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Do You See What I See?

Investigations into the Underlying
Parameters of Visual Simplicity

Doctoral thesis

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NTNU
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Parameters of Visual Simplicity

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To young children everywhere

Your wisdom often guides us to the simple answers

...if only we choose to listen.

Abstract

Motivated by a longstanding interest in timeless design, this research focused on visual simplicity due to its potential as a core value of a design's longevity. Multiple studies were conducted to investigate how people view, interpret, and understand visual stimuli, with simplicity as a fundamental aesthetic approach. The research goal was to uncover what the underlying components of visual simplicity may be, and how people judge those components. The research into visual simplicity is rooted in the following questions:

    I. What is visual simplicity and what are the graphic design parameters that determine it?
    II. How do people interpret visual simplicity?
    III. Does everyone agree?

The range of visual stimuli tested here included aspects of the real world as well as the computer realm. The stimuli included (in order): CD covers, architecture and/or public spaces, miniaturized poster art, graphical user interface ('GUI') screen layouts and GUI icons. The initial studies included adult participants only. Results revealed a consistency in responses: In both the real world and GUI realms, adults answered consistently that "simple" design meant a scant amount of detail and minimal use of line, color, and other graphic design parameters— whereas "complicated" visual design meant the opposite. For adults, there seemed to be a reliable set of design parameters that when

combined, elicited a "simple" or "complicated" response to a visual design, regardless of media. However, the final set of studies revealed an unforeseen phenomenon: youths (≤ age 13) did not respond consistently with adults. In general, youths did not consistently associate detail-scant GUI icons with simplicity, but in many cases with being more complicated. This revealed a possibility that people go through a period of transition during which they change their interpretations of minimalized, abstracted imagery and then associate those characteristics with being "simple". This phenomenon led to a discussion regarding the potential existence of 'visual archetypes' and how they might be interpreted by viewers of various ages. 'Visual archetypes' refer to a design that uses the least amount of visual information required to communicate the message.

The contributions of this doctoral research include:

- expanded awareness of design parameters that are associated with the relationship between visual Simplicity-Complicated
- insight into the emotional aspects connected with visual Simplicity-Complicated
- awareness that not all viewers interpret Simplicity-Complicated identically (age-based differences were revealed—there may be other differences)
- recognition of the possibility for unintentional design presumptions
- discussion of visual archetypes

This research contributes to the design community by demonstrating that people can interpret design differently than designers might presume and/or intend. Although the research raises awareness of potential interpretive differences between children and (primarily) mid-life adults, the discussion can perhaps apply to seniors as well. Importantly, the research revealed that children are highly capable interpreters of our culturally- and computer-based visual information.

Preface

After I'd begun teaching master-degree level industrial design engineering students at NTNU, I visited my former design professor Armin Hofmann. Hofmann is an internationally renowned Swiss graphic designer whose masterpieces enriched the 1970's-90's landscape and continue to inspire to this day. I interviewed him so that I could best advise my eager, talented students. When I asked him "What is the most important visual aspect of graphic design?" he instantly replied:

"Contrast."

After a long pause, he continued:

 "...Contrast between light and dark. Between positive and negative elements in a composition. Between simplicity and overdesigning.
Yes—the contrast between simplicity and too much complication".

With those few sentences, my research goal was clear. Having been fascinated with timeless design all my life, I decided to investigate the relationship between "simple" relative to "complicated". I suspected that this relationship served as a core tenet in how any design could withstand cultural and temporal trends. Being a graphic designer myself, it made sense to investigate this concept in visual design. I had no idea that I'd embarked upon a research quest that would illuminate the complexity of simplicity as a topic. Ultimately, the research provided me with profound respect and appreciation for the insightful ways in which young children view our world.

Acknowledgements

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Part I

SYNTHESIS

1 Introduction

Design—like life—is simple
That's what makes it so damned complicated.

Paul Rand, to me
Summer 1996

This research project grew from a longstanding fascination with *'timeless'* design. Examples range from ancient cave drawings in the south of France, to the great pyramids of Egypt, to a Japanese tea bowl and to an Art Deco window. Notice that none of the mentioned items require an accompanying photo to prompt one's memory. Along with so many other potential examples, each of these can be recalled with ease because they remain embedded in our collective cultural memory. These are designs that have truly withstood the test of time.

Yet when comparing the core aesthetic aspects of the aforementioned examples, it becomes clear that *'timeless'* design cannot be pinned down easily. In the four examples alone, there is a great variety of color, detail, symbolism, production methodologies, contexts etc. My interest in timeless design has centered upon trying to uncover the essential aspects of a design that guarantee its appeal long after its immediate temporal context has passed. In evaluating which aspects might comprise "timelessness", some aspects were deemed too vast and

obtuse for research purposes. For example, elegance, beauty and harmony were considered too subjective.

After much consideration, I decided to focus on one common aspect of timeless design: the relationship between visual Simplicity-Complicated. Targeting on one half of this pairing meant an inherent inclusion of the other, so *Simplicity* was chosen as a topic. Idea generation for simplicity included what it means, what it looks like, how different people interpret and/or live its lifestyle and ultimately, how visual simplicity survives the test of time. Because of my education in graphic design, art, psychology, and computer interface design, my natural approach was to investigate simplicity as an aesthetic aspect of art and design. My interest in timelessness-via-simplicity can be summed up in the following question:

What makes something look (or appear to look) 'simple'?

With presumptions fully in place, I began a journey of discovery into how complicated 'simplicity' actually is—and how these two apparently opposing aspects are deeply interrelated. Early on, it became clear that visual simplicity is more than a generic value judgment. It incorporates a highly detailed set of characteristics about which people have an opinion, even if they claim they've never thought about it. Constraining the topic to 'visual' simplicity was not automatic either: visual simplicity can range from the interior design of an up-market boutique to a philosophical ideology upon which someone agrees entirely, somewhat, or not at all. Nick Chater describes one value of visual or aesthetic simplicity as:

> Aesthetic judgments quite generally seem sensitive to simplicity. From our pleasure in 'economy of language' to our preferences for the symmetries of a snowflake rather than the muddle of a lump of mud, simplicity appears to be a guiding aesthetic principle. Simplicity is not, of course, the whole story about aesthetics—simple shapes like a plain white square seem to hold little aesthetic interest—but it seems to be at least part of the story [Chater, 1997, p. 495].

Chater proceeds to briefly describe other aspects of simplicity: quantification, cognition, perception and probability. Appropriately for this research, simple patterns, hypotheses, explanations or theories are more reliable than complicated ones. This aspect of reliability establishes an appealing association that makes simple solutions more attractive than detailed or involved ones [Chater, 1997]. Importantly, simplicity can be not only aesthetically appealing—it can be of imminent practical importance as well. Simplicity is connected with emotional, aesthetic and interpretive factors that are highly interrelated. Basing my research questions upon what constitutes visual simplicity became easier with Chater's description. This will be described in further detail in Ch. 2, Theoretical Foundations.

This research strived to discover more about the core aspects, or 'parameters' that describe visual simplicity. As Figure 1 shows, these parameters of simplicity operate on three different scales (macro, meta and micro) and across two realms (real world and computer-based compositions). After establishing that adults mostly agreed as to what constituted "simple" and "complicated" design in the real world (via CD covers, public spaces), I pursued graphical user interface (GUI) icons as an entry point into the computer realm.

GUI icons are graphic symbols that represent actions or operations, and are designed to convey ideas or information non-verbally [García & Stasko, 1994]. In the computer realm, they are pictographic representations of data or operations that have replaced commands or menus within an electronic system [Gittens, 1986]. Because GUI icons are small in size, I presumed they would provide a quick and easy 'low-level' entry point into GUI design. By using these tiny, apparently innocuous compositions, I intended to discover the underlying design parameters that frame visual simplicity, thus making simplicity more available as a design approach. GUI icons had an additional practical bonus: they were easily accessible for a global audience aided by a computer or electronic device.

Originally GUI icons were meant to serve as an initial step that would lead my research into increasingly complicated aspects of design (see Figure 1). The icons were supposed to reveal their secrets quickly, so that my research could progress up the ladder and allow me to test the design parameters in larger, more complicated compositions.

Scale:	Realm:	Potential areas of research:	Examples:	This research utilized:
		4D Composition	Film, experience design, augmented reality	
Macro		3D Composition	Architecture, public spaces tangibles, scultpure, furniture	Metropolitan spaces, self-made CD covers
	Real world	Photography	Original or edited	
		2D Composition	Art, signs, posters	Armin Hoffman's posters
Meta		2D Info visualization	Charts, graphs, tables	
		Screen design	PC, tablet or situational (e.g. air traffic control)	
	GUI	App design	Industrial or custom	Introductory screens for online booking app
Micro		GUI Info visualization	Interactive charts, graphs	
		GUI Icon	Actionable icon, emoticon	80 referential icons (analog and GUI format)

☐ Not researched
☐ Somewhat researched
■ Primary area of research

Figure 1. The progression of potential areas of research (from bottom-top), with actual researched areas highlighted in blue. Diagram made by the author.

As many others have experienced, research does not always proceed as planned. In retrospect, my approach to GUI icons as an innocent form of 2D communication was highly naïve because icons alone provide more than ample room for doctoral investigation and research[1]. Indeed, some researchers have dedicated their entire careers to these small forms of visual communication. Although GUI icons were not intended to be the primary focus of the larger research project, it concludes with a large, long-term study conducted with them (Paper 7).

1.1   Research purpose

Why Do Research?

In 1637, Descartes described in his *Discourse on Methodology* that in the search for truth, objectivity and evidence are important [Ritchie, Lewis, Nicholls, & Ormston, 2013]. The relevance of research to the current state of scientific development has been avidly discussed ever since. This fundamental 'why?' question is particularly relevant for software designers due to the field's rapid speed of development. According to Basili & Selby, "intuition is not always the best teacher" [1986 p. 1]. For them, experimentation in software engineering involves multiple iterations of a hypothesis and a testing procedure, which in turn refines the hypotheses or develops new ones. Sociologist Brené Brown [2011] defines research as the study of phenomena for the specific reasons to control and predict. In human computer interface (HCI) design, Mackay & Fayard [1997] describe the purpose of HCI research as the means to pursue a variety of goals ranging from providing general theories and their associated principles to reporting detailed observations of real-world engagement, to creating innovative new solutions in all types of research. For Mackay & Fayard, the questions of 'why, what, when & how' drive the researcher in their search for truth. Research strives to continually answer questions (large and small) about humanity itself.

The aim of this research project

The aim of this research project was to discover—through exploratory methodology and user testing—how 'Simplicity' and 'Complicated' relate to each other as underlying parameters of visual design. Importantly, I wished to discover how people interpret and assign their aesthetic value judgments, and if those interpretations/judgments held true across a variety of environments. Lastly, I hoped to learn which visual parameters potentially 'weighed more' than others in 2D/3D design.

Since "80% of the information we receive comes through our eyes" [Schwartzberg, 2011, 2:38], and so much of our culture engages our visual sense, I chose to investigate how people interpret *visual*

information over other types: haptic, auditory, and multi-sensory. Inspired by Professor Armin Hofmann, the contrast between visual simplicity and complexity provided a core construct that sufficiently covered my area of interest. Simplicity served as a 'framing concept' [Schön, 1983] in order to constrain the project.

The methodology was intentionally exploratory. I planned to begin with basic research questions and then pursue the path of inquiry as needed, by using all types of methodologies available. Because the research involved visual stimuli, I asked that participants look at something and respond to it so that I could calculate average interpretations according to subgroups of the population. In some studies, I asked the participant to verbally describe what they had seen and/or thought during the experiment. Both of these approaches led to a mixed methodology that included quantitative and qualitative research approaches as they are often characterized by the social sciences.

1.2 Limitation of scope

Early phases of this research were hindered by unclear ideas that pulled me in different directions. Exploratory research is an organic process. Although each path I pursued was intriguing, the paths often ended in periods of research and goal reformulation as I became aware of my prior assumptions. Due to this periodic slowdown, the main research approach took substantial time to crystallize. For example, I ventured into augmented reality, medical/radiological tool design and commercial aircraft cockpits[2] as potential areas in which to learn how specific users interact with simplicity (or lack thereof). Progress moved slowly and followed many unfinished leads, yet one aspect remained constant: the research would remain exploratory in nature. I continued to rely upon the fact that one research topic would lead to the next. The outer frame of the research was always rooted in the question 'How do viewers interpret visual simplicity?'. Returning often to this framing concept kept the research constrained yet flexible. Because visual

design is connected to a vast number of fields, it is appropriate to provide examples of what this research **_did not_** set out to explore in depth (although some fields were addressed lightly):

- Neurobiological perception
- Communication theory
- Cognition, precognition or memory
- Learning/education theory
- Art/color theory
- Composition theory

- Semiotics
- Mathematics
- Philosophy
- Psychology
- Sociology
- Attention theory

1.3 Research questions

The fundamental question behind this collective body of research is:

What makes something be interpreted as visually simple?

This question automatically leads to: How is "simple" different from "complicated"? Taking this question further, there are three more focused research questions (RQ's) upon which this research project is based:

I. **What is visual simplicity?**
II. **How do people interpret visual simplicity?**
III. **Do people agree?**

These three RQ's apply to any entity that displays visual simplicity regardless of scale (macro, meta, micro) or realm (real world or GUI). The following subquestions were devised to help in order to help narrow the research topic:

I. **What is visual simplicity?**
- Regardless of scale, what makes an object appear "simple"?
- What are the visual parameters that determine simplicity?
- What kind of visual information communicates most effectively: simple or complicated?

II. **How do people interpret visual stimuli?**
- What are the important design parameter(s) in visual communication?
- Is 'contrast' the most important parameter

(as Armin Hofmann believes)?
- Is visual simplicity important—if so, how?

III. Do people agree?
- Is there a consensus on what the terms "simple" or "complicated" actually mean and how they should be interpreted?
- Are there patterns in how people respond to visual simplicity?
- Is there a commonly understood visual archetype for 'simple' design that everyone understands?

The RQ's convey an implicit issue represented by two seemingly straightforward columns in Figure I (p. 4), 'Scale' and 'Realm'. Although not detailed, these gradients encompass much more diversity than is suggested by the figure. The research proceeded with an intention to discover if simplicity is consistent (or not) with regard to Scale and Realm—and if so, how?

Table I shows the RQ's addressed in the papers. Because this research approach was exploratory, it is important to note that the RQ's were somewhat mixed and overlapping at various points during the process. For example, some of the early papers introduced RQ's that were followed up in subsequent papers. It is important to recognize that even though each paper addresses all three RQ's generally, some papers focus on certain RQ's with more emphasis. Table I shows relative weight of each paper's RQ focus.

Table II. Overview of the primary research questions (RQ's) addressed in each paper

Research questions:	Research papers						
	1	2	3	4	5	6	7
I. What is visual simplicity?	•	•	•	•	•	•	•
II. How do people interpret visual stimuli?	•	•	•	•	•	•	•
III. Do people agree?					•	•	•

2 Theoretical Foundations

Despite all our efforts to simplify things—efforts constantly expanding in order to keep abreast of steadily increasing complexity—

nothing is very simple anymore.

George Nelson, in the introduction to Armin Hofmann's
Manual of Graphic Design, 1965

2.1 Visual messages

Researching simplicity in our current cultural landscape—with its overwhelming amount of visual stimuli—requires refamiliarization with the fundamental aspects of how we interpret visual messages in general. Dondis [1973] analyzed types of visual communication that describe how we express and receive visual messages on three sublevels: Representation, Symbolism and Abstraction.

Representation
For Dondis, 'representation' refers to what we actually see and recognize from the environment. We call it 'reality' and it forms our predominant visual experience. Immersive computers, visuals and videos are currently capable of rendering representational accuracy at

an astounding level of sophistication, particularly in augmented reality[3]. It is becoming increasingly difficult to determine if an animation has been filmed live or created digitally. Representative visual messages can also exist in realistic 3D models or sculptures that almost exactly mimic the original—this is known as 'art realism' [4]. For Arnheim, representational images are inherently limited due to their need to represent natural objects by using minimal structural features [Arnheim, 1954]. Mimetic images such as those made by trompe-l'oeil artists are examples of strong attempts to mimic the real world as closely as possible.

Another way of capturing a scene representatively is through a carefully rendered photograph or video in full, natural color. Unretouched photographs constitute the closest match to the original neuroperceptual human experience. Photos replicate the 'real' object within its contextual environment as best as possible. For some viewers, photographs *equal* reality. However, photographs (and photorealistic images) are distinct from reality because they capture and re-represent the scene in a compositional framework that is determined by the photographer. By pointing camera/recording device at a specific scene, the photographer eliminates the rest of the available scene, thus isolating the composition from its larger context. Although an unretouched photograph is still an encapsulated, composed subset of reality, Dondis claims that it is still the most technically dependable method of reproducing a real object [Dondis 1973]. Regardless, a photograph or video can never replicate the natural, multi-sensory experience in totality.

For this research, questions arose regarding how people interpret or assign value to highly representational visual messages. In particular: do they consider them 'simple' or 'complicated'? In other words: Do more visual elements in a representative composition make the overall message 'complicated' (due to the compounding effect of numerous visual parameters) or 'simple' (due to its closer approximation to reality)? To investigate this idea, this research used three types of real

world representative visual stimuli: CD covers, public spaces and some examples of miniaturized poster art.

Symbolism

Since early humanity, symbols have embodied the enormous range of messages that attach meaning to a condensed, distilled form of communication. Not limited to visuals, 'symbolism' can engage any of the fives senses and take many forms (e.g. visual images, dance, music, ideas, sounds, rituals, gestures etc.). Archeological discoveries in central Europe demonstrate that mankind's use of symbolism is truly ancient.[5] According to Walter [2015], it was not the invention of stone tools or other technologies (e.g. iron) that mark the greatest innovation of humankind, but the invention of symbolic expression by the first artists.

This research refers to a 'symbol' as a visually graphical composition whereby its relation to its referent is conventional or arbitrary [Gatsou, Politis & Zevgolis, 2011]. Although it can still retain some of its resemblance to the referent, a symbol need not directly imitate the referent. Importantly, symbols must be learned, and they can only function in a society that i) agrees upon their meaning and ii) interprets that meaning consistently. For Dondis, symbols are visualizations whose meaning has been 'pinned' on them [1973]. Symbols can refer to a thing, concept, group, an idea, a business, institution, political party, form of nature etc. The more abstracted a symbol is, the more the viewer is required to insert meaning in order to interpret it. This is where symbols become codified information: the symbol requires that the viewer be familiar with and learn its referent. For Susanne Langer, a 20th-century philosopher, symbols serve as an 'epistemic of community' capable of forming an individual's reality and binding a culture together. Symbols could be divided into two types: "discursive" in science/logic, and "presentational" in the humanities/arts [Lunsford, 1995]. For Frutiger, a graphic designer, symbolic elements create an implied value upon which the viewer infers an underlying meaning—this act requires that people seek an interpretation [Frutiger, 1989]. The viewer's interpretive success is determined by their experience, exposure, history, and most

importantly, their ability to recall and/or draw upon those aspects of prior learning. In Gatsou, Politis & Zevgolis' study [2011], some of the viewers, particularly elderly users, were not readily able to recognize the icon symbol's referent, thus rendering their meaning useless.

Icons depict their referent by incorporating key characteristics of the referent's appearance. According to Pierce, an icon is a type of sign that is able to represent its object due to its similarity [Pierce via Mitchell, 1986]. In this way, icons are well suited for international use, particularly when people do not share a common language [Beardon, 1992]. In the computer realm, GUI icons are a visual simplification of a complex process. For example, the startup sequence of early computers often bombarded the viewer with a scrolling checklist of text (DOS) of system-based things that could go wrong. Contrastingly, Apple®'s "smiley Mac" quietly reassured the viewer that all was well by use of a small, happy icon centered in the screen [Caplin, 2001]. Apple Macintosh® was one of the first computer systems that based its entire desktop metaphor on the user's interaction with GUI icons.

Abstraction

For Dondis [1973], abstraction refers to an object that has been reduced to its elemental visual components. This can result in a direct, emotional, and/or primitive message-making experience on the part of the viewer. Abstraction distills the multiple visual factors to only the essential yet typical features of what is being represented. Abstraction can also exist purely where it draws no connection with familiar visual data, environment or experience. For Arnheim, abstraction occurs when the mind is liberated from its normal allegiance to nature, and can organize shapes according to its own tendencies. Taken too far, high abstraction art can risk disconnecting itself from the wealth of recognizable existence [Arnheim, 1954].

In HCI design, abstract icons show constructs at a higher conceptual level [García, 1994]. Such objects tend to be less pictorial, have less obvious connections with real-world items, and make more use of

shapes, arrows, and lines [McDougall, Curry & De Bruijn, 1999; Isherwood, McDougall & Curry, 2007]. Some of the GUI icons' used for this research included visual compositions that were highly economized, minimized, and abstracted. Initially, I held broad assumptions that most (if not all) viewers would interpret the abstracted designs similarly, and I presumed the responses would be consistent. Gatsou et al. imply this when they describe: "As the level of abstraction increases, the sign becomes progressively more generic and less complex" [2011, p. 706]. At some point, highly distilled designs can be reduced to the most economical visual elements required to communicate the message: the visual archetype. Not necessarily abstracted in meaning, the visual archetype can serve as the abstracted, minimized version of the referent—so long as it retains communicability. It is better to think of the progression of abstraction towards the visual archetype as a gradient where parameters can (and very often do) overlap. This topic will be discussed further in Paper 7.

Beyond Dondis, Nelson Goodman provides another type of systematic analysis of representation and symbolism within the fields of philosophy of art and art criticism. Goodman considers all artworks to be signs ('symbols'), comprised of a complicated subset of 'symbol systems' [Goodman, 1976]. However, because this research investigated general tendencies across various media and population groups, highly nuanced discussions regarding the taxonomic systems of visual messages do not apply to this dissertation. For this project, Dondis' organizational analysis proved appropriate and has been expanded as Table II shows. Examples from native North-American artisans illustrate that Dondis' taxonomy functions well in various media and cultural traditions. Native art was chosen due to its highly historical, sensitive and dynamic aesthetic. Many native artisans are pursuing art and crafts using modern techniques as well. Even though native art provides a unique and fundamentally different way of seeing the world [Highwater, 1983], it can still adhere to Dondis' flexible organizational structure for visual messages.

Table II. Dondis' taxonomy of visual messages using Native American art

Type of visual Message	Example
Representation Shows reality and maintains high degree of representation to referent	 This image[6] shows high realism in multimedia painting. Double-exposed, monochromatic photograph. Tinted and colored manually. [Shan Goshan, 2015, image used with permission].
Symbolism Reduction to minimal amount of visual detail. May retain basic qualities and elements of the referent.	 This serigraph shows Thunderbird (demigod & protective figure) and Sisiutl (a double headed dragon-monster) in eternal struggle. Mythological motif from US Pacific Northwest (Haida). Although stylized, both figures retain identifiable qualities. [Serigraph: Bill Henderson, image used with permission].

Table II (cont.)

Symbolism (cont.) According to Dondis a symbol must refer to a group, idea, business, institution, political affiliation or element of nature.	 This ring shows ultimate simplicity stripped to irreducible minimum. Sun symbol as depicted by some native cultures of the US Southwest (e.g., Hopi, Zuni). Can also refer to mankind in general. Viewer must know coding or it is an aesthetic experience only. [Anonymous artist. Stone inlay ring purchased by the author in New Mexico, USA 1979].
Abstraction Bare and minimal clues to what is being presented. Simplification to intensify and distill the object's meaning, without need to retain visual connection to referent. Reduces image to basic visual elements.	 This hand built pot shows an abstracted and symbolic compilation of the weather systems that affect the Acoma mesa culture in New Mexico, USA. Striations symbolically depict rain whereas the angular white shapes indicate clouds and/or lightning bursts. The red color is made from— and refers to— the earthen color of the local landscape. [Anonymous artist. Purchased by the author in Acoma, New Mexico USA, 1982].

It is important to recognize that these (and other) visual messages reside on a gradient rather than occupy absolutes. Oftentimes a composition's visual messages will mix and overlap, creating a rich environment for the viewer to experience, decipher and enjoy. For example, the ring motif can be interpreted as an abstracted face, whereas the hand built Acoma pot contains elements of both abstraction and symbolism. It is up to the viewer to interpret the relationship between these aspects individually and collectively.

2.2 What is (real world) design?

This research defines 'real world design' as it originates from the natural, organic, multi-dimensional reality we experience in normal life. In the real world, design is not the same as art although both are concerned with communicating information visually. Both art and design are founded upon aesthetic representation, however design involves problem solving as its fundamental approach. For Thiel [1981], all real-world design requires purposeful planning in order to change current situations into preferred ones. Further, design can optimize how people use their limited resources of time and material in the process of actualizing objectives for which no optimal precedents exist. Quite specifically, Thiel claims that design primarily evokes the search for alternatives and rationalization in decision-making operations that occur iteratively. Thiel's operations are:

1. Identification of the problem and its contextual constraints
2. Specification of the goals and of the criteria for an acceptable solution
3. Hypothesis or invention of possible alternative solutions
4. Simulation of production of a testable representation of the proposed solution
5. Testing or the application of the acceptance criteria to the simulation of the proposed solution by the appropriate person

When all possible solutions have been generated, the process continues with the implementation and operation phases:

6. Comparison and rank ordering of acceptable solutions
7. Implementation of the most suitable alternative solution
8. Evaluation of the implemented alternative in use in the real world [Thiel, 1981, p. 32].

Many authors and researchers have discussed and argued about what design is, or what it is not. Professor K. Munshi of the Indian Institute of Technology collected 45 definitions of 'design' and 13 definitions of 'designer' [Munshi, 2002]. Armin Hofmann describes the work of the graphic designer as a service in which the designer transforms messages, events, ideas and values into visual form [Hofmann, 1965]. In Michael Kroeger's documentation of Paul Rand's conversations with students, Rand exclaimed beyond his immediate field of graphic design that "Everything is design. Everything!" [Kroeger, 2008, p. 1]. Further, Rand described visual design as being a system of proportions, hence the relationship of sizes. Most explicitly, Rand states to Kroeger "Design is the manipulation of form and content. Content is the idea, or subject matter. Form is what you do with this idea." [Kroeger, 2008, p. 82]. For this dissertation, the ongoing debate surrounding what design is (including the role of designers) lies beyond the scope of the discussion.

