Ultima Thule' was considered not timeless. The PS correlation between the two experiments was r = .92 (p < .001, df = 48), and the correlation of PS ranks between the two experiments was ρ = .83 (p < .001, df = 48). The results show high agreement between the participants in the two experiments, indicating test-retest reliability for the method of primed product comparisons.

Concerning H1, the Pearson correlation between the PSs and mean SD responses was, for the first experiment, r = .82 (p < .001, df = 48), and for the second experiment, r = .80 (p < .001, df = 48). A scatter-plot, illustrating the strong correlation, is shown in Figure 1. The correlations of the ranks were ρ = .90 (p < .001, df = 48) and ρ = .74 (p < .001, df = 48). All correlations were high, indicating that the participants made coherent evaluations between the tool and the SD questionnaire, supporting H1.

Regarding H2, the RT differences between the primes are illustrated in Figure 2 (left), which shows the mean RT

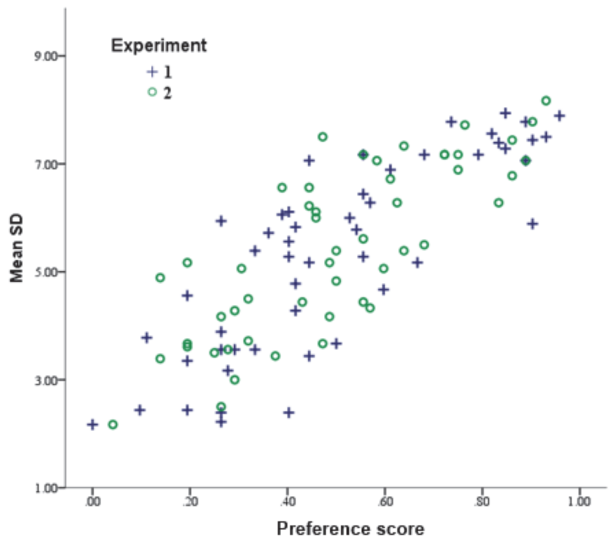
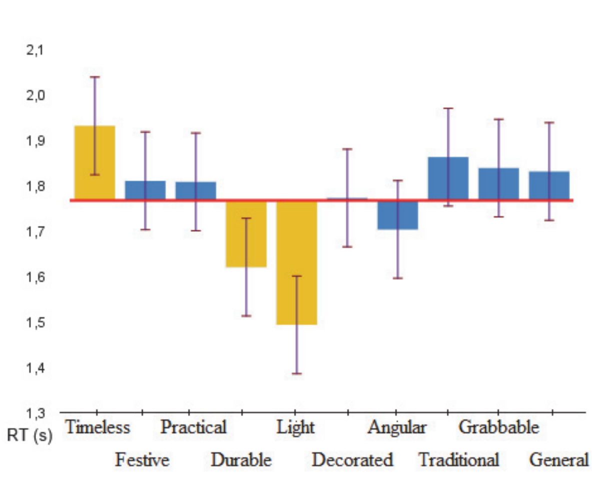


Figure 1. A scatter-plot of PS by mean semantic differential score. Each point indicates evaluation of one of the five glasses on one of the ten adjectives.



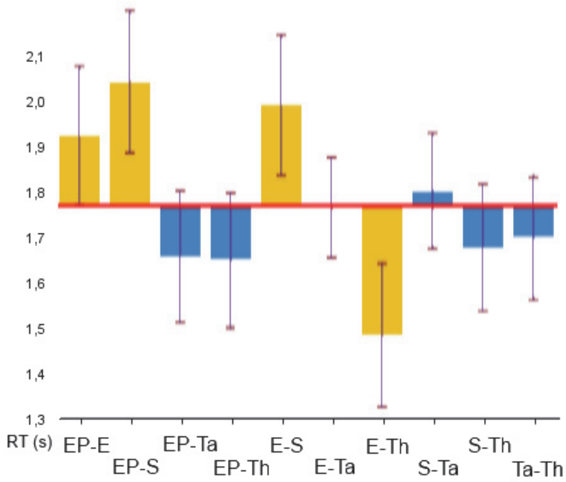


Figure 2. Left: RT deviation from the grand mean by priming adjective. Right: RT deviation from the grand mean by stimulus pair. *Note*. N = 18. The lines indicate the 95% confidence intervals (Sidak adjustment). Bars shaded gold (lighter colour) differ statistically significantly from the grand mean RT. EP = Essence Plus. E = Essence. S = Senta. Ta = Tapio. Th = Thule.

deviation from the grand mean RT between the adjectives of the study. The grand RT mean of the study was 1.76 seconds. The difference in RTs between the adjective primes was statistically significant, $F(9, 1700) = 5.0$, $p < .001$. Preferences on *timeless*, for example, took longer on average than with other adjectives, and judgments on *durable* and *light* were the fastest to make. The same effect was observed for the stimulus pairs (H3; Figure 2, right): certain pairs took, on average, longer than others to compare, $F(9, 1700) = 8.5$, $p < .001$. Whereas comparisons of 'Essence P' and 'Senta' took the longest, comparisons between 'Essence' and 'Thule' were fastest.

The interaction effect between the prime and the stimulus pair (H4) was also statistically significant, $F(81, 1700) = 1.8$, $p < .001$, indicating difference in mean RTs of the same prime between stimulus pairs. For example, judging *durability* between 'Essence' and 'Essence Plus' took longer than between 'Essence' and 'Thule', but judgments on *timeless* took as long with both pairs. The overall results of the multilevel model support all three hypotheses H2–H4, and provide evidence that there are differences in the appraisal process times depending on the nature of the resulting affective mental content.

Finally, the PSs were used to highlight the qualitative characteristics of the stimuli. These highlights are presented in Figure 3, in which each glass is given a qualitative description based on high and low PSs (mean of the two experiments). Adjectives with PSs less than .30 are presented as their opposite adjective from the SD questionnaire, and adjectives with PSs more than .70 as the adjective itself. The results show, for example, that from the five glasses used as stimuli, 'Senta' is considered a timeless, traditional type of glass, while 'Tapio' is a practical product for everyday purposes.

DISCUSSION

The large correlations between the preference scores (PSs) and the semantic differential (SD) questionnaire scores support H1. The correlations were high in both experiments ($r_1 = .82$, $r_2 = .80$). Although the participants of the first experiment had a mandatory three second contemplation period before preferential match, the participants of the second experiment, making the preference as quickly as possible (1.76 s., on average), were able to validly use the tool for evaluating the stimuli. Further, high correlations between the PSs of the two experiments ($r = .92$) give test-retest reliability for the method, and indicate that with the primes and the stimuli used, 18 participants was enough to attain consistency and generality in the results.

The observed convergence between the two sources of data (the tool and the questionnaire) indicates that the method of primed product comparisons was able to elicit similar affective mental contents as the traditional pen and paper SD questionnaire. This is expectable, as the appraisal mechanism for the both types of product evaluations are similar. The participants were asked to consider given stimuli with given criteria. As the results of both sources of data were similar, it seems reasonable to assume that the affective contents of the participants' mental representations during the tasks were coherent, and that the participants were able to report them reliably.

One of the main benefits of primed product comparisons compared to SD questionnaire is in the control that the method gives to the experimenter, and the subsequent possibilities at data collection. The differences in RTs between the primes (H2) and between the stimulus pairs (H3) support this conclusion. Certain primes allowed for faster judgments, indicating smaller information processing

Essence Plus

- Festive
- Impractical[a]
- Fragile[a]
- Light
- Smooth[a]
- Specific-purpose[a]

Essence

- Light
- Undecorated[a]
- Angular

Senta

- Timeless
- Fragile[a]
- Undecorated[a]
- Smooth[a]
- Traditional

Tapio

- Mundane[a]
- Practical
- Durable
- Heavy[a]
- Modern[a]
- General-purpose

Ultima Thule

- Fleeting[a]
- Durable
- Decorated

Figure 3. Descriptions of the stimuli based on the evaluations made during the two experiments. Adjectives with PSs over .70 or under .30 for each glass are displayed. [a]Primes with small PSs are listed using the opposite adjective. The images are not comparable in size. Images are reprinted with permission from www.iittala.com.

time and therefore different appraisal sources. The same is true for the stimulus pairs: pairs similar to each other took longer, on average, to compare, than dissimilar pairs.

The interaction effect between prime and stimulus pair (H4) further supports the analysis of product experience as an appraisal process. Some stimulus pairs were easier to compare on a given adjective, which means that the time it takes to process the stimuli and arrive at a preferential match, while being primed with certain adjective, is dependent on the interplay of the stimuli and the evaluation criteria. The important notion here is that it is not possible to explain these results without reference to both the information processing requirements and the contents associated with the primed product comparisons. The appraisal process is mostly non-conscious, but the subjective meaning of the prime and the stimulus influence this non-conscious process [33, 39].

While studies on quick exposure times suggest that very short (50 ms) exposures to stimuli are enough to arrive at reliable judgments [26, 45], the model of human visual system [43] and the notion of the three sources of appraisal with different computational demands [41] encourage longer exposure times at least with more detailed or complex evaluations. The observed differences in RTs in our experiment suggest that very short exposure times do not sufficiently take into account the different processing times associated with different affective contents [cf. 26, 45]. Taking into account the confidence intervals of the results, it seems that primed product comparisons require approximately from 1.3 to 2.2 seconds. Very short exposures are perhaps enough for processing low spatial frequencies, in which the overall outline of the stimulus is encoded [43]. This low-spatial frequency information is then used in guiding the analysis of the stimulus in detail in high spatial frequencies. High spatial frequencies and complex affective associations require more processing time, which translates into more detailed evaluation.

The largest RT difference within the adjective primes was between *timeless* (largest average RT) and *light* (smallest average RT). This is in line with the discussion, which lead to H2–H4. Different processing times between the primes can be considered both from the perspective of three sources of appraisal and the Norman's visceral-behavioural-reflective framework [28, 41]. Judgments concerning the basic physical characteristics of an artefact (e.g., *light* or *durable*) require less reasoning and associative processing than the more linguistically and culturally complex judgments (e.g., *timeless* or *traditional*) [41]. Further studies are therefore encouraged to individuate the processing of primes according to their source or level, and to connect this to what the primes actually mean and how they make sense with the given stimuli.

Further, both the notion of appraisal as subjective, relational evaluation [23], and Norman's [28] suggestion that subjective interpretations have computational impact on the reflective, but not on the visceral level, encourage research of individual differences in product experience using the method of primed product comparisons. Assuming this hypothesis, past experiences with the products, for example, should have an impact on the results of primed product comparisons (preferences and RTs), but only with primes, which require information at the associative and reasoning levels. Brand experience, for example, has been shown to influence customer satisfaction and loyalty [6], and therefore individual differences in RTs and preferences, based on previous brand experience, should be observable.

The method of primed product comparisons rests on a large number of repeated measures of short exposures. Studies utilising repeated exposures of the same stimuli have been criticised for not taking into account the *mere exposure effect*, which refers to the increased likelihood of positive evaluation as the same stimulus is presented repeatedly [5, 26, 49]. However, in the experiments reported here, the mere exposure effect was countered by having the participants always make their preference based on a pair of two stimuli. Therefore, although the participants were increasingly familiar with the stimuli as the experiment proceeded, no single stimulus was given special treatment and the effects of familiarity countered each other. In addition, no systematic decrease – or increase – in the RTs was observed during the experiment.

The stimuli for the experiments reported here consisted of drinking glasses, and the visual variable in the stimulus material was the shape of the products. The role of shape in appraisal and subsequent conscious affective mental contents was visible in the qualitative results given in Figure 3. These results, while did not relate to the hypotheses of the study, give support to the method of primed product comparisons in product evaluation context, as product shapes and forms have been considered essential in determining product success [e.g., 4, 35].

Drinking glasses are not ordinary stimuli in HCI studies, but there is no reason not to generalise the method of primed product comparisons for other product domains, such as computer interfaces, web sites, and mobile phones, all of which can be represented as pictures and hence as stimuli. This will of course require choosing appropriate primes, and the method can also be used to analyse how different primes work with different product domains. As suggested in the introduction, current interest in experience in HCI necessitates methodologically solid instruments for studying the affective process of people, who interact with technology.

Information on affective mental contents of products provide valuable support for design [33], and it is suggested here that due to its ease and speed of use, the method of primed product comparisons will serve as an important design tool especially in the early prototyping and iterative evaluation in HCI. Compared to traditional pen and paper methods, the tool allows the analysis of the thinking process that occurs when these products are evaluated, in addition to the evaluation of the products themselves.

Of course, affective and pleasurable product design also includes other product properties than shape. Therefore, future steps in developing the tool presented here should include more visual variables, such as colour. In addition, the stability and the content of the affective responses after short exposures also depend heavily on the context [37]. Experimenting with the nature of primes, such as using concept pictures or textual narratives, instead of adjectives, can be used to explore how different affective mental contents are elicited. This would serve purposes of both basic research and experience design. Further experimenting with subliminal primes and masking is also warranted, especially for the purposes of studying the cognitive process of appraisal behind experience in HCI.

As compared with other software used for user and product experience evaluation [e.g., 1, 13, 30], the tool for primed product comparisons presented here provides more versatile uses for basic and applied contexts. The combination of priming and stimulus pairing offers ways to investigate the experience process in detail, and the tool provides a relatively quick method for analysing products. In product evaluation, both early and final stage evaluations are possible, conducted according to desired evaluation criteria. Further, the theoretical background of appraisal process and mental contents provides coherence and validity for the purposes of evaluation.

Among the popular and scientifically grounded tools of user and product experience evaluation, many are based on problematic methodological assumptions. The methodological background for AttrakDiff [1], for example, is in Osgood's psycholinguistics, which uses factor analysis to reveal dimensions of affective experience [10]. However, this methodology is not supported by modern psychological interpretation of affective processes [34]. On the other hand, such tools as Lemtool [13] and Premo [14] utilise the methodology from the theory basic emotions, which assumes that there is a core set of universal emotions with corresponding physiological patterns. However, this methodological assumption is also questionable, as shown in meta-analyses of studies of basic emotions [3]. Of course, basic emotion words are still useful in research of emotional experience in HCI [34].

Although appraisal theory is likewise contested in current psychological discourses [3, cf. 39], it currently provides the most theoretically coherent account of emotion as a cognitive process, while being detailed at the same time. The ability of the theory to predict RT differences in primed product comparisons gives support to its usefulness in user and product experience research. Hence, it is maintained that the study of cognitive processes and affective mental contents with methods such as primed product comparisons is critical for scientific analysis of experience in HCI [35]. Although the experience evaluation tools, which are based on questionable methodologies, can produce relevant information for product evaluation, the explication of the connection between psychological theories and tools for experience evaluation should be more enforced in the user and product experience community.

CONCLUSION

This study presents a method of primed product comparisons, useful for basic and applied human-computer interaction (HCI) research. The method is based on the methodology of studying affective mental contents [34, 35], which are part of the appraisal process [23, 25, 38, 39]. A tool implementing the method of primed product comparisons was constructed. Product evaluations made with the tool agreed with the results of traditional pen and paper evaluation, providing validity to the method and the tool. However, compared to traditional questionnaires, the method provides additional information relating to the mental processing associated with making affective judgments. Understanding the process of product evaluation as cognitive computations and affective contents brings us closer to a psychologically explicated theory of experience [36].

In addition to the basic research implications of the method of primed product comparisons, it has possible applied uses. User-centred design processes lean on understanding the user and the assessment of design solutions, especially in the early product design processes [32]. The proposed method and its implementation as a computer software can be utilised to meet the challenges in early design phases, as well as in different stages of iterative design processes. The priming aspect of the tool offers targeted evaluation of, for example, the experience goals of the design process. Comparing the product being designed with earlier prototypes, or with different design solutions of the same phase prototype are options, which provide information to support subsequent iterations. In addition, future versions of the tool should include tablet computer solution for agile and adaptable field evaluation. Further, online analyses of the collected data during or straight after the experiment are easy to provide in computerised environment.

ACKNOWLEDGMENTS

The research has been supported by the Finnish Funding Agency for Technology and Innovation (TEKES) and the Finnish Metals and Engineering Competence Cluster (FIMECC) programme UXUS (User experience and usability in complex systems), and Doctoral Program in Computing and Mathematical Sciences (COMAS). We thank research assistant Merja Lehtiharju.

REFERENCES

1. AttrakDiff. http://attrakdiff.de/index-en.html.
2. Bargas-Avila, J.A., and Hornbæk, K. Old wine in new bottles or novel challenges: a critical analysis of empirical studies of user experience. In *Proc. CHI 2011*, ACM Press (2011), 2689-2698.
3. Barrett, L.F. Are emotions natural kinds? *Perspectives on Psychological Science 1*, 1 (2006), 28-58.
4. Bloch, P.H. Seeking the ideal form: Product design and consumer response. *Journal of Marketing 59*, 3 (1995), 16-29.
5. Bornstein, R.F. Exposure and affect: Overview and meta-analysis of research, 1968–1987. *Psychological Bulletin 106*, 2 (1989), 265-289.
6. Brakus, J.J., Schmitt, B.H., and Zarantonello, L. Brand experience: What is it? How is it measured? Does it affect loyalty? *Journal of Marketing 73*, 3 (2009), 52-68.
7. Cohen, J. A power primer. *Psychological Bulletin 112*, 1 (1992), 155-159.
8. Hartmann, J., De Angeli, A., and Sutcliffe, A. Framing the user experience: Information biases on website quality judgement. In *Proc. CHI 2008*, ACM Press (2008), 855-864.
9. Hassenzahl, M. The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction 19*, 4 (2004), 319-349.
10. Hassenzahl, M., Burmester, M., and Koller, F. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In J. Ziegler and G. Szwillus (Eds.), *Mensch & Computer*, B. G. Teubner, Stuttgart, 2003, 187-196.
11. Hassenzahl, M., and Tractinsky, N. User experience – a research agenda. *Behaviour & Information Technology 25*, 2 (2006), 91-97.
12. Hox, J.J. *Multilevel analysis*. 2nd ed. Routledge, Hove, 2010.
13. Huisman, G., van Hout, M., van Dijk, E., van der Geest, T., and Heylen, D. LEMtool: measuring emotions in visual interfaces. In *Proc. CHI 2013*, ACM Press (2013), 351-360.
14. Desmet, P. Measuring emotion: Development and application of an instrument to measure emotional responses to products. In M. Blythe et al. (Eds.), *Funology: From usability to enjoyment*, Academic Publishers, Dordrecht, 2003, 111-123.
15. Desmet, P. Faces of product pleasure: 25 positive emotions in human-product interactions. *Int. Journal of Design 6*, 2 (2012), 2-29.
16. Desmet, P. and Hekkert, P. Framework of product experience. *Int. Journal of Design, 1*, 1 (2007), 57-66.
17. Diefenbach, S., Lenz, E., and Hassenzahl, M. An interaction vocabulary. Describing the how of interaction. In *CHI 2013 Extended Abstracts*, ACM Press (2013).
18. Eimer, M., and Schlaghecken, F. Links between conscious awareness and response inhibition: Evidence from masked priming. *Psychonomic Bulletin & Review 9*, 3 (2002), 514-520.
19. Ekman, P., Basic emotions. In T. Dalgleish and M. Power (Eds.), *Handbook of cognition and emotion*, John Wiley & Sons, New York, 1999, 45–60.
20. Ericsson, K.A., and Simon, H.A. *Protocol analysis: Verbal reports as data*. MIT Press, Cambridge, MA, 1984.
21. Five Second Test, Click Test and Nav Flow – UsabilityHub. https://usabilityhub.com/

22. Fodor, J. Fodor's guide to mental representation. *Mind, 94* (1985), 76-100.

23. Frijda, N. The laws of emotion. *American Psychologist 43*, 5 (1988), 349-358.

24. Google Analytics Official Website – Web Analytics & Reporting. www.google.com/analytics/

25. Lazarus, R.S. *Emotion and adaptation*. Oxford University Press, New York, 1991.

26. Lindgaard, G., Fernandes, G., Dudek, C. and Brown, J. Attention web designers: You have 50 milliseconds to make a good first impression! *Behavior & Information Technology 25*, 2 (2006), 115-126.

27. Marcel, A.J. Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive psychology 15*, 2 (1983), 197-237.

28. Norman, D.A. *Emotional design*. Basic Books, New York, 2004.

29. Papachristos, E. and Avouris, N. Are First Impressions Only Related to Visual Appeal? In *Proc INTERACT 2011, Part I, LNCS,* Springer (2011), 489-496.

30. PrEmo. http://www.premotool.com/

31. Reber, R., Schwarz, N., and Winkielman, P. Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review 8*, 4 (2004), 364-382.

32. Roto, V., Rantavuo, H., and Väänänen-Vainio-Mattila, K. Evaluating user experience of early product concepts. In *Proc DPPI09*, Compiegne University of Technology (2009), 1-10.

33. Saariluoma P. Apperception, content based psychology and design. In U. Lindemann (Ed.), *Human behaviour in design*, Springer, Berlin, 2003, 72-78.

34. Saariluoma, P., and Jokinen, J.P.P. Emotional dimensions of user experience – a user psychological analysis. *Int. Journal of Human-Computer Interaction 30*, 4 (2014), 303-320.

35. Saariluoma, P., Jokinen, J., Kuuva, S., and Leikas, J. User experience as mental contents. In *Proc10th European Academy of Design Conference*, Chalmers University of Technology (2013).

36. Saariluoma, P., and Oulasvirta, A. User psychology: Re-assessing the boundaries of a discipline. *Psychology 1*, 5 (2010), 317-328.

37. van Schaik, P. and Ling, J. The role of context in perceptions of the aesthetics of web pages over time. *Int. Journal of Human-Computer Studies 67*, 1 (2009), 79-89.

38. Scherer, K.R. What are emotions? And how can they be measured? *Social Science Information 44*, 4 (2005), 695-729.

39. Scherer, K.R. The dynamic architecture of emotion: Evidence for the component process model. *Cognition & Emotion 23*, 7 (2009), 1307-1351.

40. Smith, C. A. and Ellsworth, P.C. Patterns of cognitive appraisal in emotion. *Journal of Personality and Social Psychology, 48*, 4 (1985), 813-838.

41. Smith, C.A. and Kirby, L.D. Toward delivering on the promise of appraisal theory. In K. A. Scherer, A. Schorr,, and T. Johnstone, (Eds.), *Appraisal Process in Emotion*, Oxford University Press, New York, 2001, 121-138.

42. Optimal Workshop. http://www.optimalworkshop.com/optimalsort.htm

43. Thielsch, M.T., and Hirschfeld, G. Spatial frequencies in aesthetic website evaluations – explaining how ultra-rapid evaluations are formed. *Ergonomics 55*, 7 (2012), 731-742.

44. Thüring, M., and Mahlke, S. Usability, aesthetics and emotions in human–technology interaction. *Int. Journal of Psychology 42*, 4 (2007), 253-264.

45. Tractinsky, N., Cockhavi, A., Kirschenbaum, M., and Sharfi, T. Evaluating the consistency of immediate aesthetic perceptions of web pages. *Int. Journal of Human-Computer Studies* 64, 11 (2006), 1071-1083.

46. UEQ-Online. http://www.ueq-online.org/.

47. UserTesting. http://www.usertesting.com/

48. Vermeeren, A.P., Law, E.L.C., Roto, V., Obrist, M., Hoonhout, J., and Väänänen-Vainio-Mattila, K. User experience evaluation methods: Current state and development needs. In *Proc. 6th NordiCHI*, ACM Press (2010), 521-530.