2.3 Graphical user interface (GUI) design

Early innovations of HCI design originated from the research conducted at universities and laboratories as early as the 1960's. Pivotal inventions included the direct manipulation of onscreen objects (1963) via the mouse (1970's), the desktop analogy with windows/folders (1974) and applications including editable text, drawing, games and CAD programs (1970's-80's). Simultaneously, the World Wide Web grew from a small group of US government-owned computers to become the vast interconnected network of today. Among this burgeoning amount of

information, some early pioneers were quick to note the need for guidelines and successful user-oriented design principles.

Jakob Nielsen was one of them—he initiated a field termed 'usability engineering' [Nielsen, 1994]. Nielsen's definition of good usability incorporated numerous aspects and became the standard for the profession. His definition is more a descriptive checklist of what good design should (and should not) entail. Nielsen's defined five usability attributes:

> *Learnability*: The system should be easy to learn so that the user can rapidly start getting some work done with the system.
>
> *Efficiency*: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
>
> *Memorability*: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
>
> *Errors*: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors, they can easily recover from them. Further, catastrophic errors must not occur.
>
> *Satisfaction*: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it. [Nielsen, 1994, p. 26].

International standards are highly debated, condensed definitions that form a baseline universal standard for common understanding. According to ISO 9241-11 (1998), section 3.1, 'usability' is the: "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [International Standard for Organization 'ISO', 2015].

For Dix, another author in human computer interaction (HCI), the purpose of an interactive system is to aid the user in accomplishing goals from some application domain. According to Dix, the 'domain' is an area of expertise and knowledge in some real-world activity. The 'tasks' are operations to manipulate the concepts of a domain, and the 'goal' is the desired output from a performed task [Dix, 2009].

This research project remained in the GUI realm much longer than anticipated. This was because it became clear that the literature had not yet fully addressed one topic: the age of the user. Because our culture currently encourages designers to cram ever-increasing amounts of information into our onscreen real estate, it is paramount that designers understand the most basic aspects of 2D composition and employ them conscientiously. Good user-interface design utilizes well-established design principles that very often emerge from paper and ink [e.g. Mullet & Sano, 1995] that help the user accomplish their task. In current smartphone programming guidelines, simplicity remains one of the foremost goals, second only to creating an enchanting visual interface. A website currently reminds developers to "simplify my life" by a) keeping information brief, b) using pictures instead of words and c) making decisions for the user yet allowing for customization etc., [Android developer site, 2016].

Aesthetically, sophisticated desktop design programs provide a wealth of opportunity for programmers and designers to dramatically increase the level of visual richness in interfaces. I conducted an informal survey and found that to the average viewer, it appears that the number of onscreen visual elements, as well as the degree to which they are designed, has increased in recent years Additionally, the screen is more populated than it was a decade ago [Skogen, 2016]. Chater provides the argument that not only is visual simplicity more appealing, it is more reliable—a crucially practical characteristic [Chater, 1997]. Overall, user interfaces must be practical as well as visually appealing. It makes sense that the time needed to absorb extra design elements detracts from the primary goal of functional applications. The primary goal of a

GUI is to convey information as quickly and easily as possible—too many visual elements detract from that goal. This is important considering that Moshagen & Thielsch [2010] suggest that simple layouts should be valued highly due to their ability to be processed more fluently than complicated ones.

For the GUI realm of this research project, investigations never left the earliest stage—the micro-level—the level that includes symbols and icons. It is easy to dismiss the importance of these small compositions because we are so accustomed to using many diverse symbols in our daily lives. We tend to take them for granted. It is therefore essential to recognize that as a concept, the use of symbolism was not a given. We must acknowledge how profoundly important the use of symbolism actually is—it might be the primary quality that made us human. Walter sums this up succinctly:

> …creating a simple shape that stands for something else—a symbol, made by one mind, that can be shared with others—is obvious only after the fact. Even more than cave art, these first concrete expressions of consciousness represent a leap from our animal past toward what we are today—a species awash in symbols, from the signs that guide your progress down the highway to the wedding ring on your finger and the icons on your iPhone®. [Walter, 2015 p. 40].

This research investigates icons and symbols in the form of GUI icons, some of which incorporated compound metaphors or multiple design parameters in combination. Historically, the programmers at PARC® (Palo Alto Research Center) used familiar metaphors (e.g. desktop with infinite folders, analog light switches) to ease people's learning of computer systems. Since then, GUI icons have become established and self-referential through their repeated use [Øritsland, 2015]. An example of this is the 'home' GUI icon that serves as an analogy for returning to the beginning of a computer experience. This demonstrates that if an icon's design is highly representational, the semantic meaning of an icon requires some degree of tacit knowledge.

2.4 Definitions of primary research terms

For this research, the term "complicated" was chosen over "complex", although both terms are used almost interchangeably in many references. To me, "complicated" conferred a sense of being able to dissect the elements within, whereas the term "complex" conferred a sense that the elements contained within were too vast and inextricable. The primary terms are described below, where 'simple' and 'complicated' have been adapted from Dondis' definitions most closely. Additional terminology can be found in Appendix: Table C where blue serves to highlight the most appropriate definitions for this research.

The primary research terms are defined as:

Simple
'Simple' refers to an object demonstrating minimal use of detail and/or visual parameters (e.g. color, perspective, shading etc) in order to communicate its meaning. It was presumed that participants would understand this term in the same (or similar) manner, either semantically or visually. In this case, *semantic* simplicity refers to how well the image communicates the meaning of the image. This is different than *visual* simplicity that refers to the graphic design-based parameters and characteristics of the image's visual composition. For this research, I anticipated that during user testing, both types of interpretation might occur—yet I wished to know if the strength and robustness of the visual aspects would outweigh the potential diversity of semantic interpretations.

Complicated

'Complicated' refers to an object that demonstrates increasing levels of detail and/or graphic design-based visual parameters in order to communicate its meaning via decoration, uniqueness, personality, elaboration, extra meaning, humor, etc. As with the term 'simplicity', it was presumed that all participants would have a relatively similar understanding of the term, either semantically or visually.

This research ascribes to Donald Norman's differentiation between 'complex' and 'complicated'. For him, 'complexity' describes the state of the world, whereas 'complicated' describes a state of mind [Norman, 2010]. Further, 'complicated' inherently includes an aspect of confusion that is addressed in the user interface studies (Papers 1, 4-7).

Design

Frankel & Racine note that 'design' can be a verb or a noun [2010], and although everyone seems to know what it means, design lacks a generalized definition upon which everyone can agree. Because design ranges across a large range of materials, subdisciplines, production requirements and research methodologies, overgeneralizing a definition can make it irrelevant. Further, some definitions seem to contradict each other, creating a lively debate in its audience and corresponding literature. This research uses a generalized definition of 'design' that can be summarized by Lauer-Pentak's statement that "design is essentially the opposite of chance" [Lauer & Pentak, 2011, p. 4].

Designer

George Nelson described the role of the designer as early as 1957: "The designer is in essence an artist, one whose tools differ from those of his predecessors, but an artist nonetheless" [Nelson, 1957]. More currently, as an industrial design engineer and artist, Assoc. Professor Marikken Høiseth states that a designer is "understood to be a construct that represents a group of people who are knowledgeable in the discipline of design and interested in theories, methods and practices relevant to design processes" [Høiseth, 2014, p. 1].

Visual parameters

These refer to the compositional devices that serve as the primary toolbox of the aesthetic designer, regardless of medium. The arrangement of visual parameters in a composition determines how the composition communicates its message to the viewer. Note that every visual composition requires a minimum of a few basic parameters in order to see it, and the more elaborate compositions often combine many parameters simultaneously. Some examples of visual parameters, itemized as best as possible, are listed below. The primary parameters investigated in this research are highlighted in bold according to weight in the research:

• **contrast**	• **size**	• repetition	• saturation
• **color**	• **structure**	• movement	• hue
• **shading**	• **placement**	• pattern	• value
• **perspective**	• **dimensionality**	• harmony	• tension
• **detail**	• **proportion**	• discord	• symmetry
• **archetypality**	• **relationship**	• contour	• asymmetry
• **abstraction**	• **context**	• balance	• angle
• **white space**	• **familiarity**	• emphasis	• gradient
• **stylization**	• **density**	• border	• direction
• **shape**	• **sequence**	• outline	• rhythm
• **visual weight**	• **focal point**	• tonality	• juxtaposition

These parameters were relevant for the studies conducted in both 2D and 3D contexts, and will be addressed further in each paper.

3   Related Aspects

It's not what you look at that matters,
it's what you see.

Henry David Thoreau

Simplicity is an age-old aesthetic (e.g. Asian sand gardens, cuneiform tablets, early petroglyphs, detail-scant mandalas, etc). In the natural world, simplicity serves as a root system. It is represented in geometric proportions such as the Golden Ratio that can be seen in the nautilus shell, the efficient physique of a shark, the symmetry of a flower, etc. Kimberly Elam's book is dedicated to the geometrical and visual proportions in design that often result in their being considered universally beautiful [Elam, 2001]. In the same vein, Rowena Reed Kostellow was a celebrated teacher whose assignments often consisted of very complicated 3D exercises in the study of 'simple' visual proportions [Hannah, 2002].

As a topic for discussion and study, simplicity is not new. In 1954, Arnheim stated about simplicity: "it may be described as the subjective experience and judgment of an observer who feels no difficulty in understanding what is presented to him" [Arnheim, 1954, p. 55]. More recently, John Maeda describes many examples of simplicity in his popular book *The Laws of Simplicity*. He has discovered how complicated

simplicity is, and he describes in detail how our culture is loyal to innovations that 'shrink, hide and embody' ('SHE') the level of technological complexity [Maeda, 2006]. According to Arnheim, Maeda and many others, it appears that the concept of simplicity carries an implicit value judgment—an inherent emotional association with desirability that the concept of complexity lacks entirely. This judgment seems to apply across many (if not all) types of aspects in certain cultural landscapes. Some examples are described below.

3.1 Simplicity as a marketable concept

As an aesthetic construct with emotional appeal, simplicity plays a strong role in the merchant-consumer dynamic. In many cases, consumers demonstrate a clear preference for 'simple' products over 'complicated' ones, although this appears to be culturally specific. Norman describes how Korean consumers prefer products loaded with buttons and options, even if they don't know how to use them. In this way, complexity becomes a status symbol [Norman, 2010].

In the west however, the predominance of 'simplicity=desirable' applies to huge product categories as merchants try to reach as many aspects of our lives as possible. A quick search in a popular online department store shows how powerful the terms can be. Online stores constantly update themselves and thus serve as a valuable barometer for the current status of popular consumerism—they are trying to sell more stuff, after all. In doing so, they reflect the marketable concepts currently in use.

Table III presents the results of an informal time-lapse search that presents how the market currently uses the terms 'simple' and 'complicated' to promote a variety of products, goods, and services, per November 2016. This table shows a wide variation in number of products using the terms, compared with each other and across three years.

Table III. Results for online store items using 'simple' and 'complicated' as search terms

	'Simple'				'Complicated'		
	2014	*2015*	*2016*		*2014*	*2015*	*2016*
ALL DEPTS.	1,927,311	13,229,260	5,952,545		8,222	15,170	24,157
Books	76,101	94,220	120,214		1,266	1,602	2,500
Computers (electronics & accessories) For 2016: "Electronics"	4,917	247,207	4,398,354		161	1,305	81,590
Grocery & gourmet food	5,421	6,173	5,377		23	21	38
Health & personal care	20,617	25,559	20,061		135	182	95
Industrial & scientific	26,951	45,094	35,121		117	221	1995
Digital music	110,735	36, 182	43,058		225	2,748	3,146
Software	2,003	2,435	1,557		71	94	40

As Table III shows, the overall number of products employing the term "simple" is higher than those employing the term "complicated". However, after an explosive growth from 2014-2015, the 2016 search shows dramatic reduction in many departments (e.g. see ALL DEPTS/'simple'). The continued increase in the 'Computer' category might be due to the use of different terminology: the 2016 category "Electronics" likely includes many more items than before. Like any sector, online department stores are dependent upon the changing whims of their target market.

Regardless, it appears that the deeply ingrained association between simplicity = desirable is robust. This preference does not seem to be restricted to aesthetic characteristics only. Chater explains:

> People are attracted to simplicity—but this is more than a mere aesthetic preference. A preference for simplicity is a key to choosing the most likely explanations of the information that we received. Hence the search for simplicity may be an important cognitive goal across many areas of cognition, from perceptual organization to learning, to everyday reasoning and scientific thinking [Chater, 1997, p. 498].

Further, the extraordinary success of Apple®, products proves that consumers will choose technologies that i) appear minimalistic, ii) give an impression of controlled (i.e. non-intimidating) functionality, and iii) are aesthetically pleasing over more seemingly complicated objects. The simple object must show a charismatically reduced aesthetic first, but if it doesn't work, the aesthetic aspect fails and the user becomes disappointed and frustrated. Although important for first impressions and longer-term pleasure, simplicity in our personal electronics still comes secondary to the functionality.

The serene minimalism used in many current computer products show high regard for *perceived* simplicity, i.e. the first impression of ease-of-use. The external design of the iPhone® serves as a good example. Its shape, form and material completely hide its advanced internal technological power. The iPhone's® external streamlining masks a compacted, internal, highly complicated and densely engineered computer that carries more computing capacity than NASA's entire mission control room for the Apollo 11 (July 20, 1969) landing on the moon [Kennedy Space Center®, 2014]. Technology can give the appearance of simplicity not only externally but in the user-interface as well, and HCI design is a vast field dedicated to making our interfaces with a computer easier to use. People continue to buy products that are (or appear) 'simple' only as long as those products continue to serve their needs functionally at the interface. Similarly, a person only

continues to use those products if the simplicity (both externally and internally) continues to give them emotional and functional security. Regardless if the object is a building, automobile, chair or a dinner knife, the 'simple' object must ultimately fulfill its user's primary needs.

3.2 Shakers

Perhaps the embodiment of simplicity as a lifestyle, the Shakers were a renowned utopian society that thrived in the United States in the 19th century. After 200 years, only a few Shakers remain to pass on their unique traditions of equality and communalism. Famous for their unusual way of life, earnest honesty, excellent quality handiwork, their name was derived from their style of dance-worship [Sprigg & Larkin, 1987]. The Shakers were a religious community that split away from the Quakers, and they lived by the premise that all manifestations of simplicity were the highest form of earthly spirituality. Sequestered from the society at large, the Shakers were self-sufficient and used every opportunity to invent many practical solutions that they themselves called 'simple'. In fact, they reveled in their constant striving towards simplicity—they referred to themselves as 'The Simple People', and composed a well-known song entitled 'Simple Gifts' [Pleasant Hill]. This is particularly true with regard to keeping organized and tidy within their living spaces. One ingenious example is the single row of pegs that lined the interior of almost every living area. The peg row was an ultimate tool in multipurpose practicality. The Shakers designed their clothing, utensils, clocks, small cabinetry, candleholders, and mirrors—almost everything—so that it would fit onto the row of pegs (see Figure 2). Even chairs could be hung from the pegs while the floors were cleaned three times a day. Unused, the row of pegs provided a pleasant visual device to break up the monotony of the large, otherwise undecorated wall spaces.

Figure 2. Examples of Shaker simplicity in residential areas
[Photos from Sprigg & Larkin, 1987. Left, p. 85. Right, p. 77]

The Shakers bestowed economy of design into virtually every aspect of their lives from architecture, clothing, furniture and tool design, cooking, to farm equipment. Everything about them reflected their love for the characteristic appeal of minimalism. To them, clutter and unessential decoration was useless, burdensome, and distracting. It might seem that, as a principle, the Shakers' austere approach to design dismissed the importance of an object's aesthetic value. It did not. Rather, the Shakers provided specific rules for how to deal with visual treatment with a sophisticated appreciation of subtle beauty. Primarily, decoration was to be used only when it was necessary and/or appropriate. The basket shown in Figure 3 is a "down basket", and demonstrates one of the finest examples of Shaker workmanship for a number a reasons.

Figure 3. Example of ingenious design, delicate aesthetic and quality craftsmanship in Shaker basketry [Sprigg & Larkin, 1987, p. 131]

Designed to protect plucked goose feathers from blowing away, the lid could be easily (and one-handedly) slid up and down, but not removed or mislaid. It opened just enough to tuck some more feathers in without losing those already gathered. The basket's shape and "twilled" lid required a specialized, deft skill that was passed down generationally. Sprigg & Larsen describe this basket as an exemplary object for Shaker design approach: firstly, make it only if it's necessary. Yet if the item proves to be necessary and useful, make it also beautiful. The decoration must be an inherent aspect of the design and should not interfere with the item's primary functionality [Sprigg & Larkin, 1987]. It is apparent that even the masters of minimalistic living had a nuanced relationship with visual simplicity. As a celibate society, the Shakers did not recruit enough converts and their culture did not survive into the 20th century. However, they left an enduring legacy of how a community can incorporate principles of simplicity into virtually every aspect of their culture.

3.3 Simplicity (or the perception of it) in art and design

Graphic design teaches us that each element in any visual composition carries 'visual weight'. The interpretation of the design relies upon how those visually weighted elements relate to each other. As the design elements are removed and the composition becomes less dense, the visual weight of each element grows and intensifies in relation to the other visual elements. Kenneth Yasuda describes this phenomenon best: "The bare spaces in a Japanese room and the austere severity of a tea-garden emphasize whatever appears in them, just as silence magnifies a thunder clap" [Kojiro, 1965, p. 7]. Further, 'Ockham's razor', attributed to William Ockham of the 14th century, is a foundational principle in which simplicity is preferred to complexity design [Hiroshi, 1997; Lidwell, 2010; Tufte, 1997]. Lidwell states:

> Implicit in Ockham's razor is the idea that unnecessary elements decrease a design's efficiency, and increase the probability of unanticipated consequences. Unnecessary weight, whether physical, visual or cognitive, degrades performance. Unnecessary design elements have the potential to fail or create problems [Lidwell, 2010, p. 142].

This principal is also known as the Law of Parsimony, Law of Economy and Law of Simplicity [Hiroshi 1997; Lidwell, 2010]. Tufte summarizes the concept as "what can be done with fewer is done in vain with more" [Tufte, 1997, p. 73]. Simple designs can save not only time, but potentially can save a person's life. Henry Dreyfuss, an industrial designer with a fascination for symbols, developed a complete system for farm machinery where operational safety was of paramount importance. Dreyfuss argues that simple forms and/or colours could reach the brain faster than the written word, particularly in an agricultural context. This immediate communication could save milliseconds in reaction time, which in turn could save a farmer's fingers, limbs, or even his life [Dreyfuss, 1983]. Some examples of simplicity (and/or the perception of it) in art and design are described below.

Möbius: the ultimate example

Perhaps the most profound example of simplicity is the möbius shape that is formed when a single strip of any material is twisted one-half rotation and then reconnected. It requires three dimensions to demonstrate its unique beauty—it cannot be experienced fully or optimally in two dimensions. Figure 4 presents a good example:

Figure 4. A version of the möbius shape, in sterling silver jewelry. Designer: Vivianna Torun Bülow-Hübe for Georg Jensen Inc.® Image used with permission.

The möbius' extraordinary elegance hides a profound characteristic: it is the only form in the universe with one edge and one surface. When one holds a möbius, it is possible to see all aspects of the shape at the same time: the front, the back, the inside, and the outside—all are visible simultaneously. The shape is one continuous form without beginning or end. The möbius' powerful continuity has inspired deep reflection and creation in many cultures around the world.

Pablo Picasso was enchanted with the möbius. His contemporary, rival and friend, Henri Matisse, noted that Picasso could be found 'turning one over and over in his hands for long periods of time' [Musée Picasso Paris®, 2002]. Although reserved for future research project, it is my belief that Picasso's intense study of this shape inspired him to explore its multifaceted character in portraiture during one of the most important art movements in history: Cubism. Arnheim describes Cubism as the artist's attempt to "give a more complete view of the object by combining various aspects" [Arnheim, 1954, p.132]. Matisse's observation of Picasso holding the möbius leads me to propose that Picasso actually

attempted to replicate the möbius' unique multiplicity and ability to show many perspectives simultaneously. For a substantial number of his portraits, Picasso painted both frontal and profiled views, something that only the möbius can accomplish. The result was a collection of distorted portraits that are considered some of his most important contributions to art. Perhaps the möbius lies at the root of inspiration upon which Picasso spearheaded one of the most revolutionary art movements in history. Inspiration can originate from modest places, and the möbius is certainly an example of a highly complicated form that gives the impression of simplicity. Some examples of Picasso's dual-perspective portraits that might have been inspired by his fascination of the möbius are shown in Figure 5. This theory of Picasso and the möbius will be saved for a future research project.

Marie-Thérèse, Face & Profile 1931
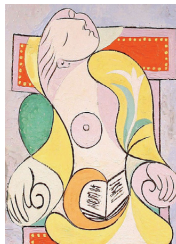
La Lecture 1932

Portrait of Dora Maar 1937
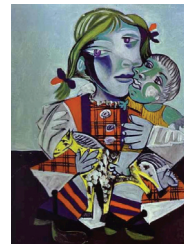
Maya with Dolls 1938

Figure 5. Examples of Picasso's art that were directly inspired by the möbius shape, as hypothesized by the author.

Henri Matisse (1869-1954)

After a long career in painting followed by a 1941 surgical procedure that confined him to a wheelchair, Matisse moved into artistic reductionism by 'painting with scissors' in which he cut gouache-covered paper into bold, streamlined, color-blocked shapes. He became fascinated with the endless possibilities for how to streamline figures to their essential form, and although drawings no longer interested him, simplicity and color held their appeal:

> *'On these elements of simplified representation place a colour derived from the sublimated local colour, or even entirely invented following my feelings warmed by the presence of nature—a kind of poem.'*

> (Letter from Matisse, 3 June 1947 – L.796 of the Correspondance Matisse-Rouveyre) [Finsen, 2005, p. 163]

Matisse used his cutout technique prolifically, and his discoveries in simplicity of form heralded a new stage of his life. In 1943, Matisse began work on a collection of cutouts that would eventually culminate in a book (entitled 'Jazz') that was eventually published in 1947. Somewhat autobiographical, the scenes derived from Matisse's memories from childhood and earlier life. Executed as paper cut designs supplemented by handwritten text, the works combine flat areas of color and sharp lines, and demonstrate Matisse's search to find 'pure means', and their specific influence within the whole [Finsen, 2005].

Matisse's cutouts demonstrate the pinnacle of abstracted, simplified, archetypal imagery. For example, Figure 6 shows that a woman can be communicated as a few minimal curves that not only present an idea of her age and shape, but her personality as well. The posturing of the figures shown in Figure 6 demonstrate how Matisse was able to capture the femininity of all women, yet of two individual women as well. This is not easy. In the figures, the slightest tilt of the shoulders in the solid blue figure to the right communicates an almost forced, tense pose of a woman who gives an air of snobbery. To the contrary, the white image to the left presents a more relaxed, natural woman who is more

approachable and relaxed. Notice that the solid blue figure appears to stand with her thighs as slightly crossed, left over right, whereas the white figure does not. This shows subtle, ingenious mastery at its best.
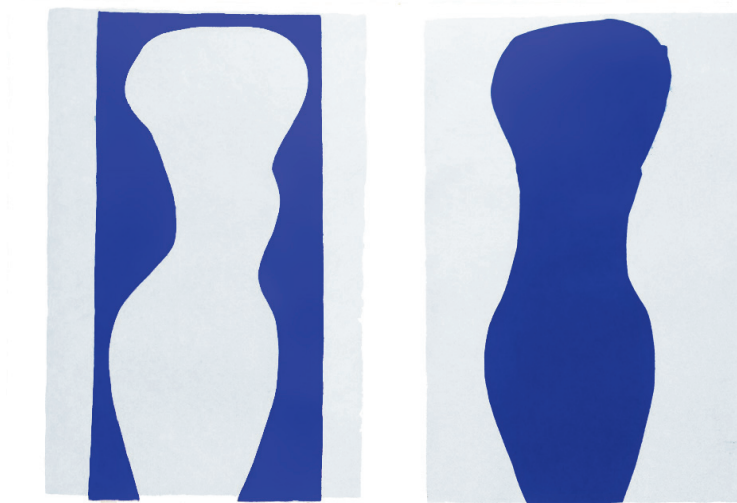
Figure 6. Examples of Matisse's extraordinary cutouts of the human figure. From Jazz, Plate IX, Forms, 1947, Stencil on paper cut out, 42x65cm [Matisse, 1992, p. 24].

As anyone will understand if they attempt to do it themselves, Matisse's uncanny ability to use scissors to render an entire human form (with implied personality intact) into a highly abstracted silhouette is more difficult than it seems. Here again is another example of visual simplicity being anything but simple. Picasso described Matisse's method as an iterative process in which he redrew a line over and over, constantly minimizing and clarifying it. Matisse often felt that the last, most stripped was the best, purest and most definitive, whereas Picasso often felt it was the first. Their respectful, almost brotherly rivalry and deep, decades-long competition inspired some of the greatest art in history [Bois, 2001].

Viewer involvement

In another example of 2D perceived simplicity, Pierre Mendell (1929-2008), a master poster designer, elegantly visualized an entire weeklong event of maritime activities with a single, precisely torn piece of paper mounted on a uniformly colored background shown in Figure 7:

Figure 7. Pierre Mendell's poster for an annual regatta in German town of Kiel [Mendell, 2001, p. 31].

Mendell's poster demonstrates how perceived simplicity requires the viewer to complete the composition, or understand the referential allusion as it is conveyed. The viewer must actively interpret the triangular shape as a wind sail, to see the rippled bottom edge as the crest of a wave, and to define the horizon between sky and water. In this composition, Mendell provides mere suggestions for the viewer to interpret and complete the design him/herself. Again here, simplicity does not come about easily: Mendell described to a group of students (including myself) that during the design process, he'd "torn about a thousand pieces of paper" before he was satisfied [Mendell, 1994].

Gestalt principles of design are another fundamental aspect of visual stimuli that relies on viewer involvement. The German term means 'form', or 'shape', although gestalt is often referred to as 'the whole being greater than the sum of its parts'. Because our brains tend to group and bind phenomena together in order to employ our preexisting knowledge about something [Maiocchi, 2014], Gestalt phenomena are applicable for all our sensory experiences. Without a viewer's involvement, gestalt stimuli cannot be comprehended. Gestalt phenomena are constantly at work in any visual scene, and our interpretation of the phenomena result in making our world more understandable. Visual designs that incorporate one or more of the gestalt principles—Closure, Continuity, Proximity, Similarity, Figure-Ground (debated)—are often considered more coherent, harmonious, unified, and timeless.