49. Zajonc, R.B. Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology 9*, 2 (1968), 1-27.

50. Zhou, H., and Fu, X. Understanding, measuring, and designing user experience: The causal relationship between the aesthetic quality of products and user affect. In J. Jacko (Ed.), *Human-Computer Interaction. Interaction, Part I*, Springer, Berlin, 2007, 340-349.

V

SEMANTIC DISTANCE AS A CRITICAL DESIGN FACTOR FOR IN-CAR INFOTAINMENT SYSTEMS

by

Silvennoinen, Johanna M., Kujala, Tuomo & Jokinen, Jussi P. P.

In review in *Applied Ergonomics* (unpublished manuscript).

SEMANTIC DISTANCE AS A CRITICAL FACTOR IN ICON DESIGN

FOR IN-CAR INFOTAINMENT SYSTEMS

Abstract

In-car infotainment systems require icons that enable fluent cognitive information processing and safe interaction while driving. An important issue is how to find an optimised set of icons for different functions in terms of semantic distance. In an optimised icon set every icon needs to be semantically as close as possible to the function it visually represents and semantically as far as possible to the other functions represented concurrently. In three experiments (N = 21 each), semantic distances of 19 icons to four menu functions were studied with preference rankings, verbal protocols, and with the primed product comparisons method. The results show that the primed product comparisons method can be efficiently utilised for finding an optimised set of icons for time-critical applications out of a larger set of icons. The findings indicate the benefits of the novel methodological perspective into the icon design for safety-critical contexts in general.

Keywords: safety-critical user interfaces; icon; semantic distance

Research highlights

- Semantic distance was operationalised as preference ratings and reaction times.
- In optimised icon set each icon is semantically as close as possible to its function.
- In optimised icon set each icon is semantically as far as possible to other functions.
- Preferences and verbal protocols alone could not discern the optimised icon set.
- The method was effective in detecting the optimised icon set from a larger icon set.

1 INTRODUCTION

As vehicle technology evolves, the complexity and connectivity of in-car infotainment systems continues to increase. This surge in technology means that the driver increasingly has access to a great number of novel in-car online applications, which can offer improved communications, entertainment, route finding, as well as other useful in-car services on the road. One unfortunate downside of this progress, however, is the increasing potential for drivers to be distracted from the safety-critical primary task of driving while utilising the services (Victor, Dozza, Bärgman, Boda, Engström, & Markkula, 2014; Klauer, Dingus, Neale, Sudweeks, & Ramsey 2006).

The evolution of in-car systems has led to a large growth in system functions and, along with this, a growth in visual icons that represent these functions. Furthermore, as novel applications are introduced into vehicle systems, easily distinguishable new icons are needed to represent these functions. In the driving context, a two-second glance off road can already be risky (Liang, Lee, & Yekhshatyan, 2012), which means the driver should be able to find and locate the desired function from the in-car menus as fast as possible. This places novel challenges for the in-car interface designers to find an optimised combination of such menu icons that can be recognised with a brief in-car glance (Dobres, Chahine, & Reimer, 2017; Dobres, Reimer, Mehler, Chahine, & Gould, 2014). Thus, effective icon design enabling fluent communication in human-computer interaction (HCI) is especially critical for interactions with in-car infotainment systems while driving.

In this interaction context time is of the essence due to the time pressure to return eyes on the road. An action to be conducted by selecting an icon can be demanding due to the competition of attention by the other icons on the display. Therefore, the focus of this paper is to examine cognitive processing fluency of icons' semantic distance, the relationship between an icon's visual representation and its intended meaning. Previous research has mainly focused on studying the semantic distance of individual icons (e.g. Isherwood, 2009; McDougall, Curry, & Bruijn, 1999). However, icon menus always include sets of icons which meanings are required to be distinguishable from the meanings represented by the other icons in the same icon set. Every icon in a menu needs to be semantically as close as possible to its intended function and at the same time semantically as far as possible to other icons' functionalities in the same icon set, to be able to recognise and select the required function safely while driving. Here, our aim is to present and validate a methodology to investigate and optimise icons' semantic distances in safety-critical user interfaces, and thus to provide insights into icon design for safe interactions while driving.

In order to find an optimised set of icons for time-critical applications out of a larger set of icons, we first explored four sets of possible icons and their semantic distances to four different in-car navigation system functionalities by studying participants' preference rankings and their verbal protocols. To examine how quickly these preferred icons can be processed, in the second experiment we tested how quickly people are able to make the preferential judgments concerning the icon functions. Finally, in order to find set of icons where the icons of different functions are easily distinguishable, in the third experiment we tested how quickly users identify icons of a given function when compared to icons of a different function. As a result, we present an icon set for the given functions, optimised for being individually quick to interpret as referring to their intended meaning, as well as being distinguishable as the icon of their intended function in the complete icon set.

2 ICON DESIGN IN THE AUTOMOTIVE CONTEXT

Icons stand for the object they represent, that is, the displayed features and properties in icons resemble or imitate the objects they signify (Peirce, 1986). Icon metaphors are often elicited from real objects to emphasise familiarity (Blackwell, 2006), and in technological artefacts, can be defined as graphical representations that symbolize actions in technological environments (Ware, 2004). Icons are powerful elements in visual communication (Poulin, 2011) and enable users to accomplish technological tasks visually (Kay, 1990). Properly designed icons reduce system complexity and mental workload (Gittins, 1986), and provide better cognitive affordances than textual user interfaces (Garcia, Badre, & Stasko, 1994). Moreover, the large extent of icon-based user interfaces highlights visual icon design, not only to enhance communicability, but also to match user preferences (Huang, Shieh, & Chi, 2002).

Additionally, effectively designed iconic representations make objects, concepts, and actions easier to find, recognise, remember, and learn (Lidwell, Holden, & Butler, 2011). Thus, icons are more universally recognised than textual information (Lodding, 1983), recognised quickly (Caplin, 2001), and are well remembered (Weidenbeck, 1999). Therefore, icons can be perceived immediately and enhance fluent communication and visual usability of interactive systems. This perceptual immediacy enables well designed icons to be grasped and understood effortlessly (Mullet & Sano, 1995) and the graphic representation of an icon affects its recognition rate and, therefore influences user perception (Gatsou, Politis, & Zevgolis, 2012). Immediate recognition and long memorability of icons raise challenges for efficient icon design. In practice, the intended functions of the icons might gain different meanings across users (Bocker, 1996; Isherwood, 2009; Isherwood, McDougall, & Curry, 2007), because icons convey semantic information through visual language that does not rely on strict rules in the same way as written words (Carr, 1986). Further, icons follow less strict rules than the written language, which also contributes to their ambiguity between individuals.

Several studies have focused on visual icon characteristics and design principles in general (e.g., Byrne, 1993; Frutiger, 1997; Gaver, 1990; Gittins, 1986; Goonetilleke, Shih, On, & Fritsch, 2001; Ng & Chan, 2008). For example, some cognitive features in icon effectiveness include familiarity, concreteness, visual complexity, meaningfulness, and semantic distance (McDougall et al., 1999; Ng & Chan, 2008). Familiarity refers to the frequency of encounters with icons, concreteness to the abstraction level of the icons visual representation, complexity to the amount of visual elements in the icon, and meaningfulness is how the icon's meaning is perceived (Ng & Chan, 2008). In addition, several icon design principles, aiming towards cognitive processing fluency, have been presented. For example, immediacy refers to effective recognition and cognitive processing fluency, in which the design focus is on the most essential visual elements through simplification and abstraction, not merely reducing the elements (Mullet & Sano, 1995). Icon design should follow the principle of generality by representing a broader category (e.g. painting supplies) of the idea, than an exact object (i.e. detailed photographic representation of some specific paint roller) in cohesive manner within an icon set. Characterisation is utilised to emphasise the most essential features of a representation, including the most advantageous viewpoint. To design for communicability, knowledge of the users, culture, and context of use is required (Mullet & Sano, 1995). In addition to these icon design principles, understanding of cognitive processing fluency of icons' semantic distance is needed to design for safe interactions while driving. Cognitive effectiveness of semantic distance has not been studied in terms of icon sets, merely concerning individual icons, and thus, icon design principles would need to include this viewpoint to semantic distance, especially in time- and safety-critical interaction contexts.

For visual information processing to be fluent and effective, pictorial representations must activate correct mental models that match the representation's function (Isherwood, 2009). In icon design this relationship is called semantic distance, a necessary factor in cognitive effectiveness of icon interpretation (Isherwood et al., 2007; Isherwood, 2009; McDougall et al., 1999; McDougall, Curry, & de Bruijn, 2001; McDougall & Reppa, 2013;

Ng and Chan, 2008). However, methodological approaches to semantic distance research have not addressed the role of semantic distance in a set of icons, or the requirements that a specific application context can set. Icon sets for specific interaction contexts have been studied in relation to, for instance, transportation and leisure activities (Prada, Rodrigues, Silva & Garrido, 2015), emergency medical information systems (Salman, Cheng, & Patterson, 2012) and user interfaces for pre-schoolers (Chiu, Koong, & Fan, 2012). A few studies have concentrated on icon design and testing in the automotive domain (e.g., Johann & Mahr, 2011). There are general guidelines for in-car user interface icons based on human factors principles and standards (e.g., ISO 15008 2009) but these are typically limited to enabling legibility and clarity of the icons while on the move. Thus, icon design research lacks studies of users' interpretations and semantic meanings of visual icon design in in-car infotainment systems for icon sets in which individual icons' semantic distances can be recognised quickly.

Recently, this interaction context has become a significant challenge for visual designers because of the explosion of in-car functionalities and services that are made available to the driver (e.g., Norman, 2007). This stresses the requirement that all the different functions available in the in-car infotainment system should have descriptive and intuitive icons communicating meanings unambiguously. Icons are required to be designed as enabling interactions with in-car systems as efficiently as possible in order to minimise the potential for distraction while driving (NHTSA, 2013). In this time- and safety-critical interaction context, milliseconds can truly make a difference. User interfaces for in-car infotainment systems in particular require icons for which semantic distance to the associated functions are as close as possible. The driver should be able to locate and select the correct function within a brief in-car glance.

According to the analysis and the early visual sampling model of Wierwille (1993), drivers prefer to keep off-road glance durations on average between 0.5 to 1.6 seconds depending on the demands of the driving situation. In addition, naturalistic driving studies have found significant statistical associations between safety-critical incident risk and the off-road glance duration. According to Liang et al. (2012) the risks start to significantly increase with over-2-second off-road glances. Later, analysis on the same 100-car study data by Liang, Lee, and Horrey (2014) suggest the general risk threshold is even lower, at 1.7 seconds, that is, near the 1.6-second upper limit of the Wierwille's (1993) model. Thus, semantic distance research in the automotive domain needs to take into account the cognitive processing fluency of icons in terms of reaction times in selection tasks as well as drivers' subjective preferences. We suggest that results of effective processing fluency can be obtained by merging reaction times with preference rankings of subjective significances of the icons' functions. Preference construction is highly context sensitive and influenced by users' goals (Warren, McGraw, & van Boven, 2011). In this study, the factor influencing user preferences is the in-car navigation system's icon's semantic distance, that is, the relatedness of the visual representation and its intended function.

In this paper, we introduce and study a method intended to enable in-car user interface designers to find an optimised set of menu icons with optimal semantic distances from a large set of alternative icon designs. Recently, Dobres et al. (2017; 2014) have introduced a similar method for finding an optimal typeface for in-car infotainment systems to provide the best legibility of digital text on in-car displays. The focus of the current study is on resolving an optimised visual icon design set for an in-car navigation system menu with primed product comparisons, based on user preferences and reaction times (Jokinen, Silvennoinen, Perälä, & Saariluoma, 2015). An optimised combination of icons for this specific design context requires optimal semantic distances. For an optimised icon set, the semantic distance needs to function effectively between one icon and its intended meaning, and also between different icons and their meanings, so that the icons differ in relation to one another enough to optimise the selection of correct icon from the set of icons.