A good example of the visual Gestalt principle of Similarity is the logo for the Los Angeles' Museum of Contemporary Art® (MOCA®), where the viewer's involvement is embedded in the success of the logo (Figure 8). As active observers, we instantly and automatically group the three colored shapes together while seeing the C as a distinct outlier [Bigman, 2015]. In addition, this logo prompts the viewer to interpret the colored shapes into the letters M, O, and A. There is a high degree of tacit knowledge required to understand that the blue box suggests an M—not an L, T, X, Z or other letter with a boxy outline. Thus, the logo requires that the small text hover below... just in case.

Figure 8. Example of Gestalt principle of Similarity in logo design for The Museum of Contemporary Art®, Los Angeles (MOCA®). Image used with permission.

In another example of viewer involvement, Rudolf Arnheim asked children in their early stages of development to produce images of the human figure. The result was a series that he condensed into the drawings shown in Figure 9 (modified for space by the author).
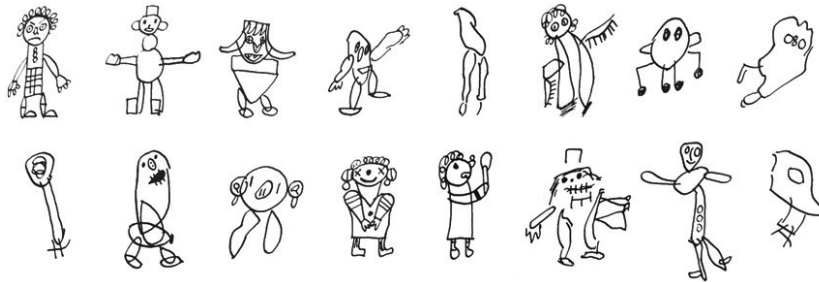
Figure 9. Children's drawings collected by Rudolph Arnheim [Arnheim, 1954, p. 143]

Arnheim describes how the drawings are simultaneously unique and similar, yet somehow individually and collectively offer a highly original interpretation of the human form. Arnheim describes the rendering of bare minimum detail as a literal interpretation of 'imagination', i.e. making the designs into images.

In interpreting the figures in Figure 9, the viewer is involved in at least two ways. First, the viewer is required to use their imagination to understand some of the more abstracted figures. Secondly and almost instinctively, the viewer begins a game of comparison and fast, intense scanning of details whereby s/he discerns similarities, differences, points of interest and perhaps eventually preferences among the drawings. Viewer involvement can activate the viewer on multiple levels in rapid succession and result in highly complicated cognitive processing and understanding, as studied by many disciplines including neurology, attention theory and psychology.

Another example of viewer involvement takes the viewer's engagement one step further. Our optical system ultimately sets limits for what we are able to perceive, and sometimes artists exploit these physiological phenomena, as shown in Figure 10.
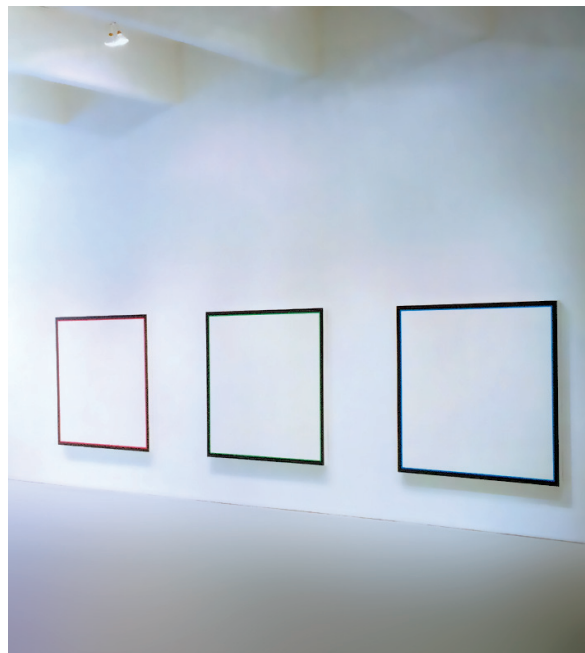
Figure 10. Jo Baer, 1965, triptych Primary Light Group: Red, Green, Blue. [Marzona, 2004, p. 37]

Unlike most artists, Jo Baer studied biology and graduate-level physiological psychology before moving into art. Her fascination with perception and optical phenomena is apparent in many of her works. The piece shown in Figure 10, *'Primary Light Group: Red, Green, Blue'* (1965), is comprised of three seemingly basic squares mounted on a wall. Around the perimeter of each square is a bounding box of black paint, with a very small band of color on the inside of the black paint. In the photo above, the inner perimeter of the left box is red, the middle is

green, and blue is to the right. With her academic background Baer knew well that humans have specialized photoreceptor cells in their eyes (i.e. 'cones') that respond to three distinct wavelengths of color, giving us trichromatic ('three color') vision. The three primary wavelength sensitivities that are responsible for color vision are non-coincidentally, red, green and blue. This work gives an appearance of simplicity because the viewer might not be familiar the physiological principles behind the concept. The luminance appearing inside each square arises from the small, colored border located just inside the black perimeter. Exploiting a halo effect, the hint of color appears to spread subliminally into the white space inside each box and creates a different luminance for each canvas. Each square is a retinal abstraction that is activated by its colored border that serves as a shutter or aperture [Marzona, 2004]. By exploiting the physiological nature of human perception, Baer has created a work in which each person engages with the work individually and creates the final effect based on neurological principles.

Just as the möbius shape represents the ultimate reduction of 3D shape and form, Mark Rothko serves as the ultimate master of simplicity in 2D painting. Rothko, a surrealist painter, reached his mature colorist style in the 1950's [Waldman, 1978]. Working within self-imposed rules to eliminate any extraneous decoration, his enormous paintings became vast spaces that are experientially rich due to their lack of obvious detail. With no more objects to 'distract' the viewer, the immense swashes of color invite the viewer into a very intimate space in which the viewer becomes almost enmeshed in the painting. It is impossible to replicate this effect in photos of Rothko's work, (see Figure 11) yet it is very noticeable when experienced live. Rothko was highly aware of this intensely personal interaction between his paintings and the viewer. He described it himself:

> A picture lives by companionship, expanding and quickening in the eyes of the sensitive observer. It dies by the same token [Rothko, 1952 via Waldman, 1978, p. 62].

Rothko's paintings serve as examples of streamlined minimalism in 2D art and they generate unforgettable experiences. The subtlety of color and interaction can only occur with the viewer's quiet commitment to engage with the intimate and almost surreal space created by the giant screens of floating color. Each painting seems to come alive, expand and hover independent of time and space. I had the opportunity to encounter a full immersion experience of Rothko in an architectural context, in the Rothko Chapel in Houston Texas, USA. During my visit, I found that being surrounded by (and becoming a part of) gargantuan Rothko works is nothing short of powerful meditation.

Figure 11. Mark Rothko, Untitled, 1961. Oil on canvas, 69" x 50". Collection Mr. & Mrs. Lee V. Eastman [Waldman, 1978]

Codified tacit knowledge

In another well-known example (Figure 12), Milton Glaser designed a text-based statement that relies on the viewer's tacit knowledge of localized, abbreviations:

Figure 12. Milton Glaser, 1975. Logo for New York City

The 'I Heart New York' mark set a precedent at the time it was launched, and many copycat motifs have followed. The strategy has been applied to numerous subgroups, such I heart "London", "science", "shoes", "dogs", "gymnastics", "vegans", "bacon" "unicorns" etc. This codified vernacular requires that the viewer must have learned two tenets: i) the heart symbolizes love (as many cultures agree, but not all), and ii) NY is an abbreviation for New York City in USA. If the viewer lacks one tenet, this statement appears cryptic and odd. By failing to understand, the viewer was excluded from being a part of the knowing, 'hip' crowd, i.e. New Yorkers themselves. Although divisive, this strategy was groundbreaking in 1968 and made a substantial impact. It helped the residents of New York City develop a distinct—if not somewhat arrogant—self-identity that served its purpose explicitly. This is an ideal example of Langer's epistemic use of symbolism to bind a community (i.e. New York City) together as a collective whole [Lunsford, 1995].

Requiring even more codified, tacit knowledge is the visual rebus by Paul Rand in Figure 13:

Figure 13. Paul Rand. Design for 1981 annual report for IBM[®]

Not only must the viewer decode the visual puzzle: an eye, a bee, and an outlier: the letter M, but they must also connect these together as visual descriptors and convert the letters to 'i & b & m'. Further, the viewer must possess the cultural exposure to understand that together in that sequence, I+B+M stands for IBM®, a multinational corporation named International Business Machines®. The trademarked, striated design of the M gives the viewer a helpful clue for recognizing the M. This multi-level decoding can happen quickly, and the clever wittiness of the design is fully dependent upon the viewer's breadth of culturally tacit knowledge.

Paul Rand (1914-1996)

Paul Rand is widely considered one of the most influential and groundbreaking graphic designers in the field. He was a creative visionary who understood color, form and composition intimately, and often experimented with them in his designs. As a problem-solving realist who understood the power of design's utilitarian function in the business world, his profiles continue to serve the international corporate landscape to this day. His compositions often give the appearance of being highly playful and light, yet he never placed an element randomly.

As a professor, his exercises and critiques could be intimidating, but his students learned valuable lessons, particularly from his intuitive sense of the five visual Gestalt principles (similarity, closure, continuity, proximity, figure/ground). In addition, he taught us about negative—or "white"—space [Rand, 1994]. White space is the compositional equivalent of absence of form, or the counter form left alone as a result of other forms interacting with another. White space is the area between, around, in, and among visual elements in a composition, and it can exist in 2D and 3D compositions. Importantly, it does not have to be the color white. Paul Rand understood the designable power of white space, and he could control it better than anyone. The delicate manipulation of white space is a defining aspect of his design legacy. His ideas, philosophies and educational approach (with focus on white space) continue to serve as the foundation of design education

programs around the world. The examples in Figure 14 show Rand's advanced treatment of white space (left: colored black; right: colored blue) that creates a powerful directive to guide the viewer as s/he navigates the forms. The viewer's eye registers the compositional white space intuitively and almost instantly. The viewer sees the form relating to its counter form, although positive form seems to receive more attention. Manipulating counter form is a difficult skill and controlling it is one of the primary tenets of a foundational design program. In Figure 14, the delicately asymmetrical positive forms provide a counterbalance to the white space resulting in two very different yet equally harmonious compositions.
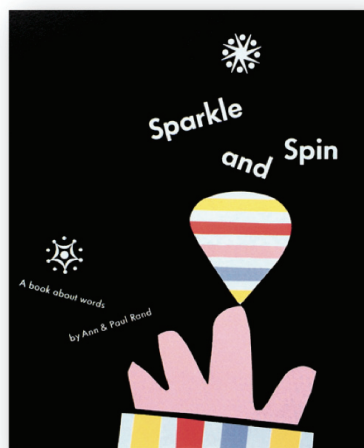
Book with illustrations
and text
1957

Book cover,
Robert Wittenborg's DADA
1976

Figure 14. Examples of Paul Rand's book cover art

In a different example, Figure 15 shows how two very different designs employ the use of two Gestalt principles, proximity and closure, in order to indicate the white head of the rooster (left). It seems simple to do this, but it is not. In the poster on the right, Rand again utilizes the

Gestalt principle 'similarity'—via the square shapes—they form a cluster based upon their common similarity, whereupon they seem to morph into flowers. They do so at the moment the viewer recognizes that the bee has been reduced to its archetypal (yet still recognizable) minimum. Both posters are examples of Rand's playful treatment of complicated compositions that exemplify perceived simplicity.

Art Directors Club poster
1988

Tokyo Communication Arts poster
1991

Figure 15. Examples of Paul Rand's poster art

3.4 John Maeda:
The bridge between art and GUI design

John Maeda is an important bridge between the worlds of art, design and technology, because he is a passionate advocate for art and design *within* technology. He has successfully straddled these seemingly opposing realms by being a distinguished graphic designer, artist, computer programmer, and sought-after speaker on all matters of simplicity. Maeda served as the associate director of research at the

MIT Media Lab for a number of years, after which he became president of the Rhode Island School of Design (RISD) for 6 years, and currently works as design partner in a private firm. He describes his initiation into design as a chance encounter and discovery of a book by Paul Rand. This gave him an artistic objective that he would strive towards for the duration of his life [Maeda, 2000]. Maeda was profoundly affected by the book and quickly became enchanted with visual simplicity, just at the dawn of the digital age—exactly when computers were becoming capable of rendering highly graphical imagery. He started a blog that he updated regularly on his quest to learn more about simplicity in culture, design, technology and life [Maeda, 2006a]. Taking his ideas further, he devised a set of "laws" and outlined them in *The Laws of Simplicity: Design, Technology, Business, Life* [Maeda, 2006b]. The laws are still completely relevant and are outlined in Table IV:

Table IV. Maeda's Laws and Keys of Simplicity
[Maeda, 2006b, p. ix]

Ten Laws		
1	REDUCE	The simplest way to achieve simplicity is through thoughtful reduction
2	ORGANIZE	Organization makes a system of many appear fewer
3	TIME	Savings in time will feel like simplicity
4	LEARN	Knowledge makes everything simpler
5	DIFFERENCES	Simplicity and complexity need each other
6	CONTEXT	What lies in the periphery of simplicity is definitely not peripheral
7	EMOTION	More emotions are better than less
8	TRUST	In simplicity we trust
9	FAILURE	Some things can never be made simple
10	THE ONE	Simplicity is about subtracting the obvious, and adding the meaningful
Three Keys		
1	AWAY	More appears like less by simply moving very far away
2	OPEN	Openness simplifies complexity
3	POWER	Use less, gain more

Although simplicity is not a new concept, John Maeda is considered a pioneer among enthusiasts due to his positioning between many seemingly opposing fields. He occupies the unique position of being able to analyze, discuss and contribute to the discussion of simplicity from both hemispheres of the brain. Although Maeda serves as the current de-facto ambassador of simplicity in the computer realm, he was not the first to do so. In 1977, T.H. Nelson observed in his essay the Home Computer Revolution:

> Designing an object to be simple and clear takes at least twice as long as the usual way. It requires concentration at the outset on how a clear and simple system would work, followed by the steps required to make it come out that way—steps which are often much harder and more complex than the ordinary ones. It also requires relentless pursuit of that simplicity even when obstacles appear which would seem to stand in the way of that simplicity [Schneiderman, 2003, p. 3].

Among many others, John Maeda, T.H. Nelson, Jakob Nielsen (who comes from an engineering perspective) all play an important role as advocates for aesthetic restraint.

3.5 Simplicity in GUI design

Onscreen crowding results from the increased ability to pack more information into the same visual space. It is important to recognize that just because technology allows us to design very complicated GUIs does not mean that we should always do so. This doctoral research describes an exploratory set of studies that attempt to systematically analyze the effectiveness and/or communicability of simple visual information across the real-world and GUI realms. This is particularly relevant in our culture of growing globalization where the products are changing, and different markets may have different needs [Auer & Dick, 2007]. Auer & Dick place the responsibility of meeting those different needs directly on the designers by insisting that HCI designers must meet the needs of their global audience regardless of their cultural background. The

authors recommended that the user interface itself should 'talk' and 'listen' carefully to ensure a smooth user experience [Auer & Dick, 2007]. Note that they stated this prior to the current voice-activated computer interfaces where talking and listening with the user interface (e.g. Siri) have become literal.

Regarding the growing degree of user-interface complexity, visual design is crucial and it can either enhance or inhibit the user's workflow. This research is rooted in the tenet that software designers should hold screen-based information to the same design standards as established, 'good' graphic design principles intended for 2D (paper-based) composition. When 'bad' design principles are used, the result can often be reduced efficiency, wasted time and an increased level of confusion and frustration for the viewer. Saadé & Otrakji [2007] describe GUI icons as a potential arena for disorientation in software use because some users may find them representative and useful, while others may find them confusing. Ultimately, well-designed (and user-tested) interfaces are essential for the efficient use of electronic applications, down to— and including the GUI icon designs.

Brief insight from Neuroscience

It is useful to briefly highlight a few points from physiological cognition. Neurologists study functionality of the brain including the systems of visual perception. Researchers in the field of 'Attention theory' study how our neurological system focuses on particular elements vs. others. Those elements we do focus upon (regardless of media) must be picked out and visually digested in an overall composition. Digesting complicated visual information takes up precious time and energy on the part of the viewer. [Bennett & Flach, 1992; Carrasco, 2011; Treue, 2003], and it is highly restricted psycho-physiologically [Huang, 2009; Miller, 1956; Ungerleider & Kastner, 2000]. This is applicable to human-computer interface design [Hollender, 2010], making it imperative that we understand the factors at work on a physiological level.

'Cognitive load' describes the amount of mental processing required for the user to understand a visual composition. Cognitive load becomes particularly relevant in the GUI realm, as objects, tasks or ideas, are compacted and squeezed into a very dense visual format. Ungerleider & Kastner describe how on a neurological level, numerous objects in our visual field compete for limited neural representation: "the capacity of the visual system to process information about multiple objects at any given moment in time is limited" [Ungerleider & Kastner, 2000, p. 315]. They explain that as our brains try to process numerous visual stimuli simultaneously, there is competition in the visual cortex. Functional brain imaging studies show that when multiple stimuli are presented simultaneously, they are not processed independently. Instead, they mutually suppress each other. Ultimately, the stimulus that is stored in the visual cortex is coded in the retrievable memory system and the motor system that determine action and responsive behaviors [Ungerleider & Kastner, 2000]. Corbetta, Miezin, Dobmeyer, Shulman & Petersen [1990] developed a psychophysical test in which they studied how subtle stimulus changes of shape, color and velocity in a visual stimulus related to attention. They found that "people can respond to only a small amount of sensory information at any moment" [Corbetta et al., 1990, p. 1556]. Further, context is important for attenuation because visual objects are rarely presented in isolation. Context can serve to contribute to cognitive overload, but can also direct the viewer's gaze to areas of importance while giving way to those objects that can be safely ignored [Chun, 2000].

'Chunking' describes the information groupings that are stored in our memory, because our brains identify patterns quickly and encode those patterns more reliably than random sequences. In his pillar article, Miller reviews a number of studies that have found that without helpful strategies, people's ability to receive, process and remember information is severely limited. He concludes that our spans of judgment and memory impose limitations on the amount of information that people can receive, process and recall. Chunking works by

organizing the stimulus input into several sequences thus breaking (or stretching) this informational bottleneck [Miller, 1956].

So that a user's memory is neither overloaded nor their gaze 'wasted', it is imperative for designers to conscientiously implement and control the design parameters associated with 'good' GUI design. The result is that the designer enables the user to focus on and efficiently access the important information rather than be distracted and overwhelmed by unnecessary visual elements. One common understanding is that visual clutter, even at the micro (e.g. iconographic) level, forces the user to filter out useful information from the extraneous, resulting in redundant and time-consuming mental processing. This extra cognitive effort results in a decrease in comprehension, retention and efficiency of the GUI. Reduced efficiency of visual communication results in an increased margin for confusion and wasted time. At the very worst, it causes the user to feel inadequate in using it.

There is a large amount of literature that addresses the diversity of aspects surrounding GUI icons' performance, for example: when Szabo and Kanuka tested screens that utilized 'good' design principles vs. 'poor' design principles, the subjects who used 'good' designs were able to do the task faster (by 21%) and with a higher completion rate (74% vs. 45%) [Szabo & Kanuka, 1999]. In bridging the gap between real world icon design and page layout, Honeywill postulates that page design offers fundamental principles that shift when we move to the computer screen [Honeywill, 1999].

Bottom-up design
We know that it is important to design GUI interfaces well, and there are many central, often-cited authors who help us to understand what 'good' user design is [e.g. Card, Newell & Moran, 1983; Galitz, 2007; Isaacs & Walendowski, 2002; Marcus, 1992; Mullett & Sano, 1995; Nielsen, 2000; Nielsen & Tahir, 2002; Preece & Rogers, 2015; Schneiderman, 2003; Ware, 2012 etc.]. Ware describes virtually every aspect of GUI design, from the physiology of perception to how to present information

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effectively [Ware, 2012]. Although their advice is decades old, Mullet and Sano's ideas can withstand the test of time solely because they apply the same principles of print and traditional graphic design to those of HCI. In other words, good design resists temporary design trends. According to Mullet & Sano, effective and/or good visual communication often incorporates visual simplicity [Mullett & Sano, 1995]. Cheon & Grant [2009] provide an overview of the variables to consider when designing HCI's that include: learning effectiveness, cognitive load, and usability. Importantly, they provide a useful summary of recommendations based upon 2D graphic design principles.

In all realms, designers should employ a bottom-up approach and begin with the data/content, and then design appropriately. Tufte tells us that often, visual displays suffer from too much ink in proportion to the data being communicated [Tufte, 1983]. In addition, Tufte provides a pragmatic solution he terms "the smallest effective difference: Make all visual distinctions as subtle as possible, but still clear and effective" [Tufte, 1997, p. 73]. Pretorius & Van Wijk recommend that designers identify the specific characteristics of the data and present it in ways that have not been considered before [Pretorius & Van Wijk, 2009]. It is essential to design the information being conveyed as well as the context in which it resides. There are many authors who assist in this, including Caplin [2001], Tufte [all], Petterson [2002], Plaue, Miller & Stasko [2004], and Resnick [2003], etc.

Generally, HCI design requires an iterative process where the goal is to consult the target user group and arrive at a list of usability issues with suggestions for interface improvements [Nielsen, 1993]. In spite of this resolute advice, there continue to be complicated, user-UNfriendly interfaces. Although this may result from many variables, I have chosen to address one powerful factor: the end user. It is important to know how the user responds with increasing levels of complicated design, particularly with various cultures and age groups.

3.6 What's wrong with 'Complicated'?

The relationship between Simplicity-Complicated need not be dualistic or mutually exclusive. As noted before, the situation with simplicity very quickly becomes complicated. During this research journey, I came across many authors who arrived at a single conclusion: that simplicity is always advantageous. There seemed to be an almost automatic, practical and philosophical dynamic between them. The default became:

Simplicity = good, organized, predictable
Complicated = bad, disorganized, randomized

But what about Complicated? Why does it seem to regularly fall on the undesirable side of the judgmental metric? Nina Eide Holtan, an accomplished illustrator and Assoc. Professor of the Department of Architecture and Fine Art, said: "I prefer the complexity of a lump of clay to the perfection of a snowflake" [Holtan, 2015].

Is it possible that Simplicity-Complicated are not only interrelated, but also interdependent? It might be that as constantly learning beings, we need complexity in order to captivate or maintain our interest. If so, the degree of balance between Simplicity-Complicated becomes paramount. If things are too simple, we become bored, yet if things are too complicated we may lose interest. If that is so, how simple should something be before we grow weary from boredom or intimidated by the effort required to decipher it? Some examples of authors' descriptions and conclusions follow below.

Barton & Barton, 1987
Implicit in the study of visual simplicity is the fundamental question whether simplicity is valuable—or even desirable—at all. It is a necessary question. Barton & Barton wonder if we should discard simplicity as an ideal in visual design. Basing their article on Charles Morris' semiotic (triangular) theory of signs, they describe many aspects of simplicity including: i.) Syntactic, or artifact-based—referring to the

level of moving visual elements within a composition, ii.) Semantic, or meaning-based—referring to the compatibility of the representation's compatibility with the real world, and iii.) Pragmatic, or contextually based—referring to the interaction of the representation and its viewer, purpose, conditions of usage and tasks. They conclude that providing there are no ideal solutions, the best accommodation is usually the simplest visual representation. Importantly, they ask the question regarding the potential value of complexity in the first place.

John Maeda, 2007

Even the ambassador of simplicity John Maeda has mixed feelings about the relationship between simplicity-complexity. In his TED talk, he mused over complexity:

0:56:   *I'm also wondering myself: what is simplicity?*
         Is it good?
         Is it bad?
         Is complicated better?
         I'm not sure.

2:52   (while referring to a photo of a spectacular, cloud-filled sunset):
         We can't help but love complexity.
         Human beings ~ we love complex things.
         We love relationships ~ very complex.
         We love this kind of stuff...

13:30:   Simplicity is about living life with more enjoyment and less pain

[Maeda, 2007].

John Gribbin, 2009

Gribbin writes on the scientific and theoretical meanings of simplicity, chaos, and complexity and provides a helpful example for how the dual aspects of the Simplicity-Complicated relationship are deeply interrelated. He describes the components of a racing bike, the wheels and levers as simple objects unto themselves. The components do not form a bicycle when they lie in a heap. The bicycle only becomes

complex when all the 'simple' pieces are arranged in the 'right way' to form the bicycle. Thus the bike is greater than the sum of its parts. This highlights the importance of how parts interrelate: only when parts interact together in a certain manner, can they become a complex system. Gribbin summarizes this phenomenon as: "And that's complexity, founded upon deep simplicity" [Gribbin, 2004, p. 137].

Donald Norman, 2010

As a pioneer in design who once only applauded the virtues of simplicity, Donald Norman appears to have experienced a change of heart. To him, simplicity need not be virtuous. In *Living with Complexity* [2010] he embraces complexity and declares it both necessary and enjoyable. Norman states:

> Complexity is an inescapable part of the world we live in. But complexity need not turn into complicated confusion. Complexity can be tamed through proper design. Why the cry for simplicity? It is an honest reaction to the confusion and complications of life; but although the intention is admirable, the proposed solution is mistaken. Everyone wants simplicity, but that request misses the point. *Simplicity is not the goal* (author's emphasis). We do not wish to give up the power and flexibility of our technologies [Norman, 2010, p. 51].

It seems that both Norman and Maeda have discovered the joy hidden within the dynamic relationship in *both* aspects of Simplicity - Complicated. The next section will explore this relationship further.

3.7 Simple—Complicated: A dynamic relationship

According to Dondis, visual abstraction is reductionistic: it requires simplification toward a more intensified and distilled meaning [1973]. However, according to my experience with Professors Hofmann and Rand, simplicity is more than mere reductionism. It involves a deep understanding of how elements interrelate to compose and effectively communicate the message. This requires that the designer simultaneously provide interest, wit, humor, meaning etc. for the viewer so that they stay with the message long enough to comprehend it. Successful designers (regardless of media) inherently understand that Simplicity-Complicated are interrelated, and are able to manipulate, balance, and exploit it in a controlled manner.

Controlling the dynamic between Simplicity-Complicated is something that people in the arts, architecture, music, philosophy, sciences, humanities, etc. have known for millennia. If one peers deeper into aspects of simplicity, things quickly become complicated...and vice versa. Simplicity and complexity are deeply intertwined and dependent upon each other. Robert Morris, an American sculptor, conceptual artist and writer, is considered to be one of the founders of the minimalist art movement in the 1960's in the United States. For Morris, 'Simplicity of form is not necessarily simplicity of experience" [Marzona, 2004, p. 78].