3 EXPERIMENT 1: RANKINGS AND VERBAL PROTOCOLS

The purpose of the Experiment 1 was to explore four sets of possible icons and their semantic distances to four different in-car navigation system functions by studying participants' preference rankings per function and the associated verbal protocols. By studying the verbal protocols behind the preference rankings, our aim is to indicate the significance of the context-specific semantic distance for icon design and to better understand its role when compared to the other icon design principles. In addition, the preference rankings act as a comparison point for further data gathered with the primed product comparison method.

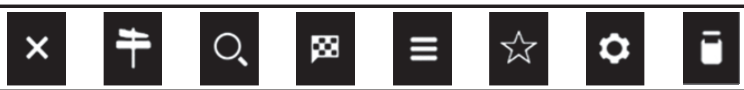
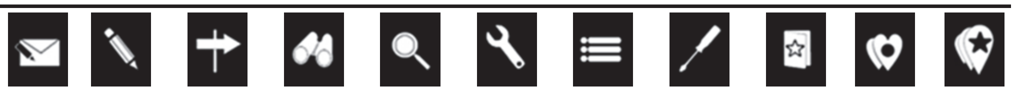
3.1 Method

3.1.1 Participants and Stimuli

Participants ($N = 21$) were recruited for the experiment (11 male and 10 female) via University's student email lists. The primed product comparison method has been validated with 20 participants (Jokinen et al. 2015), and this sample size was used as a general guideline in the experiments. The mean age of the participants was 24.3 ($SD = 5.2$, age range 20–40). All the participants had previous experience with navigation systems, and driving experience either for at least two years or for at least 20 000 kilometres.

Two sources of icons were used for obtaining the stimuli for the experiment. In total, 18 icons were included into the Experiment 1, displayed in Table 1. Eight icons were acquired from a commercial in-car navigation system under development (HERE Auto, http://360.here.com/2013/08/30/here-auto-connect-your-car-to-the-cloud/). The X-icon was excluded from the Experiment 1 due to its inappropriate conventional meaning to represent any of the four functions. However, the X-icon was later utilised as a validity check for the primed product comparisons method in Experiment 2. An additional 11 icons were designed for this experiment for comparison purposes. The new icons were designed according to icon design principles of immediacy, generality, cohesiveness, characterisation and communicability (Mullet & Sano, 1995).

(Table 1. around here) Table 1. *Icons used as stimuli in the experiments.*

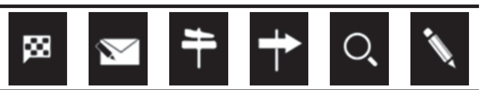
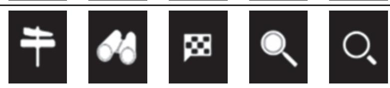
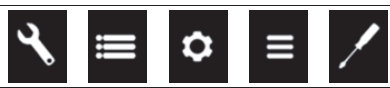
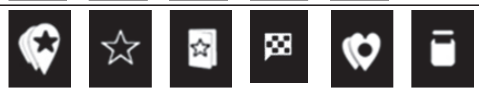
Icons from the commercial navigation system											
		X-icon	Road signs	Mag. glass	Flag	Menu	Star	Wheel	Jar		
New Icons											
	Pen enve-lope	Pen	Road signs	Bino-culars	White mag. glass	Wren-ch	Points menu	Screw driver	Star folder	Hea-rts	POI stars

Icon metaphor conventions in navigation system user interfaces and other software were also taken into account. Additionally, the icons were designed according to the style of the icons from the commercial navigation system. The style of the existing icons was mainly based on 2-dimensionality, simplicity, consistency and achromatic colour scheme, and followed design conventions of pictograms. The new icons were designed to evaluate users' preferences and interpretations of conventions; preferred level of simplicity; and combinations of metaphor conventions. These were examined in terms of users' interpretations of icons' semantic distances in in-car navigation system user interfaces.

3.1.2 Procedure

The experiment started with participants ranking the icons using the given navigation system functions as criteria. Participants were asked to select one icon as the first option to best match to the given function, then to select a second best option to express the function in question, then third, fourth, fifth and the sixth. The functions were 'Enter address', 'Search', ‘Settings’, and ‘My destinations’. Both the commercial and newly designed icons were used (except the X-icon). Combinations of icons concerning different functions are presented in Table 2. ‘Search’ and ‘Settings’ included five icons each due to conventional status of the selected icons to represent these two functions. ‘Enter address’ and ‘My destinations’ included six icons each in order to examine more options in terms of semantic distance due to the lack of established status of these explicit terms to represent the functions.

(Table 2. around here) Table 2. *Icon ranking for the four functions.*

Functions	Icons
Enter address	
Search	
Settings	
My destinations	

The participants were shown one of the four icon sets at a time, and the function above the icons on a 22-inch 1650 x 1050 pixel display. The size of the icons was 57 x 72 pixels. The task of the participants was to look at the icons and rank them in a preferential order under the given function. Icon selected to best fit the given function was asked to be selected as the first option, then the second best and so forth. Ranking was chosen as the method instead of scoring the icons for representing a function (on a scale), because ranking as a non-parametric method enables clearer results in case of a small sample size. The participants were asked to think aloud while ranking the icons in order to extract verbal protocols (Ericsson & Simon, 1980; Boren & Ramey, 2000).

3.1.3 Data Analysis

Icon ranking data were analysed to detect which icons are the most preferred in relation to the semantic distance of the function and the icon. Ranking of the icons was conducted by labelling the best option with number 1, second best with number 2, and so forth. The total rank scores from the icon ranking task were used to compare the icons with each other. Friedman test was used to test if the ranks were statistically significant from each other.

Thinking aloud data was transcribed into textual format and analysed with qualitative content analysis (Krippendorf, 2004) utilising an *interpretation framework* that defines the objects found in the data on the conceptual level, and through which the results of this experiment are produced (Silverman, 2005). The conceptual core of the interpretation framework was based on detecting semantic distances between the proximity of the relationship between the visual representation of an icon and the function it is intended to represent. In addition, icon design principles of familiarity, concreteness, visual complexity and meaningfulness served as concepts in the interpretation framework. The analysis consisted of familiarization, organization and categorization of the data. The goal of the analysis was to understand the reasons behind user preferences and interpretations of the icons' meanings and functions.

3.2 Results

Ranking of the icons resulted in the following order for the four functions (Table 3). In all the icon rankings, the mean ranks were different from one another, as suggested by statistically significant Friedman tests, which were for 'Enter address' $\chi^2(5) = 20.6$, $p = .001$, 'Search' $\chi^2(4) = 67.9$, $p < .001$, 'Settings' $\chi^2(4) = 62.9$, $p < .001$, and for 'My destinations' $\chi^2(5) = 62.2$, $p < .001$. Lower mean rank indicates higher preference. The tables also include information of how often specific icons were selected as the first option.

(Table 3. around here) Table 3. *Ranking of the icons for the four functions.*

Enter address	Pen	Mag. glass	Road signs	Pen envelope	Flag	Arrow sign
Mean rank *(SD)*	2,1 (*SD* = 1.5)	3,1 (*SD* = 2.0)	3,7 (*SD* = 1.6)	4,5 (*SD* = 1.8)	3,4 (*SD* = 1.4)	4,1 (*SD* = 0.9)
Selected 1. x times	10	6	2	2	1	0
Search	Mag. glass	White mag. glass	Bino-culars	Road signs	Flag	
Mean rank *(SD)*	1,4 (*SD* = 1.0)	1,8 (*SD* = 0.4)	3 (*SD* = 0.4)	4,2 (*SD* = 0.7)	4,7 (*SD* = 0.5)	
Selected 1. x times	16	5	0	0	0	
Settings	Wheel	Wrench	Screw driver	Points menu	Menu	
Mean rank *(SD)*	1,3 (*SD* = 0.6)	1,8 (*SD* = 0.9)	3,5 (*SD* = 0.5)	4,1 (*SD* = 0.7)	4,3 (*SD* = 0.8)	
Selected 1. x times	16	5	0	0	0	
My desti-nations	POI stars	Star	Star folder	Flag	Hearts	Jar
Mean rank *(SD)*	2 (*SD* = 0.8)	2,3 (*SD* = 1.3)	2,6 (*SD* = 1.3)	4,5 (*SD* = 1.4)	3,9 (*SD* = 1.0)	5,7 (*SD* = 0.7)
Selected 1. x times	6	8	5	2	0	0

The pen icon was selected as the first option to represent ‘Enter address’. The descriptions of selecting the pen included comments such as: *“pen symbolises entering something like writing something”* and *“because it´s for writing, I think. For me it´s the clearest, because you have to type the address and actually write it”*. The functionality was emphasised literally in resemblance to writing and the concreteness of the icon was emphasised. Entering was related to writing and writing to typing. Even though writing in navigation systems is not done with an actual pen, the metaphor of a pen as a writing tool was preferred due to concrete juxtaposition of real world objects and functions. The icon with an envelope and a pen also represented writing or entering something. However, this icon was selected as the last option because of its strong conventional status as an icon for sending email. Thus, contextual familiarity influenced the ranking of the pen envelope icon.

The magnifying glass icon was consistently preferred to represent 'Search' due to its familiarity and conventional status. Preferences were described, such as: *"I think it´s so common in referring to search, search in internet or in navigation system, so it´s the best"*. No other icons were ranked as first options. The magnifying glass (with black inside area of the glass, i.e. Mag. glass) was preferred the most due to simplicity, concreteness, clarity and good contrast. In addition, the black inside area of the glass was seen to reflect that the search has not yet been done. The white inside area of the white magnifying glass, was seen to communicate that the search has already been done, which could be utilised in indicating the stage of a search process. The white magnifying glass was chosen as the second option due to the lack of simplicity and concreteness: *"the one with the white background, the same story but it´s a little bit more detailed and it´s harder to see it fast I think"*. The binoculars icon was often selected as the third option because it also refers to looking and finding something with a meaningful semantic distance.

The wheel icon was the most preferred icon for 'Settings'. Sixteen participants chose the wheel icon as the first option, due to its convention as a settings icon, familiarity from other software, and due to the metaphor of adjusting something. The wheel, wrench and screwdriver icons were seen to belong to the same tool category. However, the wheel was selected as the best option, for instance, with the following words: *"I was struggling with these two (wheel & wrench). It…allows you to manipulate the feeling of such a system, but it* *is more pleasantly expressed, because the wrench here implies that I´m an engineer and all the settings would be for engineers”*. The wheel icon carried subtle nuances in representing ‘Settings’ which were not conveyed through the wrench and the screwdriver icons. The remaining two icons were seen to relate to menu icons, and therefore not suitable for ‘Settings’ in in-car user interfaces.

The Point-of-Interest (POI) star icon was selected as the first option to represent ‘My destinations’. The intended function of the icon was to access visited and stored favourite destinations. The POI sign was familiar from digital maps and the POI signs were seen to resemble balloons or tear drops upside down. The star represented the meaning of a favourite. Participants combined these two signs into one understandable and meaningful icon metaphor. Preferences were described, for instance with the following words: *“it has the star in it, so it refers to my favourites and also the background, the icon is used similarly in navigation systems, where this icon would be set as a marker somewhere”*. It was also stated that the POI star icon was preferred because it has multiple POI elements, which represents that there are many destinations, not only one destination. The star icon was ranked as the second best option but chosen as the first option more often than the POI star icon. Overall, participants preferred icons with stars, besides of the icon with a folder and a star because it was considered to be too complex and cluttered. The last options were the flag and the hearts icons. The flag was seen more like a destination marker and the hearts icon was seen as unfamiliar icon in comparison to the icons with stars. The jar icon was selected as the worst due to its lack of comprehensibility in in-car navigation system context. It was interpreted to represent for example, an on-off switch, battery, trash bin, memory, kitten angel, and a seat belt, without clear relation to its functionality.