In the stages prior to the focused research into the relationship between Simplicity-Complicated, I drew inspiration from many areas of interest, and continued to do so throughout the entire research process. It became clear that the relationship between Simplicity-Complicated lies deep at the heart of many aspects of our culture.

Some examples follow below.

Constellations

In order to make their universe understandable, inhabitants of the ancient world interpreted the night sky as a panorama of figures, animals, and objects. This required a transformation of the complicated night sky into recognizable references that could easily be understood. However, this simplification of the mass of stars into identifiable shapes quickly became more complicated due to the detailed stories associated with the characters. Figure 16 shows a rendition of how basic star patterns were re-envisioned as constellations. What I find most fascinating is the degree to which various ancient cultures interpreted the star patterns in a similar manner, often assigning similar creatures and stories. This occurred without their having an obvious ability to contact each other and exchange information. For example, ancient cultures such as aboriginal Australia and native North-America share many common constellations along with their associated descriptions.

Figure 16. Spread from Once Upon a Starry Night$^{®}$. Illustration: Christina Balit [Mitton, 2009]. Image used with permission.

Picasso's bulls

The montage in Figure 17 shows eleven lithographs (using only one stone) that Picasso created in Paris from Dec. 5, 1945 – Jan. 17 1946. Each lithograph is identically sized: 33.2 x 43.2 cm. Progressing from top left to lower right, each bull shows a progressive degree of abstraction and simplification, until only a line-drawn bare minimum remains. Even without its predecessors to form a context clue, the final rendering is immediately recognizable as a bull due to the drawing's inclusion of three archetypal elements: the body shape, horns and genitalia. Lacking one of these elements calls the bull's identity into question.
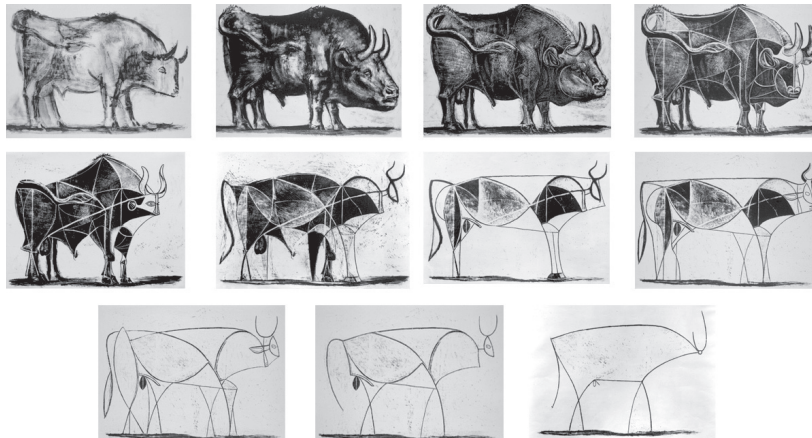
Figure 17. Bull, a series of 11 lithographs by Pablo Picasso, Permission to use images: pending, (Art Resource, NY) Montage by the author.

Most designs can be stripped down to the minimal visual elements that are required to communicate the message, known as the visual archetype. It is better to think of the progression of visual distillation as a gradient where the irreducible minimum forms the archetype (e.g. lower right in Figure 17). Picasso's bulls demonstrate this progression well. Visual archetype served as a primary research topic for Paper 7.

Logo design

Figure 18 shows the logo for an award-winning science museum in San Francisco, California USA. Exploratorium® demonstrates Gestalt principles as well as a highly restrained corporate profile design. This apparent simplicity belies the juxtaposition between simplicity and complexity.

The logo is monochromatic and uses only miniscule (i.e. lower-case) lettering, yet the circle stands out due to its enormity relative to the letters on each side. This circle is the focal point, and provides viewers with both a readable and imaginative logo. The large circle signifies much more than meets the eye. Other than functioning as the letter 'o' to complete the word, the circle suggests the Earth, a magnifying glass, or a portal of some kind. The large circle encapsulates the space within it, similar to Jo Baer's artwork (Figure 10, p. 40). The circle is a space to contain something—it invites inquisitiveness. The museum's edifice itself incorporates this circular element as an architectural device, so that visitors can physically look through an opening located near the entrance. The giant circle creates a memorable branding connection from logo to the architectural space and encourages the viewer to come in to explore. The concept of the logo offers a respectful balance between Simplicity-Complicated that offers potential for exploration— all qualities with which the museum is associated. It is an exceptional example of how intelligence, simplicity and complexity complement each other harmoniously in corporate logo design.

Figure 18. This logo is an example of how simplicity and complexity successfully complement each other in logo design. Exploratorium®, San Francisco, CA, USA.
Image used with permission.

The internet

Perhaps one of the most intriguing examples of the relationship between Simplicity-Complicated lies at the heart of our computing world: the internet itself. We are currently in the third stage of the development of the internet. The first stage, Web 1.0 (1988-2005), brought the technology out of a few programmers' laboratories towards a global audience, and functionality centered primarily on information distribution/exchange. By the end of its initial year, the internet was established and mappable to the point where it was published in the December 1998 issue of Wired magazine.

In the second stage (2005-2010), the internet became more interactive and users grew more immersed and dependent upon technology. Web 2.0 brought increased levels of advanced user-centered developments along with increases in personalization and customization. The core element of stage 2 revolves around the explosion of user-generated content (e.g. YouTube©) and the sharing, exchange and engagement in social media platforms. It advanced the levels of integration into people's school, work and home lives dramatically.

Currently, we are in the midst of Web 3.0 (2010- ca. 2020), also defined as the 'Internet of Things (IoT)'. This stage heralds an almost universal involvement in the use of internet-based technology, particularly in social media and global connectivity. Ruslan Enikeev visually mapped Web 3.0 and stated: "The Internet global network is a phenomenon of technological civilization, and its exceptional complexity surpasses anything mankind has ever created [Enikeev, 2015].

Curiously, Figure 19 shows an extraordinary comparison of Enikeev's map to the space photo of the 'Serpent' star-forming cloud taken by NASA's Spitzer Space Telescope in 2014 [NASA, 2015]. The resemblance is striking, down to the small cluster in each photo's lower left corner.
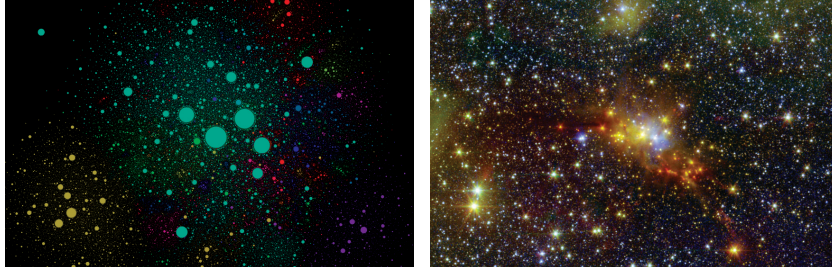
Figure 19. Comparison of Internet Stage 3 (left) and nature (right). Internet map: Ruslan Enikeev, 2016, Image used with permission. Sky photo of Serpens Cloud Core, courtesy of NASA/JPL-Caltech/2MASS®, 2014.

Importantly, Web 3.0 shifts the focus away from the user as an individual among a group, to the entity of the internet itself. This paradigm shift in our current age of humanity ('anthropocene') may rival the usage of tools by the first hominids. This is potentially a point when humanity changes forever. In Web 3.0, the internet has become an independent, self-generating macro system, into which users' electronic devices ('things') provide a small glimpse. This entity has been referred to as "the Web" or "It" (a clever pun on 'information technology/IT'). A lesser-used term with highly religious overtones is "the One". Kevin Kelly foresaw this analogy in 2002 in his article "God is the Machine", aptly illustrated in Figure 20.
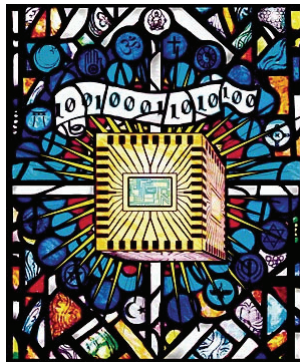
Figure 20. Alex Ostroy, 2002. Image used with permission.

Kelly, founding editor of Wired Magazine, continues to be a prominent voice in all things digital and is renowned for his guru-like status. In 2007, he somewhat presciently predicted that by 2040, "the Web will exceed humanity in processing power" [Kelly, 2007, 5:35]. Although this remains to be seen, the internet has grown into a very complicated global communication system upon which many sectors are dependent. Alternatively, perhaps the internet is yet another tool, albeit a highly intricate and advanced one. Tool making lies at the heart of humanity itself, so it follows that our tools should advance as we change and evolve. When stripped of its almost human-like persona, this powerful communication device is ultimately still ... a tool.

Regardless of the perspective one takes, the internet provides a good example of the Simplicity-Complicated relationship. This relational dynamic is best summarized by the well-known, ancient symbol depicted in Figure 21 with some of its underlying mathematical construction:

Figure 21. Yin-yang symbol, Shutterstock. Image used with permission.

Simplicity and complexity are deeply intertwined and as the yin-yang symbol demonstrates, aspects of one lie at the core of the other. Additionally, this symbol exemplifies the guiding principle of 'Notan', an Eastern aesthetic concept that describes the interdependence between form and counter form. In all realms and media types, Notan acknowledges the independent yet equally valuable importance of a shape to the space that it displaces. Like the relationship between Simplicity-Complicated, Notan reminds us that one aspect is not an afterthought of the other, but rather an integral part of a balanced dynamic between positive and negative space.

Fuji kindergarten

Sometimes a solution can be self evident, yet it requires brilliant insight to realize and manifest it. An excellent example is the Fuji Kindergarten by Takaharu & Yui Tezuka Architects in Tokyo. This design synchronizes simplicity and complexity into a harmonious structure that fundamentally caters to its primary user group: children who run, play, and enjoy being under the open sky in a protected environment. Understanding that children may often feel confined in conventional 'quiet boxes' [Tezuka, 2014, 3:20], Tezuka's ingenious design embraces children's desire (and need) to move about freely. The ability to run unhindered is particularly valuable in large cities where many residents live in small spaces and are unable to enjoy natural, outdoor settings.

Figure 22. Fuji Kindergarten. Tachikawa, Tokyo, Japan. 2007. Architects: Takaharu & Yui Tezuka Architects. [Tezuka, 2007]. Photo: Tezuka Architects. Image used with permission.

Figure 22 shows the kindergarten as it is nestled within a rectilinear, cement-clad metropolis, yet children can run around (and around, and around) in safety on the terraced roof. The children indeed sprint for

extended periods of time: the average distance covered by the children is 4 km per day, and one small boy ran 6 km in one morning, and continued on after lunch [Tezuka, 2016]. Unlike other institutions where children are often forced to remain sedentary, the Fuji Kindergarten encourages children to be active. The visionary design is successful—the children at Fuji Kindergarten are indeed more athletic than their peers in conventional kindergartens [Tezuka, 2014].

Striking a harmonious balance between simplicity and complexity, this design solution only appears simple. Underneath the terrace are non-walled, open-air classrooms that allow the caretakers and children to use as they see fit. Adaptability is endless. The kindergarten provides for a potentially complicated situation (e.g. overcrowded classroom) because flexibility is a core concept that functions seamlessly in all aspects of the building. In addition, the structure incorporates 5-6 live trees that the children clearly enjoy playing on, as shown in Figure 23:

Figure 23. Fuji Kindergarten. Tachikawa, Tokyo, Japan. 2007. Architects: Takaharu & Yui Tezuka Architects. [Tezuka, 2007]. Photo: Tezuka Architects. Image used with permission.

By using large, open areas filled with wooden planks that respond to daily weather (e.g. warm, dry, slippery, cold, icy), the children learn important lessons on how to respond to daily weather and the seasons at large. The kindergarten invites the weather 'in' as a part of the children's routines, rather than keeping it 'out there'. Weather is neither distanced nor something to be dealt with—it is an integral part of the children's daily experience. The acceptance of all weather variations combined with the structure having been built around the living trees, the structure provides children with a connection to nature that is very difficult to achieve in its densely populated cosmopolitan context.

The Fuji Kindergarten is a highly inspirational architectural structure—it reveals the architects' profound understanding, love and respect for both nature and children. It is rare to see simplicity and complexity so elegantly infused into an urban architectural project, particularly one for children. At every level, the extraordinary design of the Fuji Kindergarten gives its primary users, children, a relationship to nature while simultaneously serving their mannerisms, thinking, and needs.

Like other examples in this section, the Fuji Kindergarten demonstrates design based very prominently upon mathematical geometry. Using geometry in design is ancient, universal, and exists in many aspects of nature as well [Elam, 2001]. For Arnheim, when form making is liberated from constraints and/or complexities linked to representation, it gravitates towards "the most regular, symmetrical, geometrical shape attainable under the circumstances" [Arnheim, 1954]. Geometric designs are often considered inherently beautiful due to the mathematical relationships at their core. People often understand these rhythms immediately—even densely patterned, fractal ones. Islamic art is a good example of geometrical art. Modern typographical artists from the Middle East can also be heavily influenced by geometrical structure [Porter, 2006]. When I asked Professor Rand [Rand, 1994] the question "What makes geometrical design so enduring?", his response was:

Never argue with geometry... it always wins.

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Headspace® mobile app

Headspace® provides guided meditation through a demand-based application for small screens — it serves as a superb example of "simple" app design. Headspace's® restrained, yet personally engaging interface focuses on the task at hand, i.e. accessing the next lesson in guided meditation. Its design ideally strikes the delicate balance of presenting content-appropriate entertainment as well as science-based information regarding the health benefits of meditation. In addition, the visual design manages to address all user groups simultaneously—this is not an easy task to accomplish.

All well-designed GUI presentations incorporate four tenets of usability that Bruce Tognazzini has discussed since 1992. These four tenets become imperative for designers of small screens and include:

i) Discoverability – ease of discovering what actions are available
ii) Actionability – ease and clarity of using/engaging that action
iii) Feedback – immediate receipt of unambiguous & unthreatening feedback regarding the results of that action
iv) Recovery – ease of reversing the action without data disruption

Headspace® is an excellent example of how all four tenets can function seamlessly in an app that immediately conveys simplicity and approachability. Using a 'flat design' visual style, the information is effectively streamlined so that the user can access it quickly and easily.

As Figure 24 shows, the timeline unlocks the next level and thus quietly insists that the user progresses through the lessons sequentially. This ensures that content is delivered in the manner intended, without skipping essential instructional steps. This format also encourages the user to progress at his/her desired rate, without potentially overwhelming the user by providing total access up front. Only when the user has completed the introductory course do all aspects become available. This app teaches people how to do meditation progressively as the content requires slow, conscientious access.
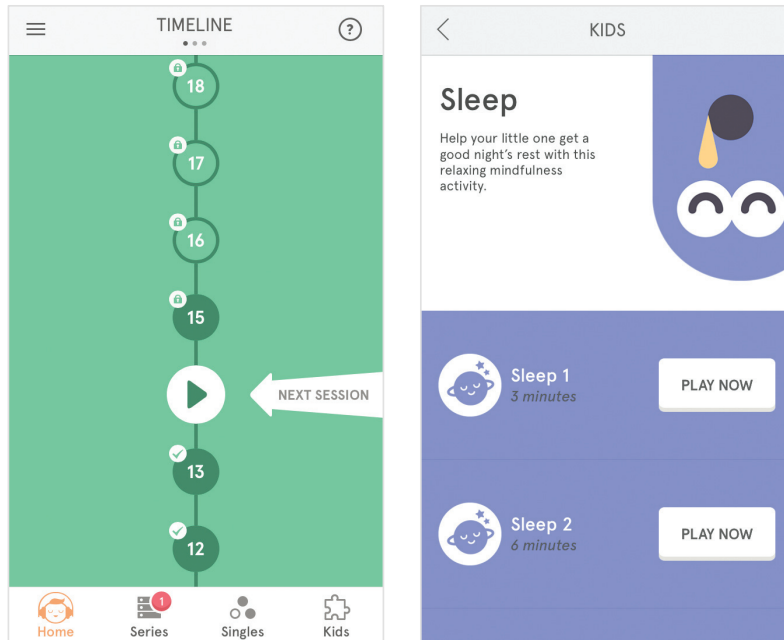
Figure 24. Examples of the flat design used by Headspace® App, 2016. Images used with permission.

For Headspace® users, the content, accessibility and visual design all synchronize in a pleasant small package. It balances the difficult design tasks of delivering content that is helpful, gender-neutral, age-appropriate (for all ages), content-appropriate, easy-to-use—while maintaining broad visual appeal. Headspace® users can enjoy the clever wit and humor in some of the sections of the app. It is an ideal example of excellent GUI design.

Space plaque

Between 1972 and 1973, NASA launched two space exploration missions beyond the range of the moon. Named Pioneer 10 and 11, the spaceships were groundbreaking in numerous ways but they also carried something unique: a visual communication plaque designed by Carl Sagan and Frank Drake. Using few lines and no text, the gold-anodized aluminum plaque succinctly visualizes an intricate level of detail—where we are, what our species looks like, and the date when the mission began. Briefly, the arrangement of 14 pulsars places the sun as our home star, while our solar systems depicts the launch of the spacecraft from Earth soaring past Jupiter. The hydrogen atom serves as a "universal clock" to allow interpretation of the decrease in frequencies from the time Pioneer was launched. The hydrogen atom is also used as a measurement to relate sizes of humans (male and female) to the spacecraft. The man's hand gesture signals goodwill.

With only a minimum of astrophysical symbols and a presumably universally codified visual language, this plaque was designed to communicate to a non-terrestrial species at some point in the future. After it was launched, the plaque shown in Figure 25 was never intended to be seen by humans again.
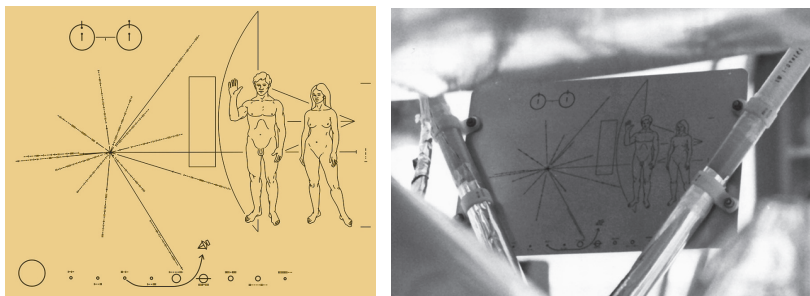
Figure 25. Pioneer 10 & 11's Space Plaque. Line drawing (above) vectorized by Mysid from a public NASA image. Original art by Linda Salzman Sagan. Photo of mounted plaque courtesy of NASA, public domain.

4 Methodology

Everything should be as simple as it is, but not simpler.

Albert Einstein

Design research is often a combination of methodologies borrowed from other academic traditions. The methodological approaches used in this doctoral research were:

1. Exploratory
2. Grounded theory
3. Triangulation
4. Mixed (HCI)

These approaches will be described in detail below, with general information followed by how the methodology was appropriate for this research. The specific techniques included:

A. Field Studies
- Physical interaction with visual stimuli
- Open-ended interviews and discussion
- Targeted questioning/survey
- Analog single or dual-axis test

B. HCI Studies
- Computer-based user test
- Open-ended interviews post user test
- Think aloud during test (rare)
- Computer-input user comments
- Eye-tracking (unused dataset)

4.1 Exploratory

As the name indicates, the focus of exploratory research is the exploration of a phenomenon about which the researcher is curious. The process of exploration is often two-fold: it involves the researcher delving into a topic qualitatively that is then followed by a quantitative phase, as opposed to explanatory research which starts with quantitative followed by qualitative support [Creswell & Clark 2007]. In addition, the design of the methodological exploration has an effect. According to Ritchie et al. [2013], exploratory studies are less likely to use highly structured data collection methods, particularly if one of the key objectives is to understand how participants' speech and/or narrative reveal their conceptions or values. In the case of this research, the explorative path jumped from meta-macro-micro scale, unintentionally. The path started qualitatively (CD covers, urban spaces, poster art and screens for an app) and ended with a large quantitative analysis of GUI icons.

Ritchie et al. [2013] emphasize that it is because of the inherent nature of qualitative research (i.e. it is exploratory, interactive and interpretivist), that it can make the unique contributions that it does.

4.2 Grounded Theory

Although often associated with qualitative research in general, grounded theory includes some very unique characteristics appropriate for all research. Grounded theory research can start 'from the ground up', meaning that data collected from the research process yields a set of ideas or perspectives that serve as the origin for (i.e. *ground)* the new ideas, perspectives and/or theories. An important aspect of grounded theory methodology is that it does not require a detailed, formalized, specific hypothesis upon which to base the research design. Although grounded theory is not necessarily intended for research into visual stimuli, it served as an appropriate source of inspiration due to

its goal of producing new theories that are grounded in the gathering of qualitative data during the research process [Cairns & Cox, 2008]. This research used a combination of exploratory and grounded research as a general methodological approach, as summarized by Cairns:

> The researcher may go into the research knowing that they want to find out about a particular area… but without knowing exactly what it is they expect to find. The process of doing the research formulates the theory and therefore produces potential hypotheses for further study. [Cairns & Cox, 2008, p. 139].

DeVilliers [2005] synthesized the process of grounded theory into the concise diagram found in Figure 26. His flow chart visualizes the process of emergent theories and principles that are appropriate for a generalized research approach using grounded theory:
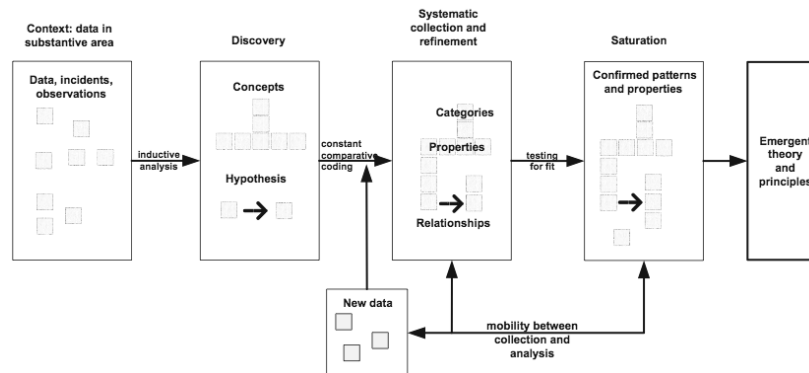

Figure 26. DeVillier's synthesized model of grounded theory emergence [DeVilliers. 2005, p. 118]

For this research project, the DeVillier's diagram describes the general research approach and philosophy rather than the specific research progression. The research approach used for this project can best be described as the combination of Exploratory-Grounded Theory.

4.3 Triangulation

General

Another dimension of design research that designers use often, Triangulation, can be roughly translated as the use of numerous methods in action that all point to a collective, corroborated result. As in geometry where multiple points increase accuracy, researchers can improve the accuracy of their understanding by gathering different types of data surrounding the research question [Jick, 1979]. Ritchie et al. [2013], describe Triangulation methodology as using different methods and sources to assure the integrity of (or to) expand inferences that can be drawn from the data. Further, triangulation adopts an assumption that by using different sources of information, this will help to confirm and improve the precision of a research finding. Triangulation can even serve to support and validate the qualitative evidence [Ritchie et al., 2013]. Jick describes the benefits of Triangulation because it:

> ...provides researchers with several important opportunities. First it allows researchers to be more confident of their results. This is the overall strength of the multi-method design. Triangulation can play many other constructive roles as well. It can stimulate the creation of inventive methods, new ways of capturing a problem to balance with conventional data-collection methods [Jick, 1979, p. 608].

Adami & Kiger [2005] propose that Triangulation was originally intended to help confirm apparent findings, yet it offers a second purpose: completeness. Jick [1979] sums up the use of Triangulation as its ability to capture the unit(s) under study in a more complete, holistic and contextual portrayal.

Triangulation methodology in HCI

Triangulation can be used in virtually every area of research, and it is a particularly useful area in the multi-disciplinary field of HCI. Wilson describes triangulation as an approach to data collection/analysis that

utilizes methods and measures to find convergence on problem areas, while often serving to be more persuasive to colleagues [Wilson, 2006].

Mackay and Fayard argue that among scientific and design disciplines, Triangulation is more likely to be beneficial, particularly in interdisciplinary fields such as HCI [Mackay & Fayard, 1997]. In their review of mobile HCI methods, Kjeldskov & Graham reviewed a number of methods for mobile interfaces. Although this research project did not focus on mobile applications, the information reviewed by Kjeldskov & Graham is appropriate and applicable for all aspects of HCI.

Table V. Kjeldskov & Graham's summary of research methods, based upon Wyencoop & Conger [Kjeldskov & Graham, 2003, p. 318]

	Method	Strengths	Weaknesses	Use
Natural setting	Case studies	Natural settings Rich data	Time demanding Limited generalizability	Descriptions, explanations, developing hypothesis
	Field studies	Natural Settings Replicable	Difficult data collection Unknown sample bias	Studying current practice Evaluating new practices
	Action research	First hand experience Applying theory to practice	Ethics, bias, time Unknown generalizability	Generate hypothesis/theory Testing theories/hypothesis
Artificial setting	Laboratory experiments	Control of variables Replicable	Limited realism Unknown generalizability	Controlled experiments Theory/product testing
Environment independent setting	Survey research	Easy, low cost Can reduce sample bias	Context insensitive No variable manipulation	Collecting descriptive data from large samples
	Applied research	The goal is a product which may be evaluated	May need further design to make product general	Product development, testing hypothesis/concepts
	Basic research	No restrictions on solutions Solve new problems	Costly, time demanding May produce no solution	Theory building
	Normative writings	Insight into firsthand experience	Opinions may influence outcome	Descriptions of practice, building frameworks

In Table V, Kjeldskov & Graham borrowed heavily from Wynecoop & Conger's descriptions of research in general, then adapted it to research within mobile HCI. Referring to the "Method" column in Table VI, there are four types of research described by Kjeldskov & Graham that are appropriate for this research [adapted from Kjeldskov & Graham, 2003]. The four types of research include:

1. Laboratory experiments

Compared with field studies, laboratory studies are conducted in a controlled environment with a specific task. Advantages include being able to focus on the targeted area and are often highly replicable

[Kjeldskov & Graham, 2003]. For this research, laboratory experiments were suitable for evaluating GUI icon design in controlled environments with little or no distractions from the outside. The disadvantage being that as with any HCI laboratory, no constructed environment can exactly replicate the natural environment. This can lead to limited relation to the real world and the potential lack of generalization outside the laboratory environment [Kjeldskov & Graham, 2003].

2. Survey research

Surveys are able to gather large amounts of data and can lead to generalization of the findings. However, they provide only a snapshot of the targeted phenomena and they rely heavily on the participants' subjective views on the topic [Kjeldskov & Graham, 2003]. An inherent problem with interviewing methodology is that all interviews are biased towards people who participate in them. In this research project, surveys and interviews were conducted to learn more about the participants' subjective responses. The techniques for this research could be broadly considered 'survey' research in order to gain a deeper understanding how people interpret visual stimuli. According to Basily & Selby, no experimental framework can be used in a vacuum. The framework and knowledge gained during the research complement one another and should be considered 'synergistic' [Basily & Selby, 1986]. The term 'synergistic' is appropriate for this research project because as it grew, the lessons and experiences that were gained in one stage of the research had a synergistic, influential effect upon the development of the next stage of research.

3. Applied research

Applied research is research based in trial and error, and while it uses a process in which the goal might be known, the methods to achieve it are not [Kjeldskov & Graham, 2003]. This is an appropriate description of this research project as well. The goal of applied research for this project was to investigate and define a set of visual parameters (with corresponding terms) that could be useful for all types of visual designers.

4. Basic Research

Similar to applied research, basic research is rooted in trial and error and relies on the competency of the researcher to follow the natural steps by following the theoretical frameworks. For example, it is important to understand the fundamental issues regarding GUI design issues, so that variations in users' interpretations can be understood and fed back into initial GUI design processes. Basic research can aid in identifying new problems and possible solutions related to human-computer interaction. While it is a very open approach, it allows for creativity in searching for methods and solutions (e.g. memory recall for GUI icons). However, it can be time consuming and result in nothing at all [Kjeldskov & Graham, 2003].

4.4 Mixed

This doctoral research was never intended to be exclusively quantitative or qualitative—the RQ's called for the use of both types of data to support the emergent results. When used in combination, qualitative and quantitative approaches provide a better understanding of research problems than can be understood by either approach alone [Creswell & Clark 2007].

The research included both qualitative and quantitative methodologies that became clearer as the exploratory approach expanded. McGrath & Johnson urge researchers to use paradigms simultaneously, i.e. positivistic and un-positivistic, as well as the complementary use of quantitative and qualitative methods in combination [McGrath & Johnson, 2003]. Further, Mathisen describes mixed methodology as *necessary*. For him, good research practice requires the researcher to:

> … use multiple methods, data sources, and researchers to enhance the validity of research findings. Regardless of which philosophical, epistemological, or methodological perspectives an evaluator is working from, it is necessary to use multiple methods and sources of data in the execution of a study in order to withstand critique by colleagues [Mathison, 1988, p. 13].

Mixed methodology in HCI

According to Mackay & Fayard, the field of HCI is multi-disciplinary by nature and utilizes paradigms/techniques from both the natural sciences and the design disciplines. They assert that HCI cannot be considered a pure natural science because it studies the interaction between people and their artificially created artifacts, rather than naturally occurring phenomena, thus violating several basic assumptions of the natural sciences. As shown in Figure 27, HCI does not suffice as a pure design discipline because it strives to independently verify design decisions and processes—it borrows many values from scientists [Mackay & Fayard, 1997].

Using a mixed methodology approach for this research allowed me to take advantage of the multiple backgrounds inherent in HCI and the methodologies that correspond to them. The advantage with this approach is that the research can build a knowledge base that appeals to a much broader audience. Figure 27 illustrates the major subdisciplines within HCI clearly.
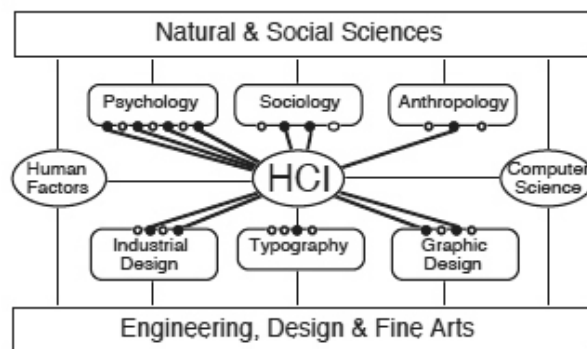

Figure 27. Multidisciplinary approaches in HCI research [Mackay & Fayard, 1997, p. 3]

Mackay and Fayard describe HCI researchers as constantly borrowing, inventing and re-inventing techniques during the process. They describe the need to converse with researchers and scientists on both applied

and theoretical levels, while the work must remain fundamentally sound for each discipline from which the research is drawn.

Like Wilson and Mathison, Mackay and Fayard express a deep insecurity felt by mixed-methodology researchers: if the work is 'scientific enough' [1997]. All three authors describe an important value of the mixed-methodological approach as a way to bolster their research argumentation among professionals and colleagues.

4.5 Generalization

A major issue concerning the results from this (and any) research is the extent to which the findings from the samples and context can be generalized to the larger population [Ritchie et al., 2013]. There is considerable argument about validity and inference to a wider audience, particularly when results are derived from a single study. Ritchie et al. claim that such a conflict depends on the meaning assigned to the qualitative research and whether it has relevance beyond its original context. They support the idea that results can be generalized beyond the research context, but propose that there must be clear frameworks in which it is appropriate to do so. They structure generalization into three related yet unique aspects:

> *Representational generalization*: whether what is found in a research sample can be generalized to, or held to be equally true of, the parent population from which the sample is drawn.
>
> *Inferential generalization*: whether the findings from a particular study can be generalized, or inferred, to other settings or contexts beyond the sampled one
>
> *Theoretical generalization*: whether theoretical propositions, principles or statements can be drawn from the findings of a study for wider application [Ritchie et al., 2013, p. 285].

For this research, all three of the above aspects are applicable and overlap in the results for each paper (except Paper 1). When the results are supported by further triangulation methods, they provide a base for the results to be generalized to a wider population (albeit conservatively). This research project used multiple methods from the start. This approach resulted in an exploratory, developmental progression from one specific study topic to the next. Overall, the methodology of this research was synergistic and grew according to the need of the studies as they evolved in scope and breadth. Table VI lists the methodologies according to each paper. There are no marks for the first paper because it theoretically established the research domain.

Table VI. Table of main methodological techniques per paper

Methodological Techniques	Research papers						
	1	2	3	4	5	6	7
A. Field Studies:							
Analogue interaction with visual stimuli		•	•	•		•	
Open-ended interviews and discussion		•	•	•		•	•
Targeted questioning/survey		•	•	•		•	•
Analog single or dual-axis test		•		•		•	•
B. HCI Studies							
Computer-based user test					•		•
Open-ended interviews post user test					•		•
Think aloud during test					•		•
Computer-input user comments					•		•
Eye-tracking (unused dataset)							

5 Summary of papers

Simple things are always the most difficult.

Carl Jung

This section provides a succinct summary of the primary information and contribution associated with each paper.

The entire research project has been a journey of discovery that was often understandable only in retrospect. The beginning of the research explored the concept of white space as an indicator of simplicity, and the emotional power that this design parameter holds. The research then progressed towards what white space is, how different people interpret it, and how it potentially relates to visual simplicity. From white space in small and large three-dimensional compositions, the research moved into GUI/HCI design, using icons as an introductory, easily testable object. The insights gained from the 3-part study of GUI icons (Paper 7) proved to be more than sufficient for research in how people see visual stimuli within the framework of simplicity.

All citation tallies are from Google Scholar, December 2016.

Paper 1

OBJECTIVE: Establishment of primary research domain

Full title	Simplicity in Complicated User-Interface Applications
Author	Martha Skogen
Paper type	Conference proceedings
Presented at:	Nordcode05, 4th Nordcode Seminar & Workshop. NTNU, Trondheim, Norway (2005)
Reference:	Skogen, M. G. (2005). Simplicity in Complicated User-Interface Applications. In *Paper for Nordcode05, 4th Nordcode Seminar and Workshop.*
# of citations	4
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli?
Summary of paper	• Paper serves as introduction to my research topic. • At this time, I anticipated a much broader level of research (more than GUI icons). • Paper was presented at conference, helpful feedback received. • No formal user test conducted. • General research questions addressed. • Breakdown of organizational themes and aspects of HCI. • Proposed research topics and testable situations.
Objective of article	• Introduce theoretical approach to topic of simplicity in HCI
Result	• Article clarifies concept (with examples) of visual simplicity. • Describes its relation to other fields. • Includes statement of research project's overall objective: i.e. to establish design strategies to improve the overall use of electronic tools.
Main contributions	• Introduction and explanation of two important concepts that are taken further: perceived simplicity and white space
What's next?	Investigate whether white space is an indicator of simplicity by conducting an informal, quantitative test and gathering real responses from participants

Paper 2

OBJECTIVE: Focus on 'white space' in micro scale 3D compositions

Full title	Visual White Space and Emotional Exclusivity: A Student Exercise
Author	Martha Skogen
Paper type	Conference proceedings
Presented at:	5th Conference on Design & Emotion Chalmers University, Göteborg, Sweden (2006)
Reference:	Skogen, M. (2006). Visual White Space and Emotional Exclusivity: A Student Exercise. In *Proceedings of the Design & Emotion Conference, Göteborg, Sweden.*
# of citations	2
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli?
Summary of paper	• Paper describes white space in detail (with e.g.). • Emotional interpretations of white space only. • Provides numerous sub-research questions. Connects to white space as an electronic user interface design issue. • Qualitative test was conducted with students and their self-made CD covers—they ranked and placed the covers according to various terms assigned to the dual-axis matrix. Photo documentation. • Inclusion of two examples that exemplified white space as focal test objects.
Objective of test	• Discover real-world interpretations of white space and its emotional associations. • Create a discussion regarding emotional connections, and the specific vocabulary used to describe white space.
Result	• Discussion regarding what people see as white space and how they experience it emotionally.
Main contributions	• Intro: what constitutes simple/complicated design • Dual-axis matrix employed (large-scale, analog) • People were not consistent/did not agree on what constitutes simple vs. complicated design. They interpret white space based upon subjective, definable criteria. • Simplicity meant different things to different people, and everyone was correct
What's next?	Continue investigation into white space, but in large-scale, 3D architectural environment. Focus on vocabulary & verbal descriptors, look for (in)consistent patterns in the data.

Paper 3

OBJECTIVE: Focus on 'white space' in macro scale 3D public space

Full title	An Investigation into the Subjective Experience of White Space in an Urban Environment
Authors	Martha Skogen & Hilde Østerås Berntsen
Paper type	Conference proceedings
Presented at:	5th Conference on Design & Emotion Chalmers University, Göteborg, Sweden (2006)
Reference:	Skogen, M. & Berntsen, H. (2006). An Investigation into the Subjective Experience of White Space in an Urban Environment. In *Proceedings of the Design & Emotion Conference, Göteborg, Sweden.*
# of citations	0
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli?
Summary of paper	• White space can be applied to architectural environments—it appears to generate emotional associations. Comparison of 2 sites in Bergen, Norway, deemed by the researchers to represent white space & non-white space. • Qualitative interviews were conducted with public. • Verbal responses were gathered, tallied and categorized to see if patterns arose from the responses.
Objective of test	• Expand upon knowledge gained from small compositions and see if they apply to large-scale architecture • Gather terms to describe architectural white space
Result	• People agreed that the visual & material austerity of Festplassen's architectural white space created a feeling of emptiness that people moved through (rather than be in)—the faster the better. The plaza that we'd deemed as non-white-space was considered a much more comfortable place to shop, rest, and take a slow walk. They liked to people-watch there, not in Festplassen. • Architectural white space must be treated sensitively in order to create emotional associations of comfort and being welcomed.
Main contributions	• Meaning of white space comprised different factors. • In general, people agreed and used common verbal descriptors. • White space (and/or simplicity) does appear to have a framework of unique characteristics with rules upon which people agree.
What's next?	This & the previous study provided knowledge about white space, its connection to simplicity, & its emotional associations. Need to discover more about the rules associated with the characteristics of visual simplicity. The next test moves into GUI/HCI design to investigate simplicity in visual communication at the smallest level: computer icons.

Paper 4

OBJECTIVE: First investigation into interpretation of GUI icons

Full title	An Investigation into the Subjective Experience of Icons: A Pilot Study
Author	Martha Skogen
Paper type	Peer-reviewed, journal-level conference submission
Presented at:	10th Int'l Conference on Information Visualization, IEEE London, United Kingdom (2006)
Reference:	Skogen, M. G. (2006, July). An investigation into the subjective experience of icons: a pilot study. In *Information Visualization, 2006. IV 2006. Tenth International Conference on* (pp. 368-373). IEEE. ISBN:0-7695-2602-0
# of citations	8
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli?
Summary of paper	• This paper moves the research into GUI/HCI design, although still analog (i.e. non-computer) • User test was conducted—8 students ranked block-mounted computer icons on a dual-axis matrix (Simple-Complicated vs. Familiar-Unfamiliar). • Order of icon pickup was considered indicative of which icon was understood first (comprehension). • Pickup order was mapped to dual-axis matrix. • Weakness of test included uncontrolled testing of numerous parameters simultaneously. This will be addressed in follow-up research.
Objective of test	• To measure how different people interpret identical GUI icons, & to establish protocol for GUI user test
Result	• Using light statistical analysis, results showed a consensus regarding visual design, pickup order, placement and scaled ranking that I'd assigned.
Main contributions	• People seem to react faster to 'simpler' visual information as long as it is familiar. Complicated visual information takes longer to understand, especially when dissociated from the symbol's archetypal elements. • 'Visual archetype' becomes a topic for research.
What's next?	Replicate this user test in its native media: computer.

Paper 5

OBJECTIVE: Categorization of verbal responses to GUI icons

Full title	Say, What Did You See? A Qualitative Interview Reveals How Users Interpreted GUI Icons
Author	Martha Skogen
Paper type	Conference proceedings
Venue:	9th Conference on Design & Emotion—The Colors of Care. Bogotá, Colombia (2014)
Reference:	Skogen, M. (2014). Say, what did you see? A qualitative interview reveals how users interpreted GUI icons. In *Proceedings of the 9th Conference on Design & Emotion—The Colors of Care.* Bogotá, Columbia. (pp. 332-337).
# of citations	0
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli? III. Do people agree?
Summary of paper	• This paper describes the results from the purely qualitative results from the user test (St. Olav's Study I, described in Paper 7.) • Article summarizes the verbal interviews only (post user test) • Not only did the pilot test reveal differences in interpretation of the data, but the manner in which the participants described their criteria differed substantially as well. • The data was analyzed and broken down into the types of responses provided: four categories of words were documented and discussed.
Objectives of test	• To support and expand upon the user test that the participants had taken • To determine if verbal answers had any relationship to the computerized answers
Result	• Participants used a number of strategies and criteria regarding the GUI icons and the criteria that they used to judge Simple-Complicated icons during the user test • Although people used the same target words, that does not indicate that they interpreted the meaning similarly.
Main contributions	• Although there were commonalities, Youths' answers differed from Adults' in both content and delivery.
What's next?	Continue to delve deeper into the differences between youths and adults.

Paper 6

OBJECTIVE: Comparison of responses across three types of visual stimuli

Full title	What Can GUI Designers Learn from 2D Poster Art?
Authors	Martha Skogen & Helle Kristine Hoem
Paper type	Conference proceedings
Venue	The Value of Design Research
Reference:	Skogen, M., Hoem, H. K. What Can GUI Designers Learn from 2D Poster Art? In *The Value of Design Research—Proceedings of 11th International European Academy of Design Conference,* April 2015
# of citations	n/a
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli? III. Do people agree?
Summary of paper	• This study set out to discover if users' assessment of visual information was consistent across three types of analog visual stimuli, HOME icons, miniaturized poster art, and screen design for booking application. • Investigation whether the users agreed amongst themselves. • In addition, 'too much' and 'too little' design (determining factors of simplicity) were investigated.
Objective of test	• To specify in greater detail, the visual parameters associated with visual simplicity, and whether they remained consistent across various types of media.
Result	• Participants' responses showed a consistency in how users interpreted Simple and Complicated designs, regardless of media.
Main contributions	• Principles of visual composition are applicable and appropriate across various types of media • People are more-or-less in agreement about the interpretations of Simple and Complicated. • This study like others, investigated adults only, yet they demonstrated the terms simple and complicated are robust and have commonly-understood visual characteristics.
What's next?	Move GUI visual stimuli to its native media: the computer.

Paper 7

OBJECTIVE: Large investigation into GUI icons in three different user scenarios

Full title	An Investigation into the Subjective Experience of GUI Icons: Age Differences Revealed
Author	Martha Skogen
Paper type	International journal
Status	To be submitted
# of citations	0
Primary RQ's	I. What is visual simplicity? II. How do people interpret visual stimuli? III. Do people agree?
Summary of paper	• This large study describes three data sets that were gathered in three user scenarios: HCI laboratory, field study of schools and crowd-sourcing (www) data • The first study was considered the preliminary study and revealed an unforeseen phenomenon. This drove the researcher to investigate the phenomenon more deeply via HCI testing in the field (schools) and en masse testing via the internet.
Objective of test	To gather quantitative data from as many users as possible
Result	• The preliminary test revealed that in general, children aged ≤13 did not respond consistently with the adults' responses to Simple-Complicated GUI icon ranking.
Main contributions	• People do not see things the same way, nor do they always see them as the designer presumes. • Children and adults interpret simplicity in GUI icons highly differently • Description and discussion of visual archetype • There may be a window of transition in which children (about age 13) learn to understand abstracted, minimalized imagery • It is important to recognize there may be presumptions in how we design

6 Contributions & Conclusion

Simplicity is the ultimate form of sophistication.

Leonardo da Vinci

6.1 Contributions

The research project's contributions can be divided into two aspects, theoretical and practical.

The primary theoretical contributions include:
- Different age groups have different viewpoints
- Abstracted imagery may be learned

The practical contributions include:
- Systematizing the GUI icons' visual parameters
- Suggestions for designers

Each contribution will be described in detail below.

Different age groups have different viewpoints

This research demonstrated that in general, adults tended to assign similar value judgments to visual stimuli, regardless of media or realm. The characteristics associated with simplicity were robust and held relatively true even when viewers based their understanding on seemingly conflicting uses of the terms (i.e. semantic vs. visual interpretation). However, the final study of this research (Paper 7) demonstrated clearly that children and youths did not respond to the visual stimuli in the same manner as adults. Interestingly, this finding corresponds directly with the fourth and final stage of Jean Piaget's theory of cognitive development. This stage is called the 'formal operational' period of development and occurs between adolescence and adulthood, or approximately ages 11 through 15-20. It is during this latter stage that people are able to think about abstract concepts and logically relate them to the use of symbols [Piaget, 1969]. Future research may focus on this connection alone.

The revelation that youths and adults respond dissimilarly to GUI icons appears to be novel in the literature. I found no evidence where GUI icons were used to compare young children's' (e.g. aged 5-10) and adults' responses in a dedicated experiment. Zammit, who studied 11-12 year olds asserted that for the GUI realm: software developers should consider the types of pictorial icons they use/design if younger users are to access their products [Zammit, 2000]. This research provides a platform for discussion that educators, researchers and parents inherently understand: children are highly capable interpreters of many aspects of their visual landscape.

Abstracted imagery may be learned

This research began with exploratory investigations regarding how people interpret visual stimuli, and ended with hints that children do not come predisposed to automatically understand highly abstracted imagery. Rather, they appear to learn to identify a basic form of an object and build a mental visual archetype with continued experience.

Santos describes the accumulation of knowledge as the capacity of human minds to project the past into the present, which people then recycle, abstract, categorize, and use at every opportunity. The user gains this knowledge from levels including:

  i) common knowledge that users have inherited or absorbed in childhood,
 ii) conceptual knowledge learned through schooling,
iii) semantic networks and categorization schemes from secondary and higher education, facts, generalizations, and
 iv) abstractions that users have accumulated in their professional lives through specialized training [Santos, 2008].

Note that Santos states that some knowledge can be 'inherited' in childhood, leading one to presume that all users would interpret GUI icons in the same manner. However, the results in Paper 7 showed that this was not the case. Santos suggests that 'abstractions' can be obtained later in life through specialized professional training. Paper 7 showed that for visual compositions, people's interpretations of GUI icons appear to change at a much earlier age. The most important contribution of the final stages of this research is the implication that there is a definable period in which youths change their interpretation of abstracted images. Further, it appears that this understanding remains for the duration of their lifetime. Dondis hints that archetypal elements may lie at the object's irreducible minimum:

> The process of abstraction is one of distillation, the reduction of multiple visual factors to only the essential and most typical features of what is being represented. [Dondis, 1973, p. 71].

It is important to note that many aspects of visual archetype are unknown, including how cultural context influences the elements that are deemed 'archetypal'. For example, the vertical grooves in the trash bin GUI icon in Table VIII are normally seen on trash bins in Northern America, not Europe. This topic remains for future research.

McDougall Curry, & de Bruijn found that concrete symbols incorporating familiar, real-world objects allow the user to ascertain meaning even when they are encountered for the first time. In contrast, abstract symbols are only likely to become meaningful after users learn the symbol-function relationship [McDougall et al. 1999]. Chiu Koong, & Fan [2012] refer to McDougall et al. (1999) and suggest that children develop through a period of learning in order to understand the meaning of an abstract symbol. As mentioned earlier, this learning stage appears to corroborate with Piaget's cognitive development theory. The emphasis here is that children appear to learn to identify and understand abstracted imagery. The research in Paper 7 inadvertently discovered the (approximate) age window during which that transition might occur. Further research can reveal more insight regarding this phenomenon, including how the increase in data usage (particularly by younger users) has a potential affect on GUI icon learning processes.

Systematizing the GUI icons' visual parameters

The terminology we use to describe the things we create is important because language is richly nuanced and there are often many ways of saying the same thing. Unintentionally, the terminology we currently use to discuss and describe our designs may carry deeply ingrained biases and presumptions. This study revealed that even two words "simple" and "complicated" carried associations that were not consistent across age groups. Regarding visual parameters, Caldwell calls for a systematic ranking of visual parameters, particularly those that appear to carry the most weight [Caldwell, 2009].

Recall that even in a small design composition such as a GUI icon, many visual parameters can (and often do) work in parallel. The most minimalized icons (e.g. black and white) will have at least two parameters: color and line type. The qualities of the icons in the middle of the range begin to overlap and interact with each other, while some qualities even seem contradictory. Table VII outlines a number of visual parameters for how the characteristics associated with "Simple" compare to those associated with "Complicated". The terms in this table

originated from research with GUI icons, yet they can apply to any realm or scale of design.

Design has not established its own terminology of basic theory, methods or processes. Therefore, I have used common humanistic descriptors from all aesthetic fields and specified them to this context, rather than inventing new terminology. In Table VII, the leftmost column denotes the nuanced differences between the Symbolic values of an icon (i.e. what the icon represents, its referential interpretation) and the Visual Design aspects (i.e. how the icon actually looks, or its immediate appearance).

If we as designers choose not to develop new terminology to describe our design work, then we must be aware of the biases that may lurk in the terms that we use. While making Table VII, it was easy for me to fall into the trap of using potentially judgmental terminology, even when I was highly aware of the presumptions that the terms often inherently embody. Finding completely neutral terminology is not easy. "Basic" became the new term for 'Simplicity' to reflect how an icon incorporates visual parameters, rather than imposing a value judgment on its design. The antonym term, 'Complicated' became "Elaborate". Table VII is intended to serve as a set of suggestions/guidelines for further discussion—not steadfast rules.

Table VII. Table of rephrased GUI icon parameter terminology

		BASIC Previously: "Simple"	ELABORATE Previously: "Complicated"
Symbolic Meaning	**VISUAL PARAMETERS:**		
	Number of metaphors	Single metaphor (e.g. Edit: pencil only)	Multiple/Compound metaphors (e.g. Edit: pencil plus paper)
	Cultural reference	Conventional, Familiar	Unconventional, Unfamiliar
	Time reference	Historical	Modern
	Archetypal	Yes	No
Design	**Amount of detail**	Low	High
	Form	Geometric Rectilinear	Organic Curved
	Edges & corners	Angular, Hard, Sharp, Pointed	Soft, Rounded
	Line type	Line/outline only	Lines plus anything else
	Color	Little or none	Yes
	Shading	Little or none	Yes
	Abstraction	Highly abstracted	Little to none
	Stylization	Little or none	Moderate to High
	Contrast	Strong (i.e. black & white)	Varying
	Illustrative likeness	Low degree (suggestive)	High degree (representative), even photorealistic
	Perspective	Flat or neutral	Tilted and/or 3D
	Proportion	Natural	Unnatural

In reference to 'Amount of detail', Alexandra Forsythe supports the use of 'detail' to describe the amount of visual elements in a composition. Forsythe describes the word 'detail' as "perhaps being a more neutral description of the structural components within an icon" [Forsythe, 2009, p. 163].

Suggestions for Designers

This research teaches us that we must be cautious in using the terms "Simple" and "Complicated". In doing so, designers of all types of media can make unintentional presumptions about a user's participatory experience. By using these terms unchallenged, a designer may impart his/her presumptions onto the user group, which may (or may not) be appropriate. This can lead to more presumptions including: i) the user has already established his/her archetypal representation for an object, and ii) the user is capable of abstracting that representation. Finally, a designer might errantly presume that a user group "prefers" one type of design over another, adding a level of subjectivity. Perhaps even pictorial icons are insufficient when compared with textual ones. Zammit states:

> ...designers of icons seem to assume that their chosen symbolic representations are in some way universal and easier to understand because the corresponding written text is either limited or non-existent. Moreover the move has been away from textual icons to the use of images for navigation, but this overlooks the fact that images may be more ambiguous than text [Zammit, 2000, p. 218].

This study demonstrates that as designers of all media types, we need to be aware of our tendency to design from our own perspective. We should not presume that other user and/or age groups share that same perspective. For this research project, the initial stages incorporated a number of unintentional presumptions that were revealed only in retrospect. The only way to release potential inherent presumptions is threefold: i) design the icons according to the needs of the target group, ii) communicate *directly* with the target group, and iii) use constant testing methodologies to ascertain the success of the design. This applies to design work for all age groups, in all realms and scales. A minimal and rather pragmatic requirement for user-centered design is to involve children as testers of products, and include them as participants in user tests [Markopolous & Bekker, 2003]. Unfortunately, this is not always the case.

6.2 Revisiting Dondis' taxonomy of visual messages

A major contribution of this research is the suggestion that visual archetypes may be inextricably connected to a symbol's 'irreducible minimum' [Dondis, 1973]. Moreover, the discovery of an apparent age-based 'window of transition' in which people appear to understand highly abstracted archetypes (see Paper 7) was unanticipated. Visual archetypes are in early stages of awareness and more research is needed to establish a knowledge base around them.