Overall, the participants expressed frustration if the icons were not easily recognisable, and if they could not arrive into a sensible interpretation of the icon’s representation to its meaning within first interpretation. The first described impression of the icons' meanings functioned as a strong predictor of the intended function in the ranking the icons while thinking aloud. If participants were hesitant about the meaning, they were not willing to pursue interpreting the icons. Frustration in interpreting the icons was expressed, for example, when interpreting the jar icon with the following words: *"I have no other clear implication what the kitten angel icon resembles to me"* and in interpreting road signs: *"I haven't seen it, it could be…I don't know, do I really have to say?"*.

3.3 Discussion

The rankings show that pen icon for 'Enter address', magnifying glass icon for 'Search', wheel icon for 'Settings', and star icon for 'My destinations' were the most preferred icons to represent these four functions. These icon metaphor conventions from other information systems software were interpreted as meaningful and understandable in in-car navigation systems. In line with these findings, in-car user interface design guidelines (e.g., NHTSA, 2013) recommend the use of internationally agreed upon standards or recognised industry practice relating to icons and symbols. However, conventional design does not automatically contribute to effective design (McDougall & Curry, 2004). Thus, icons' semantic distances need to be investigated in novel interaction contexts to understand whether the semantic distance elicits required mental models for the intended actions in the specific context of use, and how quickly the icons can be recognised among other icons. For example, in the 'Enter address' icon rankings, the interpretations of the pen envelope icon indicated the influence of conventions, familiarity, and context. Therefore, the context in which icons are to be applied, acts as a significant determinant and modifier in interpretations of semantic meanings.

Conventions function through familiarity, which are learned from corresponding products. Besides familiarity, products that include something new are preferred if the combination of familiarity and novelty is optimal. The key is in providing something new while preserving familiarity (Hekkert, 2006). The balance between novelty and familiarity was encountered in the users' preferences of the integrated POI star icon, which combined elements from two different visual design contexts in one icon. Users were able to interpret the conventional star and the cartographic POI mark together and process the new integrated icon with meaningful semantic distance. According to this result, in-car navigation systems could benefit from a specific set of icons that combines conventional metaphors from operating systems and, for instance cartographic signs.

In HCI confusing interaction design leads to frustration and stress (Rogers, Sharp, & Preece, 2011), which also applies to icon processing fluency. If the semantic distance of an icon metaphor and its intended function is not understood, users become frustrated quickly and lose interest in trying to interpret the icon, which underlines the importance of understanding users' interpretations of icons, and what kinds of actions are mentally represented. Insights into icon design with subtle nuances can be gained with user studies on preferences and verbal protocols associated to these. For instance, this study informed the design metaphor to be used for 'Settings'. Wheel icon was considered suitable to represent 'Settings' in that it represents universalistic design, without implicating specific levels of expertise. New integrated icons for a specific interaction context can enhance intuitive interaction between users and technology, but need to be designed according to the icon design principles and tested with user studies.

4 EXPERIMENT 2: PREFERENCES AND REACTION TIMES

In the first experiment, the participants ranked the icons into a preferential order in a relation to four different in-car navigation system functions. However, especially in safety-critical design contexts, preference is not the only criterion for good icon design. In addition, the user must be able to quickly make the intended interpretation which leads to the required action. Therefore, a second experiment was designed in order to test how quickly people are able to make preferential judgments concerning icon functionalities with primed product comparisons (Jokinen et al. 2015) and if it takes less time to make the judgment for the more preferred than for the less preferred icons. The basic idea of the method is that the participant is first shown a prime, such as a function that an icon intends to refer to, and then two stimuli, such as two icons, from which the participant then needs to choose the one that they prefer more, given the prime (Figure 1). The participant is asked to do this preferential judgment as quickly as possible, and the task is repeated many times with different combination of primes and stimulus pairs. The resulting data contains prime-specific preferences as well as reaction times, indicating how quickly the participants were able to make the comparison.

(Figure1. around here)

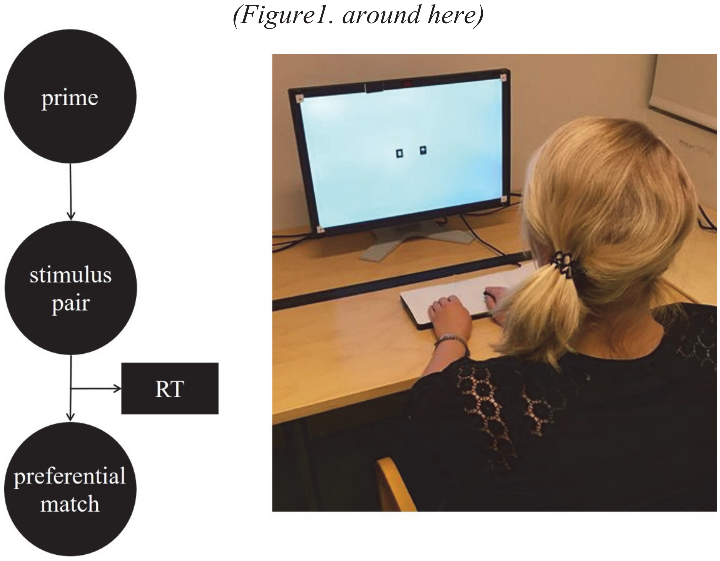


Figure 1. The procedure of primed product comparison method and experimental setup.

In order to validate the icon preferences obtained in the first experiment in a more time-constrained context, the we first hypothesise that

H1. Preferences from the comparisons tasks correlate with icon rankings of Experiment 1.

Further, we propose that the comparison judgments should be conducted quickly. Because the method of primed product comparisons (Jokinen et al. 2015) cannot be directly used to analyse processing times of single stimuli, we use this experiment to explore the reaction times associated with pairwise icon comparisons. In the analysis, we focus on the upper threshold of 1600 ms by Wierwille's (1993) visual sampling model, that is, an icon should be identifiable during a brief 1.6-second (maximum) in-car glance time. The reaction times do not correspond directly to in-car glance times in the real world but we wanted to have a plausible maximum acceptable limit for a reaction time of a pairwise comparison. Our focus here was to find the optimised icon for each function in terms of semantic distance. There should be icons that are faster to process, and thus we should see variance between reaction times of different icon pairs:

H2. There are differences in mean reaction times between icon comparisons.

In addition, we suggest that preference is at least partly due to the speed with which the participant is able to give a preferential match between a function and an icon, and thus:

H3. More preferred icons are selected faster than the less preferred icons.

4.1 Method

4.1.1 Participants and Stimuli

Participants (N = 21), 11 male and 10 female, were recruited with the same requirements as in the Experiment 1: all had previous experience with navigation systems and driving experience of either at least two years or at least 20 000 kilometres. Driving experience in terms of monthly kilometres driven was also asked when in the beginning of the experiment. In addition, the participants were required not to have taken part in the experiment 1, because familiarity with the icons would have influenced the reaction time data. Participants' mean age was 28.5 (*SD* = 4.7, age range = 22–39).

The icons from the Experiment 1 were reused as stimuli. The icons were presented on the same display as in the Experiment 1. The participants' task in this experiment was to compare two icons at a time. The participant's viewing distance from the display varied approximately between 70 and 75 cm. The horizontal visual angle between the icons varied between 5.7° and 6.1°, that is, more than 5°, which places them outside of parafovea where visual acuity is very poor (Rayner, 1998). That is, the participants were able to observe accurately only one icon at a time. However, the distance between the icons was kept small (4.3 cm) in order to enable fast eye movements between the icons.

4.1.2 Procedure

The procedure followed the method for primed product comparisons developed by (Jokinen et al. 2015). The participant sits on a computer screen with a reaction time keyboard with two buttons (as shown in Figure 1). First, the participants are presented a prime, which can be any word. After a fixed time, a pair of stimuli is shown side by side, and the participant's task is to choose from the two stimuli the one that she judges to match more the prime, which was shown before the stimulus pair.

In the experiment reported here, the primes were the four in-car navigation functions as in the experiment 1: 'Enter address', 'Search', 'Settings', and 'My destinations'. Each prime was associated with all possible pairwise combinations of the icons, meaning that the participants were shown, in random order, one of the four functions coupled with any two of the icons that were intended to represent that function, until all possible combinations of function and a pair of icons had been displayed. In addition, for each four functions, one icon not intended to refer to that function was added to each functionality group from the icons of the first experiment. These extra icons (one function) served as a validity check for the method: the non-fitting icon was hypothesised to be preferred the least from the group of icons associated with certain functionality.

For 'Enter address' the icon was the jar icon, for 'Search' the X-icon, for 'Settings' the star icon, and for 'My destinations' the wheel icon. Thus, a single task consisted of one of the four functions (displayed for three seconds) and a pair of icons, from which the participants had to choose the one they preferred as being more associated with the given function. There were 72 tasks in total.

4.1.3 Data Analysis

The method of primed product comparisons provides two kinds of data. First, the preferential matches, made by the participants by choosing which stimuli match with which primes, can be used to calculate preference scores (PSs). These scores have a range between 0 and 1, and indicate the preference level, or 'proportion preferred', compared to the other stimuli on a given prime. For example, a preference score of 0.9 would mean that a particular icon was chosen 90 percent of the time, when compared with the other icons used in the study for that function.

A comparison of the PSs reveals which icons are most preferred on given functions. Thus, PSs can be correlated with the rank scores obtained from the Experiment 1 to provide validity for the preference results of the first study. Another interpretation of H1 is that the preferences of the icons in the two studies have a large shared variance (R^2), indicating that the ranking task in the Experiment 1 and the primed product comparison task in the Experiment 2 result in similar icon evaluations.

In addition to the PSs, the method of primed product comparisons provides reaction time data associated with different choices. Here, the analysis focuses on the reaction time differences between the icon pairs (H2). Faster judgment times when comparing two icons related to a given prime indicate that the icon is encoded quickly, providing support for the use of the icon in time-critical contexts, such as in-car navigation systems. The proposition here is that people favour icons, which can be quickly associated with given functionalities, and thus comparisons of icons with large difference in PSs should be faster than those with similar PSs (H3). The hypotheses were tested using generalised linear mixed modelling, as suggested by (Jokinen et al., 2015). The dependent variable was reaction time in seconds, and icon pair was the independent variable. The analysis was conducted four times, separately for each function. The distribution of reaction time was observed to be a gamma distribution, with reaction times over 5.0 seconds deviating from the theoretical gamma distribution and thus excluded from the analysis as outliers.

4.2 Results

The PSs of the icons within the four in-car navigation system functions is displayed in Table 4. Shared variance between icon rank scores from the Experiment 1, and icon PSs from the Experiment 2 were for ‘Enter address’ R2 = .11, ‘Search’ R2 = .98, ‘Settings’ R2 = .99, and ‘My destinations’ R2 = .66. This means that the icons for Search and Settings were rated very similarly between the two experiments. Icons for My destinations were also rated similarly, but not as strongly as for these two. Finally, there was very little shared variance between the icon scores for Enter address between the experiments.

The grand mean reaction time of all primes and stimuli pairs across all participants was 1.61 s (*SD* = 1.17, skewness = 5.15), but for the analysis, reaction times more than 5.0s were removed, resulting in mean reaction time of 1.51s (*SD* = 0.74, skewness = 1.43). The hypothesis that there are different reaction times between icon pairs (H2), was tested separately for each function. For ‘Enter address’, there were no statistically significant differences between the icon pairs, but for the other primes there were, as evidenced by statistically significant F-tests in the multilevel model. Of interest are the fastest and slowest comparisons: for example, under ‘Search’, the participants used the least time for evaluations containing one of the two magnifying glass icons, unless both were present. This correlates with the overall preference of the magnifying glass for ‘Search’, and supports H3 that preference is at least partly due to the speed with which the participant is able to give a preferential match between function and an icon.