Cultural context counts

Table VIII uses Dondis' taxonomy with a GUI icon: "Trash" as the visual example. It is important to keep in mind that cultural conditioning forms a basis for understanding of the icons. The visual and cultural landscape in which a GUI icon resides gives it a context that can be helpful or confusing. Early software developers at PARC invented the contextual metaphor for 'trash' in the earliest stages of GUI icon design. The referential analogy for 'trash' is worthy of focus: it serves as a place to get rid of unwanted items in a computer. Physical trash bins are an everyday household item, and their design will take some time to become outdated. However, there are some almost non-existent symbols still in use today. Perhaps the most prominent anachronisms still in current use include:

1. ☎ icon that refers to the almost completely obsolete system of landline telecommunications

2. 💾 icon to denote the "save" function. This icon is so obsolete that younger users likely do not know the original reference (icons designed by the author). A designer and blogger, P.J. Onori proclaims the Save icon is "broken" and claims:

> Metaphors are great, until they lose their meaning. Then they become confusing, seemingly arbitrary phrases to those

not in the know. The save icon is an idiom in visual form and there's nothing good about that. [Onori, 2013].

This potential disconnection between a symbol and its anachronistic referent creates a generation gap that can best be summarized by Figure 28 (per July 2016):
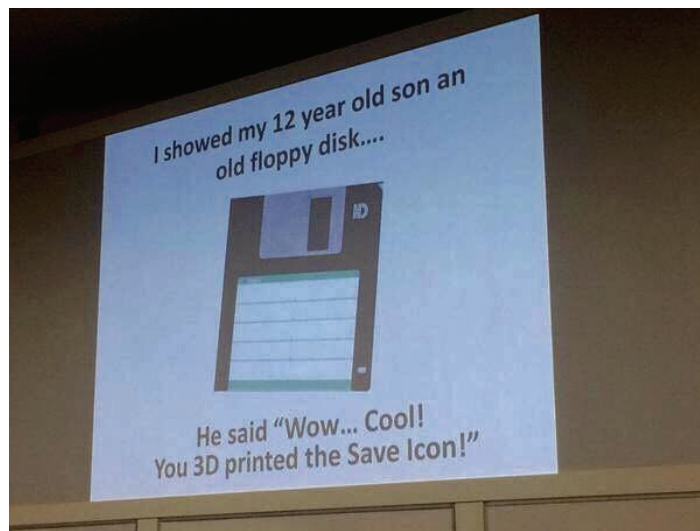

Figure 28. Generational differences [source unknown, 2016].

Table VIII demonstrates one of the researched GUI icons (Trash) within the framework of Dondis' taxonomy of visual messages (see 2.1), while also referring to the icons' visual archetype where appropriate. Multiple examples are used for purposes of comparison between variant, international versions of the same GUI icon.

Table VIII. Revisitation of Table II, with Trash icon as (as per Dondis)

Type of visual message	Example
Representation	
Shows reality and maintains high degree of representation to referent	These icons clearly depict the image of a container, and within the GUI realm, are highly realistic representations (almost photo-realistic). Note that the black bin (right) lacks the identifying, archetypal vertical grooves, yet communicates trash (due to the plastic bag insert). However, this is weak as it could be mistaken as a can of paint.
Symbolism	
Retains some real qualities and basic visual information of the referent	The left icon shows the archetypal grooves of a North-American trash bin, and yet is highly symbolized by the strong outline, rounded bottom and lack of grounding. The grooves in the side are a symbolic necessity because without them, this image would be easily mistaken for a cup or other generic container. The middle icons only barely contain the vertical striations (and make the bin look more like a comb), yet this icon still manages to communicate its message by the presence of the lifting lid. The third icon, although representative as a highly realistic image, does not show the conventional visual elements that immediately identify it. The transparent surface is not normally associated with trash bins, nor is the tilted, floating perspective. Thus, the required element that only may communicate trash bin (in context) is the presence of the green arrow that is often used to communicate recycling. This compound metaphor is needed to support what might otherwise be mistaken as a glass.

Table VIII (cont.)

Type of visual message	Example
Abstraction	
Reduces image to basic visual elements. Simplification to intense and distilled meaning, without need to retain visual connection to referent	Barely recognizable as a trash can even with its North-American archetypal vertical grooves, the left icon may be understandable only in context (e.g. it could be a Greek edifice). Although it retains the identifiable grooves, they may be an archaic identifier. Despite the fact that many international, modern trashcans lack vertical grooves, it is a necessary (and archetypal) element to communicate the message, even to users whose bins do not resemble the original referent. The middle icon retains two vertical grooves yet comes close to resembling a cooking pot. This icon is likely only understandable in context. The third icon shows the bin from a different angle, and like the first, lacks a handle for the lid. Yet this third icon, although highly abstracted, has sufficient details (i.e. the shape, grooves, and side handles) that collectively reinforce its communication as trash, NOT cup, flower vase, architectural building, or cooking pot etc.

It is important to note that the research in Papers 4, 5, and 7 was based upon a highly selective group of icons within very strict metaphors for the type of objects they represented. For example, only one type of refuse-containing solution represented Trash. Other metaphorical representations could have been used, but I chose to keep the root metaphor consistent per icon category. Some examples of the Trash versions used by different countries are shown in Figure 29:

Figure 29. Some examples of icons that metaphorically represent a variety of trash receptacles (Per June 2015).

In Figure 30, it becomes clear that the vertical grooves on the sides of the trash bin function as an archetypal element even internationally. When using this shape, the grooves are mandatory in order to distinguish a trash bin from a cup:

Figure 30. Trash receptacles lacking archetypal grooves become easily confused with a cup or thermos

An icon can only succeed if the core visual parameters are present to communicate the message of its referent to the knowledgeable viewer. The icons in Figure 30 shows three icons with unusual color and/or lack distinguishing characteristics that communicate trash. Regarding color, yellow is not normally used for trash bins. The third lacks another aspect of trash bins, the trash itself. The unusual shape and outline of the third trash bin might be more recognizable (even in international cultural contexts) if the trash were present.

Even with all archetypal elements in place, things can still go wrong. The archetypal elements of the trash bin the vertical striations with accompanying outline shape, can be demonstrated in this icon:

However, this icon shows a complete disassociation from conventional color use, representation, dark/light norms, and shading that render it difficult to determine what it is trying to communicate. It is only barely discernible as a trash bin. This icon sits precariously on the edge of communicability: one highly experienced designer and Associate Professor interpreted it as a cupcake.

6.3 Limitations of the research

Several limitations occurred in this research, the foremost being the lack of a clearly devised research itinerary (with concise, definitive hypotheses intact) prior to the start of the project. As a result, substantial amounts of time and energy were spent as the mature topic evolved into full view. However, there are distinct advantages to using an unspecified, exploratory methodology. I chose to see that each stage was a stepping-stone to whatever came next—this kept my progression along the research process fresh and intriguing. Although some leads became dead ends, it was enjoyable to proceed along an unspecified journey of discovery that led from one topic to the next. Such an organic process could not be accomplished with a predetermined research plan. However, some specific limitations remain and are summarized in the bullet points below:

- The majority of studies (Papers 2, 3, 4, & 6) did not include youths or children.

- The later studies (Papers 5 & 7) included children, yet could have had many more participants, and including those from various environments. Even the data gathered globally (Study III: 'www') in Paper 7 lacked a substantial amount of participants in the age range 5-13. In addition, the studies would have been improved by the inclusion of senior (65+) HCI users. The first attempt to gather data for Paper 7 yielded a large dataset including users aged 5-13, as well as 184 results from users aged 50-94. There was one centenarian. Unfortunately, the customized user test contained a tiny hidden code error that rendered the entire quantitative dataset unusable. Since the results gathered from the GUI user test were dependent upon users' initial impressions only, repeat testing was impossible: the study was based upon responses taken by first-time viewers only.

- In Paper 7, the methodologies used to collect data for Studies II & III could have been more rigorous and controlled, but the dataset would have been much smaller and narrower.

6.4 Future work

As is typical for many research projects, this doctoral research raised more questions than it answered. Topics to be addressed in future studies could include:

Targeted age groups

Additional research could continue investigation into the phenomenon discovered by the final three studies: that children and adults appear to interpret "simple" and "complicated" design differently from each other. The age group differentiation should be examined further, as well as international/cultural influences that might affect user responses. It would be interesting to know more about how cultural context affects which visual aspects people consider to be archetypal. Visual stimuli could expand from GUI icons to larger, more involved compositions.

Return to analog art (& Piaget's cognitive development)

The current research project only briefly touched upon meta- and macro- scales, because it unintentionally spent a long time on the micro scale computer realm (i.e. GUI icons). In the future, I would like to research how people interpret visual stimuli—particularly art—exclusively in an analog (non-computerized) format. Using large and small scales and representative and abstract art, this research might be relevant for educators, designers and parents. Closely tied to this would be investigations into how children's responses corroborate with the four stages of Piaget's cognitive development theory.

Context

For highly sensitive areas of GUI (e.g. hospital devices), visual simplicity might constitute a required aesthetic to aid ease-of-use. In his dissertation investigating the interaction of doctor-patient mobile devices at the point-of-care, Alsos provides numerous guidelines and advises user interface designers to reduce the physician's cognitive load as well as to streamline the doctor-patient bedside processes. Describing how to achieve this, Alsos states: "To prevent negative

effects on doctor-patient communication, input should either be kept to a minimum or made as simple as possible" [Alsos, 2011, p. 100]. As healthcare itself (including all medical devices) become more digital-based, the need for well-designed interfaces becomes essential for enhancing the patient-physician interaction. However, this should never come at the expense of the human connection.

An initial idea could include a review and analysis of applications and designs currently in use. They could then be critiqued according to well-established practices of good HIC design, with the intention to reduce time spent in the learning curve and increase optimal performance for all who engage with the tool.

Art

For me, this research sparked a fascination for how children interpret all types of art. This includes the terminology they use to describe their interpretations. In respecting children's different ways of seeing visual stimuli, I would like to investigate how children respond to modernistic, abstracted art (e.g. Cubism) compared with how they respond to classical art (e.g. Renaissance). I feel that as an adult and a mother, I have much to learn from children's innate ability to communicate directly (and often succinctly) the very complicated aspects of two-dimensional art.

Physiological component

Early attempts at gathering eye tracking data had to be discarded due to compromised calibration and this path was left behind. It was appropriate (and initially a strong motivational factor) to use eye tracking techniques to determine precisely where the user looked first when looking at a visual composition (e.g. GUI icon). This continues to be highly interesting considering that there may be a difference between the physiological evidence and the interpretive (e.g. GUI ranking scale) evidence. It would be interesting to see if those two datasets relate or differ from each other.

The eye tracked data for this project, although incomplete and unusable, did reveal a distinct phenomenon that was not as dependent upon precise calibration. It was the larger eye movements—the user's gaze pattern—that revealed the general manner in which the user's focus zipped around the screen. Firstly, I noticed that people's natural gaze patterns appeared to be independent of the visual stimuli. More captivating, I found that family members seemed to share similar gaze patterns regardless of age, although gender did appear to be a slight factor (even predictive). Each participant seemed to have a unique gaze pattern when viewing items on the screen, which was remarkably consistent throughout their progression through the user test. The strongest (i.e. most contrast-laden) icons appeared to grab a user's attention and interrupt their identifiable (although fast) gaze pattern. This does not imply that each participant followed a fixed routine, but rather s/he had a personal viewing strategy, with commonalities occurring among family members. Some users went clockwise around the icon circle, some viewed the icons in a counter-clockwise pattern. Some users zigzagged across the circle, some seemed to scan it top-down.

Although the sample was small, there were distinctly similar gaze patterns between parents and their children. Because each participant performed the user test individually, it would not have been possible for a person to "copy" another person's natural gaze pattern. This leads us to ask: is the manner in which we view an optical stimulus — the actual eye-movements we use — inbuilt and/or genetically determined? This topic is highly suggestive and conjectural at this point. This phenomenon must be studied further under highly controlled conditions, preferably with as many users as possible. Ideally the data should include twins' (fraternal and identical) responses.

Children's' drawings of Simple-Complicated
One uncompleted study involved using a production method whereby children were asked to generate drawings associated with Simple and Complicated. I started this spontaneously as I sat on a train after

completion of Study I of Paper 7. As I somewhat randomly collected children's drawings (in various situations), the drawing began to show a number of interesting phenomena regarding how children interpreted the terms. Such field-based methodological approach should be planned carefully in order to control for inconsistencies as best as possible Yet the methodology should also i) allow margin for the child to use their creativity in full and ii) provide opportunity for the child to respond to the task in open-ended interviews. See Appendix: Incomplete studies-2, 'Children's drawings for Simple-Complicated' for further description and examples of the drawings.

6.5 Conclusions

The intention behind this research was to learn about how people interpret visual stimuli and to make the knowledge (particularly regarding the relationship between Simplicity-Complicated) easily accessible to software developers. Current literature provides extensive research regarding simplicity in design, yet the literature provides little insight on how people of younger ages interpret this value when compared with adults. This exploratory research deepens the knowledge base and contributes to the discussion regarding the visual characteristics that are associated with this foundational visual aesthetic. In addition, the research revealed that adults interpret the terms relatively consistently across a variety of media and scales (e.g. architectural city marketplaces in Bergen compared with GUI icons). For younger users, this may not be the case. This is essential for designers to understand and use conscientiously: that their designs (particularly when using abstracted, minimalized visual archetypes) might miss their target group altogether.

It is important that designers test their designs with their targeted user group repeatedly and effectively, and be sensitive to the needs of each age group *as they mature and change*. This research project found that despite skilled training, experience, and best intentions, designers may

still harbor deep presumptions about knowing what is best for everyone. By allowing such presumptions to exist unchallenged, visual designers may potentially miss their target group (i.e. youths). Worse, we may unintentionally carry biases and underestimate children's adept abilities in interpreting visual information. This research addresses how people respond to visual stimuli within the framework of the aesthetic relationship between Simplicity-Complicated. It is necessary for designers to be conscious of all aspects of the design implications whether or not their designs relate to visual simplicity.

One question

As designers move through their design processes, I would like to see one question become integral to each phase, particularly in the earliest developmental stages. I would like to see this question taught as an integral part of design education programs for all subdisciplines. I would like to hear this question discussed often between designer and client. Asking this single question also requires that the designer be fully open to the responses that it may generate, including those that the designer may not wish to hear. The timeless question is simply:

Do you see what I see...

or do you see something different?

Notes

1   Many researchers and writers have dedicated their entire careers to the study and improvement of symbols and icons, regardless of media or realm. One professor of mine spent seven years (in a team) to design the "perturbed circle" On-Off symbols that seem so universal today. This research project only glazes the surface of an enormous, important field of symbol design that caters to an increasingly global community.

2   I am particularly indebted to senior Capt. Einar Strøm (SAS) for allowing me to accompany him and his co-pilot in the training seat of their cockpit for the duration of a short flight from Bergen-Ålesund, 2011. He enjoyed describing his suggestions for how to improve the cockpit user-interface and I enjoyed hearing the cumulative lessons from his lifelong experience of flying commercial aircraft. This event gave me a deep respect for both analog and digital technologies in highly technical environments like this one. In addition, I experienced how the interpretation of "simplicity" is utterly contextual and related to personal history and situation. For him, the cockpit was simple to use.

3   In addition to the visual sense, augmented reality provides stimuli via other sensory experiences including the auditory, tactile, olfactory, vestibular (motion), thermal, and temporal senses. Experiences that engage multiple senses simultaneously result in a holistic user experience that lie beyond the scope of this research.

4   'Art realism' aims to represent the subject matter as honestly and accurately as possible, without using conventions, idealization or other deviations from the detailed depiction of nature or society. The movement was popular in the mid-19th century with painters like Gustav Courbet (1819-1877). Contemporary realism has transitioned into hyperrealism where artists like Omar Ortiz (human figure), Matteo Mazzetta (city scenes) or Joel Rea (seascapes) paint oversized 2D compositions that defy belief. Hyperrealism succeeds in 3D as well: Ron Meuck creates enormous life-like sculptures that dwarf the viewer.

5   Helleristninger (petroglyphs) carved into exposed rocks in Scandinavia are approximately 3000 years old. The famous cave paintings in Europe: Lascaux (France), Chauvet (France) and Tito (Spain) are considered to be some of the most beautiful Paleolithic art on earth, and range from 17,000-30,000 years old. Yet these works are considerably more modern than earlier findings. Some highly abstracted symbols on the ceiling of Altamira cave in Spain are approximately 39,000 years old while ochre (i.e. the earthly warm red claylike material that was often used as pigment) kits have been found in South Africa that are 100,000 years old [Walter, 2015].

     Many people, including myself, consider the ancient cave paintings as some of the most extraordinary creations by mankind. Upon exiting the Lascaux cave during a visit, Picasso was overheard as he said: *"We have learned nothing in 30,000 years..."*

6   Collage: "Kituwah Motherland". The artist describes the piece: it "helped to raise awareness about the corporate giant Duke Power and their plans to build a power plant overlooking the most sacred place to the Cherokee, the Kituwah Mound. This piece was used to raise money for grass roots efforts to legally investigate options for the Cherokee people who felt this spiritual mecca was in danger." [Goshan, 2016].

References

Adami, M. Fenech, & Kiger, A. (2005). The use of triangulation for completeness purposes. *Nurse Researcher*, 12(4), 19-29.

Alsos, O. A. (2011). *Mobile Point-of-Care Systems in Hospitals: Designing for the Doctor-Patient Dialogue.* Doctoral dissertation, Norwegian University of Science and Technology. Trondheim, Norway.

Android developer site (2016) for apps and smartphones. https://developer.android.com/design/get-started/principles.html. (Retrieved October 2016).

Arnheim, R. (1954). *Art and visual perception: A psychology of the creative eye.* University of California Press.

Auer, S., & Dick, E. (2007). When does a difference make a difference? A snapshot on global icon comprehensibility. In Human-Computer Interaction. *Interaction Platforms and Techniques.* Springer Berlin Heidelberg. 3-12.

Barton, B. F., & Barton, M. S. (1987). Simplicity in visual representation: A semiotic approach. *Journal of Business and Technical Communication*, 1(1), 9-26.

Basili, V. R., Selby, R. W., & Hutchens, D. H. (1986). Experimentation in software engineering. *Software Engineering, IEEE Transactions on*, (7), 733-743.

Beardon, C. (1992). CD-Icon: an iconic language based on conceptual dependencyBrighton. *Digital Creativity (Intelligent Tutoring Media,* 3(4), 111-116.

Bennett, K. B., & Flach, J. M. (1992). Graphical displays: Implications for divided attention, focused attention, and problem solving. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 34(5), 513-533.

Bigman, Alex. (2015). Updated. Gestalt principles and the psychology of design. http://99designs.com/designer-blog/2014/08/12/gestalt-principles-psychology-design (Retrieved June 2016).

Bois, Yve-Alain. (2001). *Matisse and Picasso.* Flammarion.

Brown, B. (2011). "The Power of Vulnerability". TED 2010. http://www.ted.com/talks/brene_brown_on_vulnerability. (Retrieved June 2016).

Cairns, P., & Cox, A. L. (Eds.). (2008). *Research methods for human-computer interaction* (Vol. 12). New York, NY, USA: Cambridge University Press.

Caldwell, J. (2009). Safety icons and user: A Peircean reanalysis. 2009 IEEE International Professional Communication Conference, 1-8.

Caplin, S. (2001). *Icon design: Graphic icons in computer interface design.* Watson-Guptill Publications, Inc.

Card, S. K., Newell, A., & Moran, T. P. (1983). *The psychology of human-computer interaction.*

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision research*, 51(13), 1484-1525.

Chater, N. (1997). Simplicity and the mind. *The Psychologist,* 10(11), 495-98.

Cheon, J., & Grant, M. M. (2009). Are pretty interfaces worth the time? The effects of user interface types on web-based instruction. *Journal of Interactive Learning Research,* 20(1), 5-33.

Chiu, S., Koong, C. S., & Fan, S. H. (2012). Icon Design Principles for Preschoolers: Implications Derived from Child Development. *Procedia-Social and Behavioral Sciences*, 64, 228-237.

Chun, M. M. (2000). Contextual cueing of visual attention. *Trends in cognitive sciences,* 4(5), 170-178.

Corbetta, M., Miezin, F. M., Dobmeyer, S., Shulman, G. L., & Petersen, S. E. (1990). Attentional modulation of neural processing of shape, color, and velocity in humans. *Science*, 248(4962), 1556-1559.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing & conducting mixed methods research.*

DeVilliers, M. R. (2005). Three approaches as pillars for interpretive information systems research: development research, action research and grounded theory. In *Proceedings of the 2005 annual research conference of the South African institute of computer scientists and information technologists on IT research in developing countries* (pp. 142-151). South African Institute for Computer Scientists and Information Technologists.

Dondis, D. A. (1973). *A primer of visual literacy*. MIT Press.

Dreyfus, Henry. (1984). Symbol Sourcebook: An Authoritative Guide to International Graphic Symbols. Wiley, 1984. and Thomas P. Moran,

Allen Newell. *The Psychology of Human-Computer Interaction.* Lawrence Erlbaum Associates, Inc.

Dix, A. (2009). *Human-computer interaction*. Springer US. 1327-1331.

Elam, K. (2001). *Geometry of design: studies in proportion and composition.* Princeton Architectural Press.

Finsen, H. (Ed.), (2005). *Matisse: a second life.* Happy Books.

Enikeev, R. (2015). The Internet Map. Image used with permission. www.internet-map.net. (Retrieved 2016).

Forsythe, A. (2009). Visual Complexity: Is That All There Is? *Engineering Psychology and Cognitive Ergonomics* Springer. Berlin Heidelberg. 158-166.

Frankel, L., & Racine, M. (2010). The complex field of research: For design, through design, and about design. In *Design & complexity: International conference of the Design Research Society*. Design Research Society. (URL March 2015).

Frutiger, A. (1989). *Signs and symbols: their design and meaning*. Van Nostrand Reinhold Company.

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

Gatsou, C., Politis, A., & Zevgolis, D. (2011). From icons perception to mobile interaction. In *Computer Science and Information Systems (FedCSIS), 2011 Federated Conference on.* IEEE. 705-710.

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.

Gittins, D. (1986). Icon-based human-computer interaction. *International Journal of Man-Machine Studies*, 24(6), 519-543.

Goodman, N. (1976). *Languages of Art.* Hackett Publishing Co., Inc.

Goshan, Shan. Eastern Band Cherokee Native American artist. Collage: "Kituwah Motherland". www.shangoshorn.net. (Retrieved 2016). Image used with permission.

Gribbin, J. (2009). *Deep simplicity: chaos, complexity and the emergence of life.* Penguin UK.

Hannah, G. G. (2002). *Elements of design: Rowena Reed Kostellow and the structure of visual relationships.* Princeton Architectural Press.

Highwater, J. (1983). *Arts of the Indian Americas: Leaves from the Sacred Tree.* HarperCollins Publishers.

Huang, W., Eades, P., & Hong, S. H. (2009). Measuring effectiveness of graph visualizations: A cognitive load perspective. *Information Visualization*, 8(3), 139-152.

Hendersen, Bill. Kwakiutl or Kwakwaka´wakw Master Artist & Carver. Serigraph: "Thunderbird and Sisiutl". Image used with permission.

Hiroshi, Sugihara. (1997) Updated. Original by Phil Gibbs, 1996. http://www.math.ucr.edu/home/baez/physics/General/occam.html. (Retrieved 2016).

Hofmann, Armin. (1965). *Graphic Design Manual, Principles and Practice*. Van Nostrand Reinhold.

Hollender, N., Hofmann, C., Deneke, M., & Schmitz, B. (2010). Integrating cognitive load theory and concepts of human–computer interaction. *Computers in Human Behavior*, 26(6), 1278-1288.

Holtan, N. (2015). Personal communication.

Honeywill, P. (1999). *Designing icons for the graphical user interface*. Digital Creativity, 10(2), 67-78.

Høiseth, M. (2014). *Human-Centered Design Considerations in Healthcare Contexts: Young Children as Users of Medical Products.* Doctoral dissertation, Norwegian University of Science and Technology. Trondheim, Norway.

International Organization for Standardization 'ISO'. https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-1:v1:en (Retrieved 2015).

Isaacs, Ellen and Alan Walendowski. *Designing From Both Sides of the Screen*. New Riders Publishing, 2002.

Isherwood, S. J., McDougall, S. J., & Curry, M. B. (2007). Icon identification in context: The changing role of icon characteristics with user experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 49(3), 465-476.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. Administ*rative science quarterly*, 602-611.

Kelly, K. (2002). "God is the Machine". Wired Magazine, December 2002. Issue 10.12. www.archive.wired.com/wired/archive/10.12/holytech.html?pg=1. (Retrieved 2016).

Kelly, K. (2007). "The Next 5,000 Days of the Web". TED 2007. http://www.ted.com/talks/kevin_kelly_on_the_next_5_000_days_of_the_web#web#t-329052. (Retrieved March 2015).

Kennedy Space Center®, (2014). Mission Control Room Display (on the bus tour of Cape Canaveral) Florida, USA. Fact presented in replication of original takeoff sequence. Personal visit by the author: January, 2014.

Kjeldskov, J., & Graham, C. (2003). A review of mobile HCI research methods. In *Human-computer interaction with mobile devices and services*. Springer. Berlin Heidelberg. 317-335.

Kojiro, Y. (1965). *Forms in Japan.* East-West Center Press.

Kroeger, M., & Rand, P. (2008). *Paul Rand: conversations with students.* Princeton Architectural Press.

Lauer, D., & Pentak, S. (2011). *Design basics.* Cengage Learning.

Lidwell, W., Holden, K., & Butler, J. (2010). *Universal principles of design, revised and updated: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design.* Rockport Pub.

Lunsford, A. A. (Ed.). (1995). *Reclaiming rhetorica: Women in the rhetorical tradition.* University of Pittsburgh Press.

Mackay, W. E., & Fayard, A. L. (1997). HCI, natural science and design: a framework for triangulation across disciplines. In *Proceedings of the 2nd conference on Designing interactive systems: processes, practices, methods, and techniques.* ACM. 223-234.

Maeda, J. (2000). *Maeda at media.* Rizzoli International Publications.

Maeda, John. (2006a) Blog: The laws of simplicity: http://lawsofsimplicity.com (Retrieved June 2015).

Maeda, J. (2006b). *The laws of simplicity: Design, Technology, Business, Life.* MIT Press.

Maeda, J. (2007). "Designing for simplicity". TED 2007. http://www.ted.com/talks/john_maeda_on_the_simple_life. (Retrieved 2016).

Maiocchi, M. (2014). *The Neuroscientific Basis of Successful Design: How Emotions and Perceptions Matter.* Springer.

Marcus, Aaron. (1992). *Graphic Design for Electronic Documents and User Interfaces.* ACM Press.

Markopoulos, P., & Bekker, M. (2003). Interaction design and children. *Interacting with computers,* 15(2), 141-149.

Marzona, D. (2004). *Minimal art.* Taschen.

Mathison, S. (1988). Why triangulate? *Educational researcher*, 17(2), 13-17.

Matisse, Henri. (1992). (*Original: Jazz. 1947, Published by Tériade*). New edition published by George Braziller, New York.

McDougall, S. J., 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., de Bruijn, O., & Curry, M. B. (2000). Exploring the effects of icon characteristics on user performance: the role of icon concreteness, complexity, and distinctiveness. *Journal of Experimental Psychology: Applied*, 6(4), 291.

McGrath, J. E., & Johnson, B. A. (2003). *Methodology makes meaning: How both qualitative and quantitative paradigms shape evidence and its interpretation.*

Mendell, P. (1994). Personal communication, Brissago, Switzerland Design Program for the Yale School of Art.

Mendell, P. (2001). *Auf den ersten Blick: graphic Design für den Alltag*. Lars Muller Publishers.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological review*, 63(2), 81-97.

Mitton, J., Bali, C. (2009). *Once upon a starry night: A book of constellations*. National Geographic Books.

Mitchell, W.T. (1986). *Iconology: image, text, ideology*. University of Chicago Press.

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

Mullett, Kevin and D. Sano. (1995). *Designing visual interfaces: Communication-oriented techniques*. (Vol. 2550). Englewood Cliffs. SunSoft Press: a title of Prentice Hall.

Munshi, K. *Design Definitions*, Constructed booklet. 2002. Contact: munshi999@yahoo.com or munshi@idc.iib.ac.in

Musée Picasso Paris®. (2002). 5 rue de Thorigny, 75003 Paris, France. Personal visit by the author: April 2002.

Museum of Contemporary Art®, The. Los Angeles (MOCA®). 2016. Image used with permission. www.moca.org. (Retrieved 2016).

NASA/JPL-Caltech/2MASS. 2015. Image courtesy of NASA. www.nasa.gov/jpl/spitzer/pia18014. (Retrieved 2015).

Nelson, G. (1965). *Problems of design*. Whitney Library of Design.

Nielsen, Jakob. (2000). *Designing Web Usability*. New Rider Publishing.

Nielsen, Jakob. (1993). Iterative user-interface design. *Computer*, 26(11), 32-41.

Nielsen, Jakob. (1994). *Usability Engineering*. Elsevier.

Nielsen, Jakob & Marie Tahir. (2002) *50 Homepages Deconstructed*. New Riders Publishers.

Norman, D.A. (2010). *Living with Complexity*. MIT Press.

Onori, P.J. (2013). Metaphors, Idioms and Why the Save Icon is Broken. www.somerandomdude.com/2013/05/11/metaphors-idioms-save-icon-broken. (Retrieved 2015).

Petterson, Rune. (2002). *Information Design — An Introduction*. John Benjamins Publishing Co.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child*. Basic Books.

Plaue, C., Miller, T., & Stasko, J. (2004). Is a picture worth a thousand words?: an evaluation of information awareness displays. In Proceedings of Graphics interface 2004. *Canadian Human-Computer Communications Society*. 117-126

Pleasant Hill, Kentucky, USA. Multiple visits by the author (1970-2011).

Porter, V. (2006). *Word into art: Artists of the modern Middle East.* British Museum Press.

Preece, J., Sharp, H., & Rogers, Y. (2015). *Interaction Design-beyond human-computer interaction.* John Wiley & Sons.

Pretorius, A. J., & Van Wijk, J. J. (2009). What does the user want to see? What do the data want to be? *Information Visualization*, 8(3), 153-166.

Rand, Paul. (1994). Personal communication, Brissago, Switzerland Design Program for the Yale School of Art.

Resnick, Elizabeth. *Design for Communication*. Wiley, 2003.

Ritchie J., Lewis, J., Nicholls, C. M., & Ormston, R. (Eds.). (2013). *Qualitative research practice: A guide for social science students and researchers*. Sage.

Rothko. Mark. (1952). In 15 Americans. Exhibit #507, Museum of Modern Art (MoMA), New York, NY, April 9-July 27. p. 18

Saadé, R. G., & Otrakji, C. A. (2007). First impressions last a lifetime: effect of interface type on disorientation and cognitive load. *Computers in human behavior,* 23(1), 525-535.

Santos, L. (2008). Simplicity in Your Mind. http://www.uxmatters.com/mt/archives/2008/05/simplicity-in-your-mind.php (Retrieved 2016).

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action* (Vol. 5126). Basic books.

Shneiderman, B., & Ben, S. (2003). *Designing the user interface*. Pearson Education India.

Schwartzberg, Louie. (2011). Gratitude. TEDxSF conference. Talk available at https://www.youtube.com/watch?v=gXDMoiEkyuQ. (Retrieved June 2015).

Shen, Patrick. (2016). Pursuit of Silence. Full-length film. Transcendent Films. www.pursuitofsilence.com (Retrieved July 2016).

Skogen, M. (2016). *Informal survey taken with residents in the city of Trondheim, Norway.*

Sprigg, J., & Larkin, D. (1987). *Shaker: life, work, and art.* New York: Stewart, Tabori & Chang.

Szabo, M., & Kanuka, H. (1999). Effects of violating screen design principles of balance, unity, and focus on recall learning, study time, and completion rates. *Journal of Educational Multimedia and Hypermedia*, 8(1), 23-42.

Tezuka Architects, Takaharu +Yui (2007). Fuji Kindergarten. Tachikawa, Tokyo, Japan. Photos: Tezuka Architects. www.tezuka-arch.com. Images used with permission.

Tezuka, Takaharu, (2014). "The Best Kindergarten You've Ever Seen". TED: http://www.ted.com/talks/takaharu_tezuka_the_best_kindergarten_ you_ve_ever_seen. (Retrieved 2015).

Tezuka, Takaharu, (2016). Lecture attended by the researcher. The Oslo School of Architecture and Design. Oslo, 2016.

Thiel. Philip. (1981) *Visual Awareness and Design*. University of Washington Press.

Tognazzini, Bruce. (1992) *TOG on Interface*. Addison-Wesley Longman Publishing Co., Inc.

Treue, S. (2003). Visual attention: the where, what, how and why of saliency. *Current opinion in neurobiology*, 13(4), 428-432.

Tufte, E. R., & Graves-Morris, P. R. (1983). *The visual display of quantitative information* (Vol. 2, No. 9). Cheshire, CT: Graphics press.

Tufte, E. R., & Weise Moeller, E. (1997). *Visual explanations: images and quantities, evidence and narrative* (Vol. 36). Cheshire, CT: Graphics Press.

Ungerleider, S. K. A. L. G. (2000). Mechanisms of visual attention in the human cortex. *Annual review of neuroscience*, 23(1), 315-341.

Waldman, D. (1978). *Mark Rothko: 1903-1970 A Retrospective*. New York: Harry N. Abrams. Inc. and The Solomon Guggenheim Foundation.

Walter, Chip. (2015). First Artists. *National Geographic*. 227(1), 32-57.

Ware, C. (2012). *Information visualization: perception for design*. Elsevier.

Wilson, C. E. (2006). Triangulation: the explicit use of multiple methods, measures, and approaches for determining core issues in product development. *interactions*, 13(6), 46-ff.

Zammit, K. (2000). Computer icons: A picture says a thousand words. Or does it? *Journal of Educational Computing Research*, 23(2), 217-232.

Øritsland, Trond Are. (2002-2016). Associate Professor, Institute for Product Design, Norwegian University of Science and Technology (NTNU), Trondheim, Norway. Personal discussions & inspiration.

Total number of references: 130

Appendices

Table A shows only a brief sampling of study areas that were not discussed in detail in this research.

Table A. Examples of visual icon subtopics not discussed in detail

Topic	Basic description	Examples of keywords	Examples of Authors and contributors
Communication Studies	The study of processes of communication between humans and how messages are interpreted	Communic-ation Meaning Messages Signs Codes	Fiske J. Shannon & Weaver
Iconography (historical)	The identification, description & classification of symbols, themes & images in a work of art	Images Stories Allegories Dates Literature	Gombrich, E. Panofsky, E. Ripa, C. (1593)
Iconology	Methodology of study & interpretation of the social-historical, contextual & situational themes behind symbols, subjects & images in a work of art	Historical interpret-ation

Meaning Social Values | Gombrich, E. Goodman, N. Mitchell, W. Panofsky, E. |
| **Linguistics** | The scientific study of | Language | Chomsky, N. |

theory	the nature of language and how people communicate	form, meaning & context	de Saussure, F. Lakoff, G. Weinreich, M.
Semiotics	The study of signs and sign processes, symbols and message making between the signifier and the signified.	Icon Index Metaphor Sign Symbol	Cassirer Goodman N. Langer Morris, C. Pierce, C.
Symbology	The study of symbols	Symbol	Frutiger, A. Tillich, P. Zimmer, H.

Table B. Definitions of various aspects of HCI terminology

Term	Definition	Source(s)
Human computer interaction (HCI)	The study of people and computing technology and the ways that they influence each other.	John, B. E., Bass, L. J., Sanchez-Segura, M. I., & Adams, R. J. What is HCI?
Graphical user interface design (GUI) *AKA:* *Human computer interface design (HCI Design), General Screen Layout, User Interface Design, Interaction Design etc.*	i. In human-computer interface design, ...designers must actively pursue techniques to reduce the mental processing operations required just to be able to use the tool. ii. Interaction design is about how the artifact produced is going to affect the way people work: the design of interventions.	i. Brown, C. M. (1999). p. 4. Human-computer interface design guidelines. Intellect Books. ii. Dix, A. (2009). Human-computer interaction (pp. 1327-1331). Springer US.
Computer Icon *AKA:* *Icon, Visual icon, symbol, etc.*	i. "Icons" are pictographic symbols that are used as part of the dialogue in order to represent processes and data in the computer. ii. An icon is the simplest type of representation since it consists of a pattern of lines that physically resembles what it 'stands for'. Icons display features that resemble the objects they signify	i. Gittins, D. (1986). Icon-based human-computer interaction. International Journal of Man-Machine Studies, 24(6), 519-543. ii. Pierce, C.S. (1902). Logic as Semiotic: The theory of signs. In Gatsou et al., (2011)
Information Visualization	i. The use of interactive visual representations of abstract data to amplify cognition	i. Ware, C. (2012). Information visualization:

AKA: Information Design , Information Graphics, Graphical Display of Information, Statistical Graphics etc.	ii. Graphical displays consist of complex ideas communicated with clarity, precision and efficiency.	perception for design. Elsevier. ii. Tufte, E. R., & Graves-Morris, P. R. (1983). The visual display of quantitative information. Cheshire, CT: Graphics press.

Table C. Definitions of key terms used in this research

Term	Definition	Source(s)
Simplicity	The subjective experience and judgment of an observer who feels no difficulty in understanding what is presented to him.	Arnheim, Rudolf. (1954). Art and visual perception: A psychology of the creative eye. Univ. of California Press
Abstractness	Within the representational realm, many styles of picture-making lend themselves to portraying things of nature with just a very few structural features. The patterns that result from limiting representation to just a few features of the object are often simple, regular and symmetrical.	
Simplicity	Order contributes a great deal to the visual synthesis of simplicity, a visual technique of directness and singleness of elemental form, free from secondary complications or elaboration.	Dondis, D. A. (1973). A primer of visual literacy. MIT Press.
Abstraction	Abstraction, visually, is simplification toward a more intense and distilled meaning. Abstraction can exist in visual matters not only in the purity of a visual statement stripped down to minimal representational information, but also as pure abstraction, which draws no connection with familiar visual data, environmental or experiential.	
Complexity	A visual intricacy made up of many elemental units and forces and results in a difficult process of organizing the meaning in the pattern.	

Abstraction	A specific kind of artistic distortion is called abstraction. Abstraction implies a simplification of natural shapes to their essential, basic character. Details are ignored as the shapes are reduced to their simplest forms.	Lauer, D., & Pentak, S. (2011). Design basics. Cengage Learning.
Simplicity

Abstract

Complicated | Freedom from complexity, intricacy or division into parts

Of or pertaining to the formal aspect of art, emphasizing lines, colors, generalized or geometrical forms, etc., esp. with reference to their relationship to one another.

Composed of elaborately interconnected parts, complex. Difficult to analyze, understand or explain. | Webster's Encyclopedic Unabridged Dictionary, (2001). Thunder Bay Press |

Incomplete studies

Three studies were begun but left incomplete for differing reasons. Each will be described below.

1. Eye tracking

For Study I (the pilot study) in Paper 7, an eye tracker was set up to capture the physiological data of pupil movement (i.e. 'saccades'). Each participant agreed to use it. However he data was deemed to be unusable due to a combination of many factors that are described below. Calibration was not consistent across all users due to:

1. *Miscalibration*: refers to the slight differences in each person's calibration. The calibration needed to be consistent across all participants in order to make the dataset usable—it was not. This meant that the exact placement of the eye saccades could not be determined with complete assuredness. In other words, some peoples' calibrations were "tighter" to the target than others, and we could not be sure it was due to calibration or the actual eye movements.

2. *Shifted set*: some participants' response sets were shifted (again the issue with calibration) although we could compensate for this by use of the 'apple slicer' tool described below. This was the least of the worries.

3. *Multiple views*: the data showed that people often viewed an icon multiple times. They bounced around the circle, and then even bounced inside the icon itself. On many occasions a person's eyesight wandered out in the white non-icon area. These issues combined to make data analysis extremely difficult, inconsistent, and fundamentally at risk for quality control.

Four types of data were collected:

1. *Order viewed*: in which order/sequence each icon was seen
2. *Fixation number*: which saccade was registered by the eye tracker
3. *When seen*: as fractions of seconds, i.e. the time for each saccade fixation point from beginning of the category
4. *Duration*: amount of time for which the participants' focus was held at that particular icon (for first time icon has been looked at).

Icons were mapped to visual charts for Order viewed and Duration.

Data analysis for 'Order viewed' required manual observation of each saccade (numbered) and then determining the sequences related to each icon, per category.
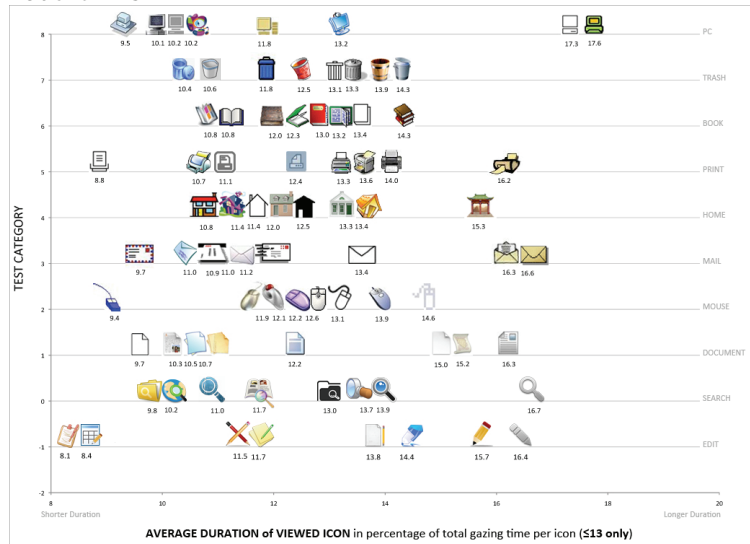
Youths ≤ 13:
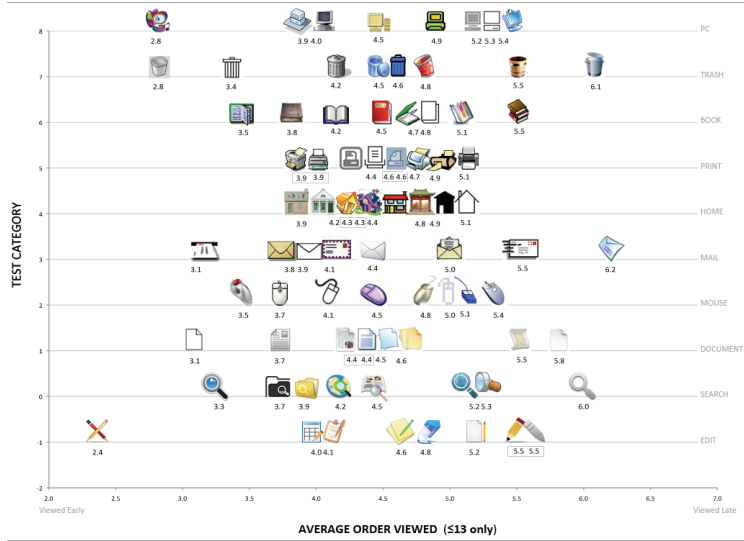
Adults > 16 :
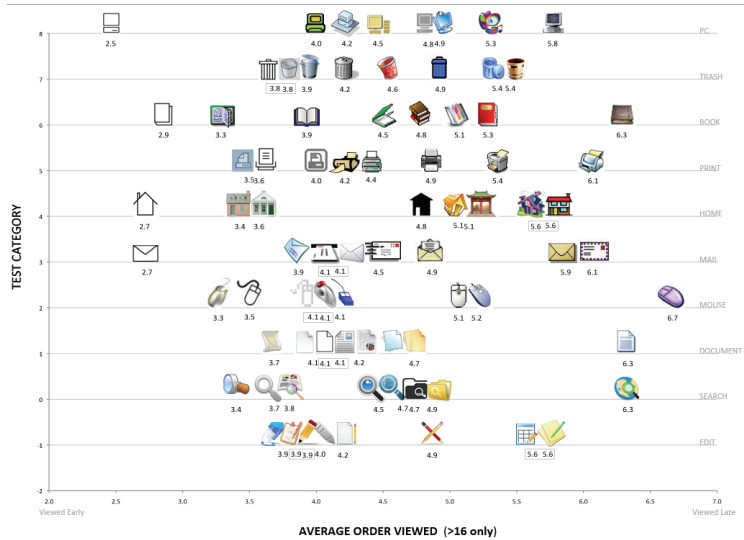
Figure A. Examples of the eye tracking input for Order viewed

'Duration' data was gathered by manually going through each focal saccade and determining seconds dedicated to each icon.
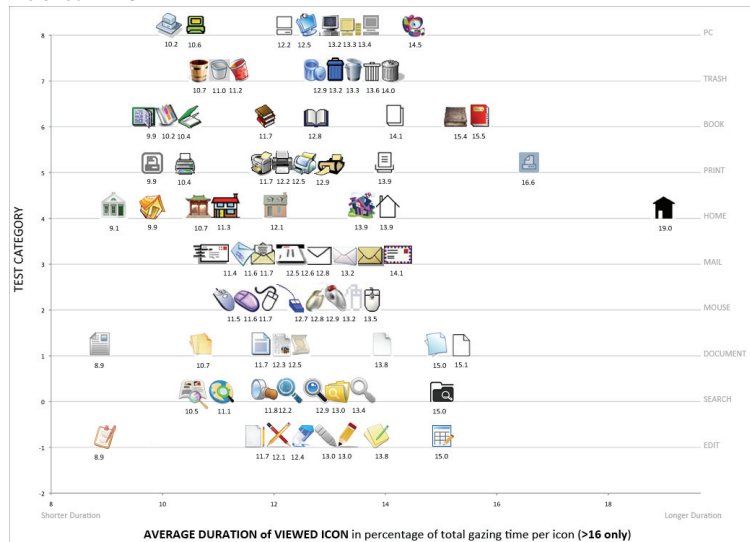
Youths ≤ 13:

Adults > 16 :

Figure B. Examples of the eye tracking input for Duration

Although the eye tracking data did not yield a successful dataset regarding how users see visual stimuli physiologically (e.g. what do users see first, is it contrast as Armin Hofmann declared?), there were numerous insights to be gained as can be seen in the charts above.

NB:
Where not specified, all icons used in this research project were collected from arbitrary online sources by using the search term "free _____ icons" and then accessing images, where the blank was filled in with specific term. For each icon, considerable efforts were taken to ensure that each icon was available for free, unrestricted use.

2. Children's drawings for 'Simple-Complicated'

This experiment occurred at the same time as the pilot study at St. Olav's where it became apparent that youths ranked the GUI icons markedly differently than the adults. I decided to use a production methodology to delve further and see if the pattern was replicable on paper, with children producing rather than responding to my visual stimuli. I began to generate set of data about how children drew a house that was simple as opposed to complicated This research happened spontaneously and lacked control and consistency. It really just began as an experiment in curiosity, when I sat next to a young girl (age 6) on a train and spontaneously asked her to do a little request. I brought out a piece of paper I happened to have, drew two long lines and wrote 'Enkel' (Norwegian for 'Simple') on the left, with 'Komplisert' (Norwegian for 'Complicated') on the right. Knowing that my research was going to involve the Home icon, I then asked her to draw a home in whatever way she felt matched the two descriptors. She said she'd understood. She spent approximately 7 minutes drawing and started with the Complicated version. I kept silent the whole time. Her example is shown in Figure C:
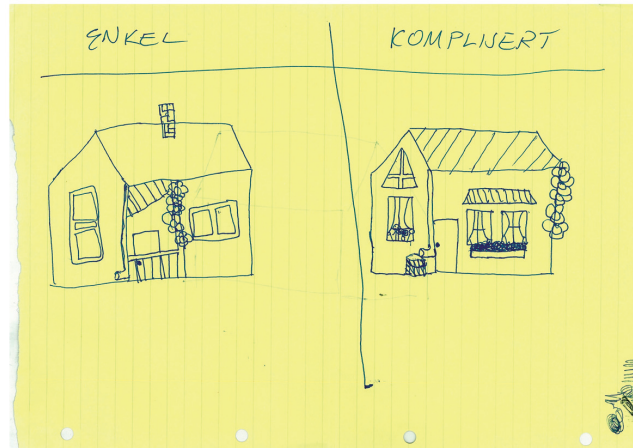
Figure C. First productive drawing technique
(female, age 6)

Her Simple version is somewhat less detailed than the Complicated version. Knowing the left-to-right influence from our western culture might have a powerful confounding effect, I began to experiment with mixing the placement of the terms.

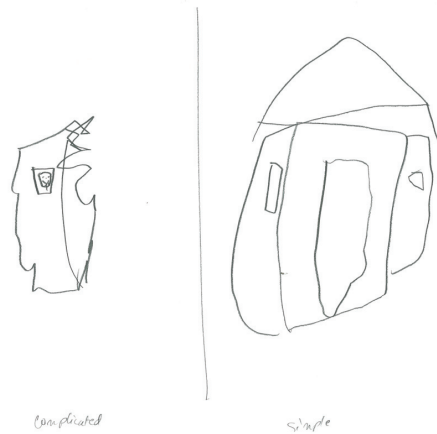Figure D shows a version from a 5 year old, Complicated on the left, Simple on the right:

Figure D. Another example of productive drawing with changed format (male, age 5)

Note the confidence exhibited by the Simple (this time on the right) vs. the Complicated on the left. Already the methodology was starting to deviate from controlled circumstances, as I collected drawings only when it seemed appropriate or convenient for the child. One final version is shown in Figure E:
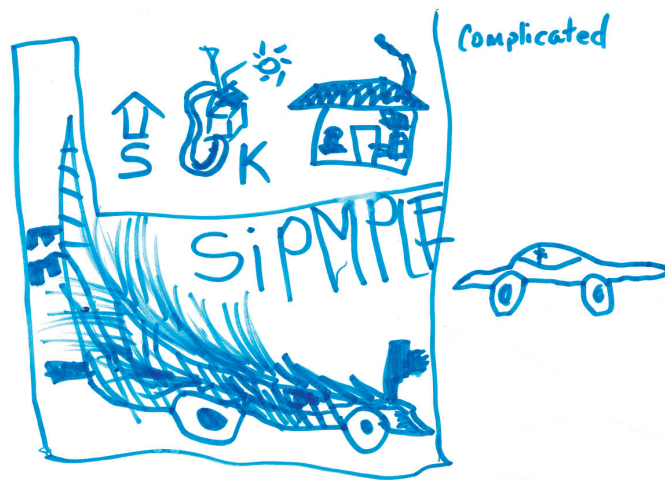
Figure E. Another example of productive drawing with changed format (male, age 5)

For this example, I wrote only the Complicated word on the right, and asked him to complete the rest of the test format himself. He chose to draw cars as well as the home motif. After the child made these drawings, I began to survey other children in school scenarios, and collected an additional 84 drawings from students aged 5-7. Due to the need to prioritize other lines of research, I unfortunately did not complete the study.

Part II

RESEARCH PAPERS

Paper 1

OBJECTIVE:

Establishment of primary research domain

Author: Martha Skogen

Full title: Simplicity in Complicated User-Interface Applications

Presented: Nordcode05, 4th Nordcode Seminar & Workshop
NTNU, Trondheim, Norway (2005)

Simplicity in Complicated User-Interface Applications

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Perfection is achieved *not* when there is nothing more to add, but when there is nothing more to take away.

Antoine de Saint Exupery

Abstract

As technological applications become increasingly complicated, the need for simplicity in user-interface design grows. Visual design can be used to reduce the amount of intimidation that the user experiences, and hide the application´s complicated functionality. This is a phenomenon I call "perceived simplicity". It holds potential for helping to solve a paradoxical problem experienced by user-interface (UI) designers: increase usability without sacrifice of functionality. Simplicity will serve as a design strategy and inspiration will be gathered from other traditional disciplines including art, design, and architecture. Specific design issues will arise from a case-study, either in the medical or petroleum sector.

Introduction

Popular culture is currently in the midst of a burgeoning revolution. Philips has targeted the issue by rebranding itself with the tagline "Sense and Simplicity". The Economist used its Survey in Information Techonology (Oct. 28, `04) as a call to arms: the survey was entitled "Make it Simple". Even a local Norwegian grocery chain Rema1000 currently advertises that "The Simplest is Often the Best". There appears to be an undercurrent of change: to make life less complicated, less intimidating. This is especially true in information technology, the sector of society which might reflect complexity to the greatest degree. John Maeda highlights this on his webpage promoting simplicity [15]:

With all of the choices available to us today, there is a quiet wish to choose from less, instead of more.