(Table 4. around here) Table 4. *Icon preference scores and the order of preference (rank) from the Experiment 2 compared to the ranks of the Experiment 1.*

		EXPERIMENT 1		EXPERIMENT 2	
Function	Icon	Mean rank	Grand rank	PS	PS rank
Enter address	Arrow sign	4.1	5	.68	2
	Flag	3.4	3	.52	4
	Mag. glass	3.1	2	.37	6
	Pen	**2.1**	**1**	**.73**	**1**
	Pen envelope	4.5	6	.45	5
	Road signs	3.7	4	.57	3
	Jar	-	-	.18	7
Search	Binoculars	3	3	.65	3
	Flag	4.7	5	.28	5
	Mag. glass	**1.4**	**1**	**.86**	**1.5**
	Road signs	4.2	4	.33	4
	White mag. glass	1.8	2	**.86**	**1.5**
	X-icon	-	-	.03	6
Settings	Menu	4.3	5	.34	5
	Points menu	4.1	4	.35	4
	Screwdriver	3.5	3	.48	3
	Wheel	**1.3**	**1**	**.90**	**1**
	Wrench	1.8	2	.84	2
	Star	-	-	.09	6
My destinations	Flag	4.5	5	.31	5
	Hearts	3.9	4	.71	3
	Jar	5.7	6	.23	6
	POI stars	**2**	**1**	**.84**	**1**
	Star	2.3	2	.53	4
	Star folder	2.6	3	.77	2
	Wheel	-	-	.10	7

The shared variance between PSs and reaction times were for 'Enter address' R^2 = .34, 'Search' R^2 = .55, 'Settings' R^2 = .51, and 'My destinations' R^2 = .50, indicating that generally, about half of the reaction times was explainable by how clearly the preferential match between two icons could be made. For example, when comparing wheel and menu icons to represent 'Settings', only two participants preferred the menu icon. The mean reaction time for this task was 1061 ms. Conversely, the participants were divided when comparing points menu and menu (38% chose the latter), and the mean reaction time was 1959 ms.

Further, for each function, an icon associated with another function in the Experiment 1 was included to serve as a validity check for the method (see Table 4, jar icon for 'Enter address', X-icon for 'Search', star for 'Settings', and wheel for 'My destinations'). These icons were hypothesised to be preferred the least from the group of icons associated with certain function. The validity check resulted as hypothesised; these icons were rated as the last option and preferred the least in comparison to the other icons within a given function.

4.3 Discussion

The Experiment 2 resulted in preference scores that in general correlated highly with the preferences of the Experiment 1 (H1 supported), although there were low levels of shared variance between the preference rankings of Experiment 1 and the preference scores of Experiment 2 on the 'Enter address' function. Further, reaction times indicated that preference was associated with faster judgment times, indicating that more preferred icons are also faster to process visually and mentally (semantic distance, H2 and H3 supported).

However, this experiment did not analyse how well the icons work as a whole set of menu icons, because only some of the icons were displayed with certain functions. This means that it may still be possible that when compiling the total menu icon set for all the necessary in-car navigation system functions, there may be conflicts in the semantic distances between icons and different functions (e.g., Experiment 1: magnifying glass for 'Enter address' and 'Search'). In order to test this, the Experiment 2 must be extended so that the icons are compared to each other under all functions. The optimised set of icons is a combination of icons with each having the best preference score for its own intended function and the fastest reaction time when compared to any of the other icons under this function. In the current context, the reaction times for each of the selected icons should also be preferably under 1600 ms (Wierwille, 1993).

5 EXPERIMENT 3: OPTIMISED ICON SET

In the Experiment 3, our aim was to find a best possible icon set by (1) minimising the semantic distance between the icons and the functions they represent, and simultaneously (2) maximizing the semantic distance between the icons and the other functions they do not represent.

5.1 Method

5.1.1 Participants and Stimuli

Participants (*N* = 21), 11 male and 10 female, were recruited with the same requirements as in the previous experiments: all had experience with navigation systems, and driving experience of either at least two or more years, or at least 20 000 kilometres. Participants' mean age was 24.8 (SD = 4.6, age range = 20–37). Participants were required no to have taken part in experiments 1 and 2. All the icons from the Experiment 2 were included (in total 19 icons). The icons were presented in the same display as in the Experiment 1 and 2.

5.1.2 Procedure

The procedure followed the same method as in the Experiment 2, primed product comparisons (Jokinen et al. 2015), and the experimental setup was also same as in the Experiment 2. However, now the icons were not segregated by their function; instead, all icons were compared to each other under all four functions. Thus, the total number of trials was 180 (the number of all possible pairs from ten icons, 45, multiplied by the number of functions, 4).

5.1.3 Data Analysis

The PSs were calculated as in the previous experiment, but this time, for each of the four functions, each icon got a PS. The goal of the analysis was to find the best possible icon set, based both on how preferred the icons were for their own most preferred function as well as how distinguishable they were from icons preferred for other functions. For each function, only those icons with PS > .70 were chosen, per the cutline suggested by (Jokinen et al. 2015). As often with statistical cut lines, the chosen value is based on convenience rather than rigorous analysis: less than that would include too many 'preferred' items, whereas more than that would only list few top items. A cross-tabulation of pairwise reaction times for all chosen icons results in a dataset, which can be used to find the optimised icon set, based both on PS and pairwise reaction time.

This search results in a set of icons that contains icons with higher than desired minimum PS (here .70), and which have the largest overall semantic distance from the functions represented by the other icons in the set. Thus, the result is not necessarily the icon set with smallest average pairwise reaction times, but it is the icon set with smallest average pairwise reaction time for icons with PS > .70 for their chosen function. This is because the concept of semantic distance is not limited only to processing times, but also involves subjective preference.

5.2 Results

The PSs of the icons within the four in-car navigation system functions are displayed in Table 5, with PSs over .70 highlighted. For 'Enter address', pen was the clearly preferred icon, and no other icons made the cutline. For 'Search', both magnifying glass icons were preferred over the other icons. For 'Settings', the wheel and wrench icons were considered as the most suitable ones, and for 'My destinations', the preferred icons were hearts, POI stars, and star folder. Based on only PSs, a user interface designer could now freely pick from these possibilities any set of icons to represent the user interface functions. Before this, however, one should consider that while all the icons are preferred, some may be easier to distinguish from the icons which were preferred for the other functions.

(Table 5. around here) Table 5. *Icon preference scores in the Experiment 3 for each four functions.*

ICON Preference scores	FUNCTION			
	Enter address	Search	Settings	My destinations
Arrow sign PS	.64	.57	.48	.58
Hearts PS	.39	.33	.26	**.78**
Mag. glass PS	.68	**.96**	.24	.33
POI stars PS	.43	.39	.25	**.86**
Star folder PS	.43	.35	.53	**.84**
White mag. glass PS	.64	**.92**	.31	.33
Pen PS	**.92**	.60	.57	.34
Road signs PS	.67	.51	.50	.70
Wheel PS	.11	.19	**.96**	.14
Wrench PS	.08	.19	**.88**	.10

The cross-tabulation for pairwise reaction times of the icons with PS > .70 is shown in Table 6, which can be used to search for the best possible icon set, considering both preference and how easily distinguishable they are from the other icons.

(Table 6. around here) Table 6. *Pairwise reaction times in milliseconds for icons with preference scores over .70. Pairings of the same functions are suppressed.*

		Enter address	Search		Settings		My destinations		
		Pen	Mag. glass	White Mag. glass	Wheel	Wrench	Hearts	POI stars	Star
Enter address	Pen	-	1675	1466	1164	1268	1599	1448	1235
Search	Mag. glass	1066	-	-	857	914	1073	1030	984
	White mag. glass	1315	-	-	917	1171	895	1070	1091
Set-	Wheel	1129	1061	963	-	-	1007	1009	983

tings	Wrench	1206	1081	1300	-	-	1001	1031	1243
My desti-nations	Hearts	1478	1504	1544	1297	1365	-	-	-
	POI stars	1324	1517	1549	1202	1281	-	-	-
	Star	1528	1270	1554	1362	1487	-	-	-

For example, when considering pen to hearts for Enter address, the participants took on average 1599ms to indicate their preference. Comparing this to the average reaction time for pen and star folder, 1235ms, reveals that the latter comparison is easier to make. A designer should choose star folder over hearts to represent ‘My destinations’, because while both are preferred icons for the function, they differ in how well the user can tell them apart from the pen icon, when searching the user interface for ‘Enter address’. The possible number of combinations to consider gets large even with the relatively small number of candidates with PS > .70 for their respective functions. The easiest way to use Table 6 for design is to choose any set of icons that has no pairwise reaction times over certain threshold, such as 1600 ms (Wierwille 1993) (in our experiment, this would exclude Mag. glass).

However, it is also possible to search the combination with smallest average pairwise reaction times. Searching through all the combinations, following set of preferred while distinguishable icons was found (Table 7): pen for ‘Enter address’, white mag. glass for ‘Search’, wheel for ‘Settings’, and star folder for ‘My destinations’. The average reaction time for this set of icons is 1226 ms, and the largest pairwise comparison reaction time is between star folder and white mag. glass when considering ‘My destinations’, 1554 ms.

(Table 7. around here) Table 7. *The optimised icon set.*

FUNCTION	Enter address	Search	Settings	My destinations
ICON	 Pen	 White mag. glass	 Wheel	 Star folder

5.3 Discussion

The results of the Experiment 3 indicate that the primed product comparisons method can be efficiently utilised for reducing the space of possible icons for system functions based on users' preferences and reaction times, but also for finding the best possible combination of icons out of alternative designs for a menu with different functions. The observed differences between the most preferred icons per function in Experiments 1 and 2 compared to the final icon set based on Experiment 3 illustrates that it is necessary to not only look at the subjective preferences (Experiment 1) and the associated reaction times per function (Experiment 2), but in order to find the optimised set of icons, all the icons should be compared with all the functions of the menu under design.

In the Experiment 1, magnifying glass icon was ranked as the icon to represent 'Search'. The pairwise comparisons in the Experiment 2 resulted with the same scores for magnifying glass icon and for the white magnifying glass icon. Finally, Experiment 3 indicated that the white magnifying glass is the more effective one in the combined set of icons. Additionally, in the Experiments 1 and 2 the POI star icon was selected as the icon with the most efficient semantic distance to its intended function; 'My destinations'. However, in the Experiment 3 the star folder icon for 'My destinations' function had the shortest semantic distance to its intended function and the largest to the other icons representing the three other functions, and was thus selected to the final set of icons. A possible next step could be to further lower the larger reaction times of the best icon set by applying small changes to these icons by studying different icon design characteristics, such as colour as a pop-out effect within an icon set.

6 GENERAL DISCUSSION

In this paper, we have introduced and validated a method based on primed product comparisons (Jokinen et al. 2015) in the context of in-car interface icon design in order to enable an in-car user interface designer to find an optimised set of menu icons with optimal semantic distances from a large set of alternative icon designs.

In the Experiment 1, we started by exploring drivers' preference rankings of four sets of icons for four in-car navigation system functions and the role of semantic distance behind the rankings by studying their associated verbal protocols. In the Experiment 2, the high levels of shared variance between the preference rankings of the Experiment 1 and the preference scores of the Experiment 2 indicated that the primed product comparison method is able to provide highly similar results than mere preference ranking. There was a low level of shared variance between the preference rankings and the preference scores on the 'Enter address' function ($R^2 = .11$), but for the other functions the levels were high ($R^2 > .66$). The discrepancy on the 'Enter address' function suggests that there was more variance in the preferences for this function than for the others, which is in line with the findings of the both experiments. This may be explained by the lack of an established convention to represent the function. However, the Experiment 3 was finally able to discriminate the optimal icon also for this function when all the icons were compared pairwise against all the functions.

The primed product comparison method provides additional information compared to mere preference rankings. The reaction times of the Experiment 2 indicated that preference was associated with faster judgment times, indicating that more preferred icons are also faster to process visually and mentally (i.e., semantic distance is significantly associated with preference, and therefore efficiently operationalised with preference scores and reaction times). The results of the Experiment 3 clearly indicate that the primed product comparisons method can be efficiently utilised not only for reducing the space of possible icons for system functionalities based on users' preferences and reaction times (as in the Experiment 2), but also for indicating the best possible combination of icons for a menu with different functions out of many possible combinations based on semantic distances.

For time- and safety-critical contexts, in particular, such as in-car infotainment systems, the optimised combination should not be based only on users' preferences but also on processing times for associating the intended function to an icon while competing for attention with all the other icons visible on the display. An optimised icon set is such, in which each icon is semantically as close as possible to the function that it visually represents while at the same time it is as far as possible to the other functionalities represented at the same time in the user interface. The primed product comparison method was able to indicate this kind of set of icons out of a large number of possibilities (in this case 19 icon alternatives to represent four functions).

Finally, the results of this study indicate that the following icons were the most optimal combination in terms of semantic distance for in-car navigation system user interfaces out of the icons under study; the pen icon to 'Enter address, 'the white magnifying glass as the icon for 'Search', the wheel as the icon for 'Settings', and the star folder icon for 'My destinations'. It should be noted that these icons with the optimal semantic distances would have not been found and selected based on the results of Experiment 1 and/or Experiment 2 alone, but the Experiment 3 was required in order to find this optimised combined set. All of the selected icons had the highest preference scores for their intended function, and the participants were able to make the preference judgement between an icon and its intended function in less than 1600 ms when displayed with any of the competing icons. For the in-car context this time limit can be critical as it has been found to be the maximum time drivers prefer to look off road with a single glance in any traffic situation (Wierwille 1993). According to the analysis of (Liang et al. 2014) over 1700 ms long in-car glances have a significant statistical association with safety-critical incident risk in real traffic. Despite of the lack of direct comparability between reaction times and in-car glance times, the findings suggest that the primed product comparisons method can be highly valuable for icon design in general, but for time-critical contexts in particular by minimising the required time to identify a menu function among a set of menu icons. This decreases the total glance time required to search a display, and may also decrease individual glance durations in glance-like information sampling conditions (Dobres et al., 2017).

6.1 Limitations and Future Research

The proposed method applies best for optimising the first-time contact with user interface icons. After a sufficient experience with a system, the users will probably become much more efficient in recognising the icons and processing times will decrease, as familiarity with pictorial representations ease cognitive information processing (e.g., McDougall & Reppa, 2013). However, for time- and safety-critical contexts, such as in-car systems, the user interfaces should be optimised for as fast adoption as possible. It can take a while until a set of icons with ambiguous semantic distances, within an icon and between the icons in the set, is efficiently memorised, especially if the use of the system functionalities is infrequent. Future research should assess the relationship between semantic distance and learnability of the individual icons as well as the relationship between semantic distance and the efficiency of visual search of an icon among a combination of icons.

The number of in-car functions offered on a modern in-car touch screen displays will continue to increase, and the greater the number of functions, the more important will be the optimisation of the user interface to reduce visual demands (Dobres et al., 2017; 2014). However, further research should validate the assumed positive effects of the optimised menu icons on visual distraction compared to less optimal icon set, for instance, in a driving simulator experiment with secondary visual-search tasks. The reaction times in pairwise comparisons do not directly predict in-car glance times in the real world, as there were, for instance, no gaze movements from the forward roadway to the display and back simulated in our experiments. In addition, there are often more than only two icons displayed at a time in the menus of in-car navigation systems. However, we wanted to have a plausible maximum acceptable limit for a reaction time of a pairwise comparison, which was adopted from the visual sampling model of Wierwille (1993). Further experiments with visual-search tasks are necessary in order to evaluate if an icon for a given function in a menu of icons can be found in less than 1600 ms of in-car glance time.

Drivers tend to split in-car glances after a certain level of uncertainty of the driving environment is reached, for instance, if finding a menu item takes more than 1600 ms (Wierwille, 1993). Thus, one could argue that the icon processing or interpretation time is not that critical in this context. However, there is evidence suggesting that the durations of all the encoding steps required to complete an in-car task should be minimised in order to minimise the possibility of visual distraction (Kujala & Salvucci, 2015). There are a number of ways to decrease the processing time of an icon besides minimising the semantic distance to the intended function. The results of the Experiment 1 suggest that new integrated icons for infotainment systems could be further elaborated. The participants were able to combine icon convention and cartographic symbol together easily and establish meaning for the new integrated POI star icon.

Several studies (e.g., Kujala & Salvucci, 2015; Lasch & Kujala, 2012; Kujala & Saariluoma, 2011) have indicated that limiting the number of concurrently displayed in-car menu items to six (or less) decreases the probability of long glances at the display. However, it is not unusual to see more than six menu items displayed on in-car displays at a time in a modern in-car infotainment system. The proposed method can be well utilised to optimise larger sets of icons, although according to these studies, it would make sense to design in-car menu structures with the maximum of six functions displayed simultaneously per screen, and optimise each menu icon set for a screen with the primed product comparison method. This would also enable faster tests for each screen compared to testing a screen with larger number of functions.

Generalisability of the optimised icon set to other icon design contexts can be partly considered. Icons for search and settings functions can be efficiently interpreted also in other than time- and safety-critical user interfaces due to their general nature as menu functions. However, for example, POI star icon with a cartographic sign could elicit confusing interpretations if attached to user interfaces without a cartographic use context. In this study, the focus was on semantic distances of icon metaphors, and the icons used as stimuli were black and white pictograms, which might have affected the processing times, because colour information draws attention and enhances memory performance more effectively than black and white information (Farley & Grant, 1976). Moreover, not only does the processing time spend to interpret the semantic distance of an icon guide the icon design decisions, so does the design context, which sets demands for visual usability (e.g., concerning legibility). Further analysis of icons' visual characteristics could focus on detecting different design features' effects on processing times, such as saliency effects. The method can be applied to study various different designs, but the variables studied need to be controlled in order to measure the effect of the characteristic under investigation, for example colour, abstractness of pictorial metaphors, and design eras of the icons (e.g. Silvennoinen & Jokinen, 2016).

In this study the studied icons were selected to be simplistic with little number of variables in the icons' pictorial representations to focus on examining semantic distances of the icons. The primed comparison method, as described, is intended to find the optimised set of menu icons in terms of semantic distance. There could be other icon design principles (e.g., the principles presented in Section 2) based on which an icon set can be optimised. However, we have argued that for the context of safety-critical systems, semantic distance is a critical icon design factor.

Due to practical reasons and depending on the number of alternative icon designs, it can be useful to run the paired product comparisons in two stages, in a similar approach to ours here: first, reducing the overall number of icons by testing separate sets per function; and then, testing against all the functions with the smaller (combined) set. Even if this type of testing in two stages with twenty participants can require 40 hours or more, the benefits for the final product can be large compared to a design/decision process that would solely rely on the intuition of the designer(s). Because, due to the ambiguity of visual language, which does not rely on strict rules as does written language (Carr, 1986), the intended functions for the icons can be interpreted with altering meanings (Isherwood, 2009; Isherwood et al., 2007). However, images are recognised and processed faster than textual information (Lodding, 1983; Lidwell et al., 2011), thus, adding textual information to icons can reduce ambiguities but increase processing times. The method of primed product comparisons is beneficial to interaction designers in optimising the whole icon set, not just individual icons. In designing and renewing icon sets, or introducing new icons to an existing icon set, the method can be used to detect the processing times and preferences of the whole icon set.

In addition, user interfaces are not globally preferred similarly among different cultures and the design decisions also affect usability of the systems (Reinecke & Bernstein, 2011). Thus, icons in user interfaces might convey different semantic information in different cultures. Localization of icon's semantic distance could be tested with primed product comparisons to obtain the most effective semantic distance between the icon's representation and its intended function for the target culture. In addition, age, previous experiences and familiarity with technological devices can influence the interpretations and thus the results. The three experiments reported here were conducted with University students. The participants were deliberately recruited to be a homogenous group of participants for control purposes due to the first time of studying the method in terms of close and far semantic distances of icons. Therefore, future studies will include more heterogeneous participant groups, for example elderly people.

The basic tools for the primed product comparisons are easy to implement and the technological requirements are simple. Parts of the testing and analysis steps could also be automated to improve efficiency. For instance, the last step of pairwise comparisons required for detecting the optimal combined icon set, could be done by an algorithm searching for the combination with smallest average pairwise reaction times, and thus, lowering the manual workload of the process.

Future research of icon design for in-car infotainment systems will greatly benefit from studying semantic distance as the relatedness of the intended function of the icon's pictorial representation, especially as related to users' mental models of the action elicited. Additionally, the method could be applied to examine semantic distances of information obtained also with other sensory modalities than the visual modality. For instance, auditory and haptic information of in-car functionalities could be examined in terms of semantic distance. Moreover, processing fluency of combinations of sound and visual information could be studied with semantic distance, as audio and visual information are the most common output channels in current in-car user interfaces (Zhao, Brumby, Chignell, Salvucci, & Goyal, 2013), and thus are required to be comprehended quickly. Although we have focused on in-car navigation system icons here, the current findings, the method, and the design principles are likely to be applicable for the design of in-vehicle user interfaces in general. A cumulating database on icon features' effects on semantic distances and the associated processing times in the automotive context could be utilised in in-car user interface designer tools such as Distract-R (Salvucci, 2009) that are intended for rapid testing of distraction effects of in-car user interface designs.

ACKNOWLEDGEMENTS

This research was partly supported by OPTIMUM (Optimal Multitasking with Ubiquitous Media), a research project funded by TEKES, Finnish Funding Agency for Technology and Innovation [grant number 830/31/2011], Nokia, and Cassidian Finland. Many thanks to Hilkka Grahn and Niina Holmstedt for their help in conducting the experiments, and to Dario Salvucci for helpful comments.

References

Blackwell, A. (2006). The Reification of metaphor as a design tool. *ACM Transactions on Computer Human Interaction, 13*(4), 490–530. DOI:http://dx.doi.org/10.1145/1188816.1188820

Bocker, M. (1993). A Multiple Index Approach for the Evaluation of Pictograms. *Proceedings of the International Symposium on Human Factors in Telecommunication*, pp. 73–84.

Boren, M.T., & Ramey, J. (2000). Thinking Aloud: Reconciling Theory and Practice. *IEEE Transactions on Professional Communication, 43*(3), 261–278. DOI:http://dx.doi.org/10.1109/47.867942

Byrne, M.D. (1993). Using Icons to find Documents: Simplicity is Critical. *Proceedings of Conference on Human Factors in Computing Systems,* INTERACT '93 and CHI '93. ACM Press, New York, NY, 446–465. DOI:http://dx.doi.org/10.1145/169059.169369

Carr, T.H. (1986). Perceiving Visual Language. In: K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of Perception and Human Performance: Vol. 2. Cognitive Processes and Performance* (pp. 1–92). Oxford, UK: John Wiley and Sons.

Caplin, S. (2001). *Icon Design: Graphic Icons in Computer Interface Design*. London, UK: Cassell.

Chiu, S., Koong, C-S., & Fan, S-H. (2012). Icon Design for Preschoolers: Implications Derived From Child Development. *Procedia – Social and Behavioral Sciences, 64*, 228–237. DOI:http://dx.doi.org/10.1016/j.sbspro.2012.11.027

Dobres, J., Chahine, N., & Reimer, B. (2017). Effects of ambient illumination, contrast polarity, and letter size on text legibility under glance-like reading. *Applied Ergonomics*, *60*, 68-73. DOI:http://dx.doi.org/10.1016/j.apergo.2016.11.001

Dobres J., Reimer, B., Mehler B., Chahine, N., & Gould, D. (2014). A pilot study measuring the relative legibility of five simplified Chinese typefaces using psychophysical methods. *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications,* AutomotiveUI '14. ACM press, New York, NY. DOI:http://dx.doi.org/10.1145/2667317.2667339

Ericsson, K.A., & Simon, H.A. (1980). Verbal Reports as Data. *Psychological Review, 87*(3), 215–251.

Farley F.H., & Grant, A.P. (1976). Arousal and cognition: Memory for color versus black and white multimedia presentation. *The Journal of Psychology: Interdisciplinary and Applied, 94*(1),147–150. DOI:http://dx.doi.org/10.1080/00223980.1976.9921410

Frutiger, A. (1997). *Signs and Symbols. Their Design and Meaning,* second ed. Cham, Switzerland: Syndor Press GmbH.

García, M., Badre A.N., & Stasko, J.T. (1994). Development and Validation of Icons Varying in Their Abstractness. *Interacting with Computers, 6*(2), 191–211. DOI:http://dx.doi.org/10.1016/0953-5438(94)90024-8

Gatsou, C., Politis, A., & Zevgolis, D. (2012). The importance of mobile interface icons on user interaction. *International Journal of Computing Science and Applications, 9*(3), 92–107.

Gaver, W.W. (1991). Technology Affordances. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Reaching Through Technology,* CHI'91. ACM press, New York, NY, 79–84. DOI:http://dx.doi.org/10.1145/108844.108856

Gittins, D. (1986). Icon-based Human-computer Interaction. *International Journal of Man-Machine Studies, 24*, 519–543. DOI:http://dx.doi.org/10.1016/S0020-7373(86)80007-4

Goonetilleke, R.S., Shih, H.M., On, H.K., & Fritsch, J. (2001). The effects of training and representational characteristics in icon design. *International Journal of Human-Computer Studies, 55*, 741–760. DOI:http://dx.doi.org/10.1006/ijhc.2001.0501

Hekkert, P. (2006). Design Aesthetics: Principles of Pleasure in Design. *Psychology Science 48*(2), 157–172.

Huang, S-H., Shieh, K-K., & Chi, C-F. (2002). Factors affecting the design of computer icons. *International Journal of Industrial Ergonomics, 29*, 211–218. DOI:http://dx.doi.org/10.1016/S0169-8141(01)00064-6

International Organization for Standardization. (2009). Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and test procedures for in-vehicle visual presentation (ISO 15008:2009), ISO, UK.

Isherwood, S.J. (2009). Graphics and Semantics: The Relationship between What is Seen and What Is Meant in Icon Design. In D. Harris (Ed.), *Engineering Psychology and Cognitive Ergonomics, Lecture Notes in Computer Science, Vol. 5639* (pp. 197–205). Berlin Heidelberg: Springer-Verlag.

Isherwood, S.J., McDougall, S.J.P., & Curry, M.B. (2007). Icon Identification in Context: The Changing Role of Icon Characteristics with User Experience. *Human Factors, 49*(3), 465–476. DOI:http://dx.doi.org/10.1518/001872007X200102

Johann V., & Mahr, A. (2011). New Icon Selection Test for the Automotive Domain Based on Relevant ISO Usability Criteria. *Adjunct Proceedings of 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications,* AutomotiveUI 2011. Salzburg, Austria, 25–26.

Jokinen, J.P.P., Silvennoinen, J.M., Perälä, P.M.H., & Saariluoma, P. (2015). Quick affective judgments: Validation of a method for primed product comparisons. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* CHI '15. ACM Press, New York, NY, 2221–2230. DOI:http://dx.doi.org/10.1145/2702123.2702422

Kay, A. (1990). User interface: A personal view. In B. Laurel, & J.S. Mountford (Eds.), *The Art of human-computer interface design* (pp. 191–207). Boston, MA: Addison-Wesley Longman Publishing.

Klauer, S.G., Dingus, T.A. Neale, V.L. Sudweeks, J.D., & Ramsey, D.J. (2006). *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data.* DOT HS Rep. 810 594. U.S. National Highway Traffic Safety Administration, Washington, DC.

Krippendorff, K. (2004). *Content analysis: an introduction to its methodology*, second ed. Thousand Oaks, CA: Sage.

Kujala T., & Salvucci, D.D. (2015). Modeling visual sampling on in-car displays: The challenge of predicting safety-critical lapses of control. *International Journal of Human-Computer Studies, 79*, 66–78. DOI:http://dx.doi.org/10.1016/j.ijhcs.2015.02.009

Lasch, A., & Kujala, T. (2012). Designing browsing for in-car music player: effects of touch screen scrolling techniques, items per page and screen orientation on driver distraction. In *Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 41-48). ACM.

Kujala, T., & Saariluoma, P. (2011). Effects of menu structure and touch screen scrolling style on the variability of glance durations during in-vehicle visual search tasks. *Ergonomics*, *54*(8), 716-732.

Liang, Y., Lee, J.D., & Yekhshatyan, L. (2012). How dangerous is looking away from the road? Algorithms predict crash risk from glance patterns in naturalistic driving.

Human Factors, 54(6), 1104–1116. DOI:http://dx.doi.org/10.1177/0018720812446965

Liang, Y., Lee, J.D., Horrey, & W.J. (2014). A looming crisis: the distribution of off-road glance duration in moments leading up to crashes/near-crashes in naturalistic driving. *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting*. Sage, 2102–2106. DOI:http://dx.doi.org/10.1177/1541931214581442

Lidwell, W., Holden, K., & Butler, J. (2003). *Universal Principles of Design*. Beverly, MA: Rockport Publishers.

Lodding, K. (1983). Iconic interfacing. *IEEE Computer Graphics and Applications, 3*(2), 11–20. DOI:http://dx.doi.org/10.1109/MCG.1983.262982

McDougall, S.J.P., & Curry, M.B. (2004). More than just a picture: icon interpretation in context. *Proceedings of the International Workshop on Coping with Complexity*. University of Bath, UK, 73–81.

McDougall, S.J.P., Curry, M.B., & de Bruijn, O. (1999). Measuring symbol and icon characteristics: norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols. *Behavior Research Methods, Instruments, & Computers, 31*(3), 487–519.

McDougall, S.J.P., Curry, M.B., & de Bruijn, O. (2001). The effects of visual information on users' mental models: An evaluation of pathfinder analysis as a measure of icon usability. *International Journal of Cognitive Ergonomics, 5*(1), 59–84. DOI:http://dx.doi.org/10.1207/S15327566IJCE0501_4

McDougall, S.J.P., & Reppa, I. (2013). Ease of icon processing can predict icon appeal. In M. Kurosu (Ed.), *Human-Computer Interaction, Human-Centred Design Approaches, Methods, Tools, and Environments, Lecture Notes in Computer Science, Vol. 8004* (pp. 575–584). Berlin Heidelberg: Springer-Verlag.

Mullet, K., & Sano, D. (1995). *Designing Visual User Interfaces: Communication Oriented Techniques.* NJ: Prentice hall.

National Highway Traffic Safety Administration. (2013). Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices. (NHTSA-2010-0053).

Ng, A.W.Y., & Chan, A.H.S. (2008). Visual and Cognitive Features on Icon Effectiveness. *Proceedings of the international multiconference of engineers and computer scientists,* IMECS 2008. Honk Kong, 19–21.

Norman, D. (2007). Three challenges for design. *Interactions, 14*(1), 46–47. DOI:http://dx.doi.org/10.1145/1189976.1190002

Peirce, C.S. (1986). Logic as semiotic: the theory of signs. In R.E. Innis (Ed.), *Semiotics: an introductory reader*. Bloomington, IN: Indiana University Press.

Poulin, R. (2011). *The language of graphic design: an illustrated handbook for understanding fundamental design principles.* Beverly, MA: Rockport Publishers.

Prada, M., Rodrigues, D., Silva, R.R., & Garrido, M.V. (2015). Lisbon symbol database (LSD): subjective norms for 600 symbols. *Behavior research methods*, 1-13. DOI:http://dx.doi.org/10.3758/s13428-015-0643-7

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372–422. DOI:http://dx.doi.org/10.1037/0033-2909.124.3.372

Reinecke, K., & Bernstein, A. (2011). Improving performance, perceived usability, and aesthetics with culturally adaptive user interfaces. *ACM Transactions on Computer-Human Interaction, 18*(2), Article 8, 29 pages. DOI:http://dx.doi.org/10.1145/1970378.1970382

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction Design: Beyond Human-Computer Interaction,* third ed. Chichester, UK: Wiley.

Salman, Y.B., Cheng, H.-I., & Patterson, P.E. (2012). Icon and user interface design for emergency medical information systems: A case study. *International Journal of Medical Informatics, 8*(1), 29–35. DOI:http://dx.doi.org/10.1016/j.ijmedinf.2011.08.005

Salvucci, D.D. (2009). Rapid prototyping and evaluation of in-vehicle interfaces. *ACM Transactions on Computer-Human Interaction, 16*(2), Article 9, 33 pages. DOI:http://dx.doi.org/10.1145/1534903.1534906

Silvennoinen, J., & Jokinen, J.P.P. (2016). Aesthetic Appeal and Visual Usability in Four Icon Design Eras. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems.* ACM Press, New York, NY, 4390–4400. DOI:http://dx.doi.org/10.1145/2858036.2858462

Silverman, D. (2005). *Doing Qualitative Research*. Thousand Oaks, CA: Sage.

Victor, T., Dozza, M., Bärgman, J., Boda, C.-N., Engström, J., & Markkula, G. (2014). *Analysis of Naturalistic Driving Study Data: Safer Glances, Driver Inattention, and Crash Risk.* Technical Report No.S2-S08A-RW-1. Chalmers University of Technology, Sweden.

Ware, C. (2004). *Information Visualization*. CA: Morgan Kaufman.

Warren, C., McGraw, P.A., & van Boven, L. (2011). Values and preferences: defining preference construction. *Wiley Interdisciplinary Reviews: Cognitive Science, 2*(2), 193–205. DOI:http://dx.doi.org/10.1002/wcs.98

Weidenbeck, S. (1999). Use of icons and labels in an end user application program: an empirical study of learning and retention. *Behaviour & Information Technology, 18*(2), 68–82. DOI:http://dx.doi.org/10.1080/014492999119129

Wierwille, W.W. (1993). An initial model of visual sampling of in-car displays and controls. In A.G. Gale, I.D. Brown, C.M. Haslegrave, H.W. Kruysse, & S.P. Taylor (Eds.), *Vision in vehicles IV* (pp. 271–279). Amsterdam: Elsevier.

Zhao, S., Brumby, D. P., Chignell, M., Salvucci, D., & Goyal, S. (2013). Shared input multimodal mobile interfaces: Interaction modality effects on menu selection in single-task and dual-task environments. *Interacting with Computers, 25*(5), 386–403. DOI:http://dx.doi.org/10.1093/iwc/iws021

VI

AESTHETIC APPEAL AND VISUAL USABILITY IN FOUR ICON DESIGN ERAS

by

Silvennoinen, Johanna M. & Jokinen, Jussi P. P. 2016

In *Proceedings of the 2016 Conference on Human Factors in Computing Systems – CHI '16* (pp. 4390-4400). New York: ACM.

VII

APPERCEPTION AS A MULTISENSORY PROCESS IN MATERIAL EXPERIENCE

by

Silvennoinen, Johanna M., Rousi, Rebekah, Jokinen, Jussi P. P. & Perälä, Piia M. H. 2015

In *Proceedings of the 19th International Academic Mindtrek Conference* (pp. 144-151). New York: ACM.