Computers were invented to make our lives easier, and in doing so, they are supposed to be easy to use. However, as computers become more intertwined with our lives, their range of functionality expands, and the complexity in using them grows dramatically. This is especially true when developers are encouraged to pack more functionality into each system they construct, without emphasizing visual aesthetics or clarity of communication.

Although the Human-Computer Interface field is relatively young, there is a vast amount of information on how to design good interfaces. And yet, there are plenty of unfortunate examples around us. Although this could be due to many variables, I have chosen to address one single factor: the complexity (visual and functional) with which these applications are designed.

The availability of sophisticated desktop design programs (e.g. Photoshop, Flash, Director) has provided a wealth of opportunity for programmers and designers to increase the level of visual richness in interfaces. The number of designed elements, as well as the degree to which they are designed, has increased in recent years. It follows that each element in a visual composition must be contemplated and regarded in an overall visual context, perhaps in a codified, systematic manner. Digesting complex visual information takes up precious time and energy on the part of the user. I suspect that the time needed to absorb extra design elements distracts from the original intention of functional applications: to convey information as quickly as possible.

I believe that a "less-is-more" approach (Mies van der Rohe, Buckminster Fuller) may serve as a useful design strategy. This is especially true in complicated user-interface applications, in complex settings (e.g. control rooms). I advocate that the electronic interface cease to serve as a haven for experimental graphic design. Rather, the user-interface should be a forum for the ultimate simplicity of visual design interaction.

I intend to test a very basic hypothesis empirically: Aesthetic simplicity improves user experience. In other words, if visual design can be used to reduce the visual complexity of an interface, the level of intimidation a user feels can also be reduced. I suspect that the application will become simpler to use, and thus more useful.

General Research Questions

In light of the growing degree of user-interface complexity, my hypothesis is that indeed, design matters. This is relevant for *all* levels of user-interface design, from the micro (information visualization) to the macro (overall scheme) level. In this case, "micro" refers to low-level specific information, and how it is communicated through graphs, charts and other representative devices. "Macro" refers to the high-level, overall visual scheme and the aesthetic language which conveys information through a general graphic expression.

I would like to investigate general design questions in three aspects of user-interface design: visual, structural, and experiential. **VISUAL** refers to how information is communicated visually, either on the macro or micro level. **STRUCTURAL** refers to the arrangement of the information and how it is accessed, ultimately how effectively the application conveys information. **EXPERIENTIAL** refers to the general perception of the application, and the emotions that arise in the user when he/she interacts with it.

Reliable results of these types of subjective user experiences can only be assessed through quantifiable, systematic empirical testing.

General user-interface research questions include:

VISUAL
(2D Graphic Design)

• Do users prefer "minimalistic", "clean", "simple" user-interfaces?

STRUCTURAL
(Information Architecture)

• Does navigation (ease of use) affect a user´s judgment of overall quality of an application?

EXPERIENTIAL
(Overall subjective experience)

• If the application looks simple, will it be regarded so?

• In UI design, is "perceived simplicity" a desirable attribute towards which to strive?

• Are there universal principles of visual simplicity?

More specific issues regarding each aspect follow below:

Whitespace (VISUAL)
Experience tells us that humans associate whitespace with high quality. Think of the experience of entering a used-clothing thrift store versus an exclusive hand-made shoe salon. Airiness, either in a real-space environment or in an online environment ("whitespace") should be conscientiously employed to promote similar emotions and associations. Jakob Nielsen refers to this essential aspect of visual design as "unused" (Nielsen, Homepage Usability). Unfortunately this is a very typical view.

Navigation (STRUCTURAL)
Applications are becoming very complex and the complexity is often reflected in the information visualization itself, especially user navigation. Navigation is a key problem area for most developers. Ironically, this is a vital segment of an application which often overtly reveals the result of unfortunate visual design decisions. I suspect that an application that looks difficult to organize mentally will be difficult to use, and understood as such. The result can be a frustrating experience for both developer and user alike. I theorize that the degree to which the user navigates through an application affects their overall user experience.

Elegance (EXPERIENTIAL)
We know from graphic design that fewer elements on a page significantly increases how those elements relate to each other. A major issue is to determine the balance between the visual beauty of user-interface design and the application´s functionality. An application must be effective to use, after all! Can the use of "elegant" design elements increase the "perceived simplicity" of an application? If so, does it affect a user´s overall judgment of an application, even if it results in an increase in number of clicks?

Perceived Simplicity (EXPERIENTIAL)
The Apple Ipod´s raging success has proven that consumers will choose technology which is functionally minimalistic as well as aesthetically pleasing. However, the serene external beauty of the Ipod (shape, form and material) camouflages its advanced internal technological mechanism. It is a superior product, even though the niche for it had not been developed by the time of its release. Even though its primary function is singular (i.e. it just plays music), it does so in a very enjoyable manner. Even the scroll-based menu system gives the appearance of profound ease-of-use. Indeed, technology can be more humane, more familiar, more simple than it has been. The Ipod is a perfect example of "perceived simplicity": easy on the outside, advanced on the inside.

I will investigate this phenomenon of "perceived simplicity" regardless of which case-study I choose. I believe it holds potential for solving the critical and paradoxical issue which UI designers face: increase the ease-of-use without sacrifice of functionality.

Other Aesthetic Disciplines

Information is communicated on many levels through many different aspects of everyday life. In this project, it is appropriate to investigate if/how principles of simplicity are represented in other well-founded, traditional disciplines (e.g. art, design, architecture). Upon determining the specific research questions associated with the case-study, I plan to investigate those questions using simplicity as a core design strategy. With the case-study-specific issues in mind, I will investigate if/how each discipline presents its respective information in a clear, concise and communicative manner. This relationship can be shown in the diagram below:
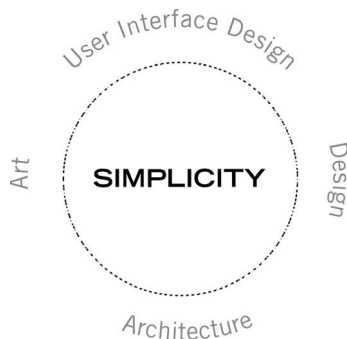
Each discipline has cross-referential subtopics which can be used for guidance and inspiration. Topics which are appropriate for this project include:

User-Interface Design
• Information visualization
• Navigation in virtual space
• Cognitive mapping

Art
• Gestalt theory
• Composition theory
• Color theory

Architecture
• Patterns (Christopher Alexander)
• Navigation in real space (wayfinding)
• Social interaction in public places

Design
• Interaction of elements (2D) and form (3D)
• Sensation and perception
• Hierarchy of communication

Objectives

The primary objective of the PhD project is to establish design strategies to improve the overall use of electronic tools. By using the properties of information communication and visual design in traditional disciplines: art, design, architecture, we can apply the relevant, identified principles to the field of UI design. This will be accomplished by using simplicity as a design strategy in case-based design issues. Ideally, the principles should be concrete enough so that practitioners can employ them in software design, regardless of their specific design issues.

Potential Case Studies

UIO-Intervention Center
Institute for Petroleum Technology (NTNU)
Statoil Onshore Control Room
St. Olav´s Hospital
Hemit

Case Study-Based Research Questions

Although I intend to survey specific questions and issues under each potential case study, I have only completed this for one area: the Intervention Center, Department of Medical Research, University of Oslo. The Center is an affiliated research group located inside the University of Oslo Hospital. They are a world leader in development, testing and provision of groundbreaking tools for advanced surgical techniques.

Specific questions for the Intervention Center

2D
• How should radiological images be presented for surgery?

• In video-assisted surgery, is a 2D "strategic map" sufficient to give an overview of instruments and other information outside of the field of view?

• How does one design a large-format screen for an operation theater so that it visualizes all of the available information sources?

2D/3D
• How can 2D cross-sectioning and 3D volume-rendering be combined to result in the best possible 3D information?

• What role should stereo visualization play in laparoscopic surgery and in virtural reality-driven surgery?

3D
• How can volume-visualization and video be combined in an augmented reality application, for general medical visualization purposes?

Eye-hand coordination
• How can eye-hand coordination be improved in order to speed up the training process for video-assisted surgery?

Research methods

The research method will include theoretical research into various disciplines which will result in a set of criteria to be tested empirically. User tests will be adapted to the specific issues presented in the case study. Research results will be published accordingly. A brief summary of the research strategy involves:

• Investigate information communication (specifically navigational communication) in other traditional disciplines

• Formulate principles of information visualization from those disciplines

• Determine how "perceived simplicity" in software affects user experience (test for varying levels of visual complexity)

• Apply the underlying information visualization principles to UI design

• Construct a set of useful guidelines for the UI community

Analysis

Analysis of user tests will follow a classic pattern established in other fields: test, collect data, analyze with statistical measurements (if/when necessary).

Expected Results

Results will hopefully include a fundamental set of information visualization criteria which crosses multiple disciplines, and can then be used to formulate guidelines for the UI programmer. These design guidelines will ultimately help UI programmers develop software which is more clear, consice, communicative, and easy to use. The degree to which "percieved simplicity" as a useful design strategy will be assessed.

Conclusion

It has been established that some types of interfaces inhibit the flow between a user and his/her task. The design process for a software program often includes visual design skills at the very latest stages of design, if at all. I postulate that the skills of a visually-oriented UI designer become more crucial with increasing degrees of software complexity.

Regardless of the conclusions of this analysis of simplicity as a design philosophy, the world of Information Technology is likely to grow ever more complicated.

As a result of this, it becomes increasingly important to include a skilled visual designer in the very beginning phases of program development, even at the initial information architecture stage.

Bibliography

[1] Albers, Josef. *Interaction of Color — Revised.* Yale University Press. 1963.

[2] Alexander, Christopher. *The Timeless Way of Building.* Oxford University Press, 1979.

[3] Berger, John. *Ways of Seeing.* BBC & Penquin Books, 1977.

[4] Card, Stuart K. and Thomas P. Moran, Allen Newell. *The Psychology of Human-Computer Interaction.* Lawrence Erlbaum Associates, Inc., 1983.

[5] Chatty, S. Sire, etc. Revisiting Visual Interface Programming: Creating GUI Tools for Designers and Programmers. *Proceedings of the ACM UIST*, ACM Press, October 2004. Pages 267-276.

[6] Cooper, Alan. *The Inmates are Running the Asylum.* SAMS, 1999.

[7] Dodge, Martin and Rob Kitchin. *Atlas of Cyberspace.* Addison-Wesley, 2001.

[8] Dodge, Martin and Rob Kitchin. *Mapping Cyberspace.* Routledge, 2001.

[8] Dondis, Donis A. *A Primer of Visual Literacy.* MIT Press, 1973.

[10] Gotz, Veruschka. *Color &Type for the Screen.* Rotovision/Grey Press, 1998.

[11] Hoffman, Armin. *Graphic Design Manual.* Van Nostrand Reinhold, 1965

[12] Itten, Johannes. *The Art of Color.* John Wiley & Sons, 1961.

[13] Isaacs, Ellen and Alan Walendowski. *Designing From Both Sides of the Screen.* New Riders Publishing, 2002

[14] Laurel, Brenda (editor). *The Art of Human-Computer Interface Design.* Apple Computer Inc., 1990.

[15] Maeda, John. *http://simplicity.media.mit.edu.* March 2005

[16] Marcus, Aaron. *Graphic Design for Electronic Documents and User Interfaces.* ACM Press, 1992.

[17] Mullett, Kevin and D. Sano. *Designing Visual Interfaces.* Prentice Hall, 1995.

[18] Nielsen, Jakob. *Designing Web Usability.* New Rider Publishing, 2000.

[19] Nielsen, Jakob & Marie Tahir. *Homepage Usability — 50 Websited Deconstructed.* New Riders Publishing, 2001.

[20] Pawson, John. *Minimum.* Phaidon Press, 1996.

[21] Rand, Paul. *Design, Form and Chaos.* Yale University Press, 1993.

[22] Ruder, Emil. *Typography.* Arthur Niggli Teufen AR, 1967.

[23] Schneiderman, Ben. *Designing the User-Interface — Strategies for Effective Human-Computer Interaction.* Addison Wesley Longman Inc., 1998.

[24] Tognazzini, Bruce. *Tog on Interface.* Addison-Wesley, 1992.

[25] Tufte, Edward. *Envisioning Information.* Graphics Press. 1990.

[26] Tufte, Edward. *Visual Explanations.* Graphics Press. 1997.

[27] Wong, Wucius. *Principles of Two-Dimensional Design.* John Wiley & Sons, 1972.

[28] Wurman, Richard Saul. *Information Architects.* Graphis Press Corp. 1996

Paper 2

OBJECTIVE:

Focus on 'white space' in micro scale 3D compositions

Author: Martha Skogen

Full title: Visual White Space and Emotional Exclusivity: A Student Exercise

Visual White Space and Emotional Exclusivity:
A Student Exercise

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ABSTRACT

In graphic design, white space (often known as negative space) is an important design parameter which when uncontrolled, can appear to be a non-designed void. However, when implemented with sensitivity, it is a visual effect that can elicit powerful emotional associations in the viewer. This study attempts to gain insight into how white space triggers certain emotional associations: good design, exclusivity, uniqueness, high quality and simplicity. To test these associations of white space, I held a class exercise for master-level Industrial Design Engineering students at NTNU. The exercise involved placing self-created CD covers on a research tool used primarily for marketing research: the dual-axis value matrix. Per my hypothesis, some students felt that prominent amounts of white space serve as a visual stimulus for objects, which are strongly associated with high quality. However, this exercise resulted in a heated debate among the students. I review the exercise and the resulting debate in detail in this paper. In today's world of often overwhelming visual stimuli, it appears that quiet visual compositions stand out from the crowd. Therefore it is intriguing to understand the multiple interpretations and effects of this vital (but often left to afterthought) aspect of design.

1. INTRODUCTION

The space in, around and between objects in a two-dimensional composition is known as *white space* (negative space). Graphic design teaches us that fewer elements on a page significantly increases how those elements relate to each other. This is apparent in the graphic design of Armin Hofmann [8], who often uses a minimum number of elements in his two-dimensional design. In using a minimum number of elements, each element gains greater

power due to there being less distraction from extraneous visual information. When there are fewer objects on a page, there is a proportional increase in the amount of white space. This means that white space becomes a powerful compositional tool, one that the designer must control with conscious sensitivity. Yet this powerful compositional aspect is often left to an afterthought — a signal that the designer has only considered the positive elements in a composition. Please consider the remarkable balance and control of white space in the examples below:

Fig. 1: Examples of Armin Hofmann's poster art

These examples show extraordinary elegance where white space is a major factor in the interplay of positive elements. Note that the term white space does not refer to the color white only. In the examples above, white space is actually colored white in only the middle example. In the first example, the dominant white space area is colored black, whereas in the third example, there are equal amounts of white space colored both red and black.

Graceful examples of white space are rare these days. In desktop design manuals, discussion about white space is often emitted entirely or relegated to a few paragraphs. To further degrade the power of white space, some authors have defined it as "…the empty but often active areas that are void of visual elements" [24]. Jakob Nielsen refers to this essential aspect of visual design as "unused" [19]. In spite of this apparent negativity, cultural experience tells us that humans often associate white space with good design, uniqueness, high quality, and/or exclusivity. Consider the Ipod®, and the Apple® corporate profile in general: both represent an extraordinary restraint of design. They are visually uncluttered and have become associated

with being *cool*. This might be due either to the popularity of the products themselves, or to the clean design, or a combination of the two.

Now imagine entering a used-clothing thrift store versus an exclusive handbag boutique. What do you see in your mind's eye? It is very likely that the thrift store will contain a large number of items tightly packed into a small space, and will look very visually dense. This is probably different from the environment you might have imagined in the exclusive boutique. Indeed, the fun of a used-clothing store is the hands-on experience: the act of digging around all the clutter, and allowing yourself to find something from all the stuff. However, I am concerned here with the *immediate impression* whereby each visual display appears to set up different emotions, associations, expectations and method of interaction.

Think of a busy webpage you may have seen recently. Some user-interfaces contain an extremely dense amount of information and visual elements. Google[®], however, demonstrates that the decisive use of prominent amounts of white space can create a powerful impression. It is extremely popular because its spacious, clean interface provides a breath of fresh air. The visual simplicity of its design differs dramatically from the constant bombardment of visual information provided by other search engines. I deduce from these examples that airiness, either in a real-space environment or in two-dimensional (2D) composition, is a powerful compositional device when applied conscientiously. It seems apparent that this airiness is also associated with emotional descriptors such as good design, exclusivity, uniqueness, high quality and simplicity.

During each fall, I teach a class entitled Visual Communication and Packaging Design for master-level Industrial Design students at NTNU. The class material covers everything from graphic design, to conventional ID projects, to short-term corporate case studies in multiple sectors. Over the semester-long course, I dedicate a substantial amount of time teaching students how to think about the white space in their compositions. Because the proper use of white space signifies that the designer was in total control of the composition, it is imperative that we understand the emotional associations it creates. The exercise with the students represents only the first small step into my investigation of this important design parameter.

1.1 Research Questions

I would like to investigate the phenomenon of white space and exclusivity and ultimately apply the knowledge to user-interface design. I have split my primary questions into three groups, one for general white space issues and the second for white space's applicability to user-interface design. This paper (and the student exercise) deals with the emotional interpretations of white space only.

The *specific* research questions addressed in this student exercise are:
- Do people consistently associate certain visual design characteristics with certain emotions (especially white space in particular)?
- Do people agree on what constitutes simple vs. complicated design?

We can stretch these two primary questions into *general* questions about white space as a visual design tool/parameter. *General* questions about white space include:
- What is "clean, simple" design anyway? What do these terms mean visually?
- How/why does the use of prominent amounts of white space give an overall impression of exclusivity?
- At what point does filling the white space change its qualities of exclusivity?
- How can these issues be tested effectively and non-subjectively?
- What is the judgment criteria for white space? When does space become *empty?*

From there we can ask how white space is influential in the layout of a computer interface. Research questions about white space as an *electronic user-interface* design issue include:
- Do users prefer minimalistic, clean, simple user-interfaces to current compositions?
- Do users prefer the status quo, more, or less visual noise?
- How important is it to control white space when designing electronic applications? My opinion is that it is VERY important. But how does one measure and/or test for this?
- How much of a user's preference is due to conditioning (by use of current software apps)?
- Most importantly, how can software developers learn to use and control white space — a major aspect of the overall design? Is it possible to determine an optimal proportion that everyone can use (based on books where approximately 50% is white)?

In user interface applications, one must determine the balance between the visual elegance of the design and the application's functionality. After all, an application must be effective to

use. Can the use of elegant design increase the user friendliness of an application, even if it results in an increased number of clicks? Why don't major software developers utilize white space more conscientiously? Would it be practical if they did?

2. STUDENT EXERCISE: DUAL –AXIS MATRIX

The exercise was carried out on 15 March, 2006. The dual-axis scale is a method most often used in marketing research and early product design processes. More specific than a single-axis scale, it can be used to plot out two characteristics simultaneously. Both axes are continuous and include the edges; there are **not** four distinct quadrants. Using this method in product/brand evaluation serves as a sufficient measure of subjective interpretation of a visual stimulus. For my purposes, it was necessary to use a large-scale physical prototype, as I'd asked the students to judge their newly created CD covers on the matrix. However, they were not allowed to move *their own* CD covers, only one done by someone else.

2.1 The Target CD Cover

Fig. 3: Ragnhild Nesbakken's CD cover from 2004, outside and inside

Since there are only 15 people in the class, I supplemented the selection with two CD covers that had been done by two women who had taken the class previously. Ragnhild Nesbakken took the class in 2004 and kindly allowed me to use her CD cover as a primary test object. Her solution shows an example of exquisitely controlled white space (in this case colored white). For the outside, she chose white space as the dominant visual device and coupled it with a textural component: corrugated cardboard. This creates a very subtle, delicate shadow effect — appropriate for the wintery associations she wanted to inspire. For the inside, she devised an ingenious representation for snow: styrofoam beads encased in transparent plastic

channel tubing. I decided to include Ragnhild's CD cover because I felt the conscientious design of white space held great potential for emotional associations of exclusivity. I wanted to see how it would be placed on the matrix scale.

2.2 Technique

Dual-axis matrices are often seen in small, A4 format. However, since this exercise involved a number of people who were asked to move numerous physical objects, I made a large-scale version with a white bed sheet as the background. Wooden sticks served for the axis lines and axis words were printed on A3 paper. This allowed me to change the words very easily. The students turned around while I switched the words between variations, until I gave the ok to turn back to the exercise. I announced the parameter I wanted them to think about, and then ran to the floor above to take pictures while they did the exercise. We completed five variations of this technique. The use of different terms allowed me to test for White space/Exclusivity without the students knowing it, and also allowed for slightly different semantic interpretations of each word. All but one student were native Norwegian speakers, and both the Norwegian and English words were visible on each A3 sheet.

2.3 Matrix Layout

The following matrix layouts represent the primary test issues.

First impression of design:

```
                 Colorful
                 Fargerikt
                     ↑
Playful                        Serious
Lekende   ←——————————→         Seriøst
                     ↓
                 Neutral
                 Nøytral
```

Visual design makes the CD look:

                    Simple
                    Enkel

Exclusive   Everyday
Eksklusivt   Alminnelig

                    Complex
                    Komplekst

Overall impression of CD cover:

                    Affordable
                    Rimelig

Unique   Common
Unikt   Vanlig

                    Expensive
                    Dyrt
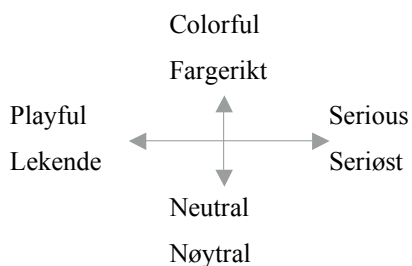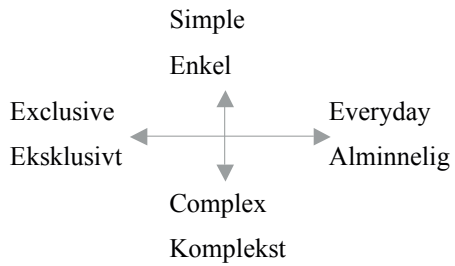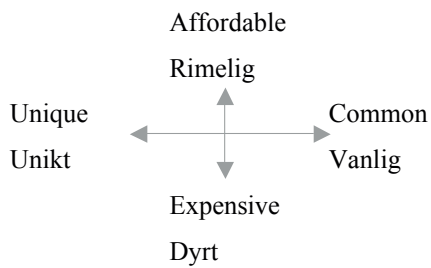
For the sake of comparison, I would like to present a few other CDs that I did not feel incorporated the visual use of white space as strongly as Ragnhild's.

As we can see, there are a number of different design strategies that generate all types of emotional associations. Although we could debate the use of white space in almost every one (with the exception of the globe in the lower left), I have chosen to investigate white space when represented by a prominent amount of the color WHITE. The CD in the upper left corner comes closest to incorporating white space as I've outlined it here, but since this example was so dependent on being seen from above, I decided to concentrate solely on Ragnhild's design. Still, I compare this one to hers briefly in the Results section.

3. RESULTS

The results of these exercises are shown in the photographs below, with the parameter repeated. Ragnhild's CD cover is highlighted by a red oval.

3.1 First impression of design:
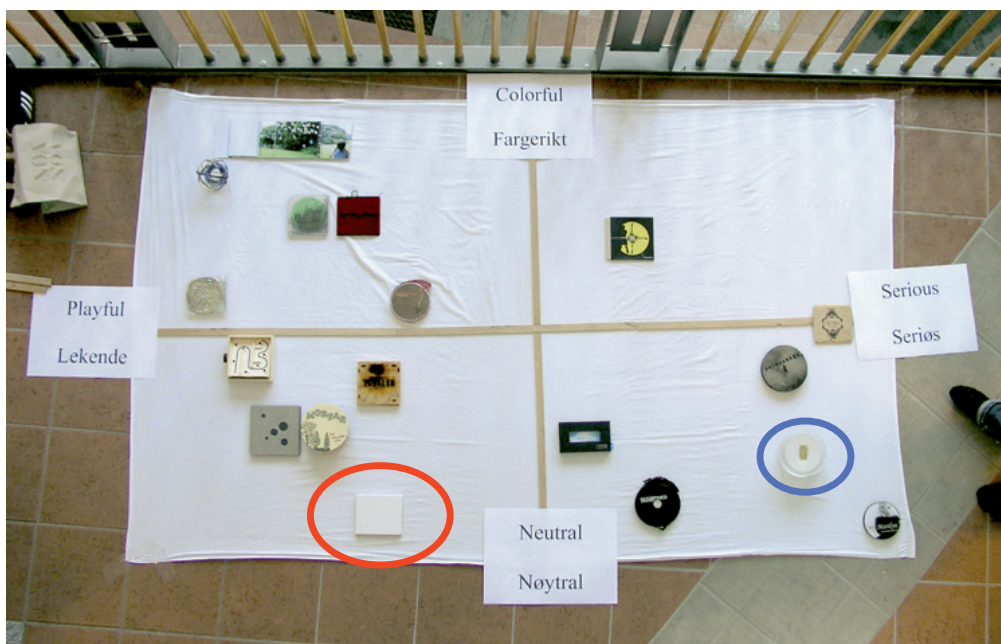
(Ragnhild's CD = red oval)

This variant was completed early in the exercise and was intended to serve as a warm-up. Because we'd held a critique the morning before the exercise, all students were aware of the materials and design choices involved in each CD cover.

The placement of Ragnhild's CD cover in this example is quite decisive. It has been placed clearly at the Neutral end of the vertical axis, and slightly towards the Playful side of the horizontal axis. The word *Neutral* was chosen as an opposite to colorful; it was my hope that *Neutral* would not have negative connotations. As we can see, the students placed covers with more visual elements towards the Playful end, and placed the covers with fewer elements towards the Serious end. This corresponds to the vertical axis as well: fewer visual elements are considered Neutral, whereas multiple elements are considered Colorful. The CD cover deemed to be most Colorful was actually opened to reveal the inside of the cover, whereas all others remained closed. This became a primary factor in the decision-making.

In some ways it was surprising that Ragnhild's CD cover was placed closer to Playful than Serious. Note the other CD cover (blue oval), made by a student in the current class. Although this CD cover displayed a comparable amount of white space, it was placed decisively towards Serious. This CD cover was made of heavy transparent plastic with gold trim; it is my suspicion that materials, size and solidity played a substantial role in its placement with reference to Ragnhild's.

3.2 Visual design makes the CD look:
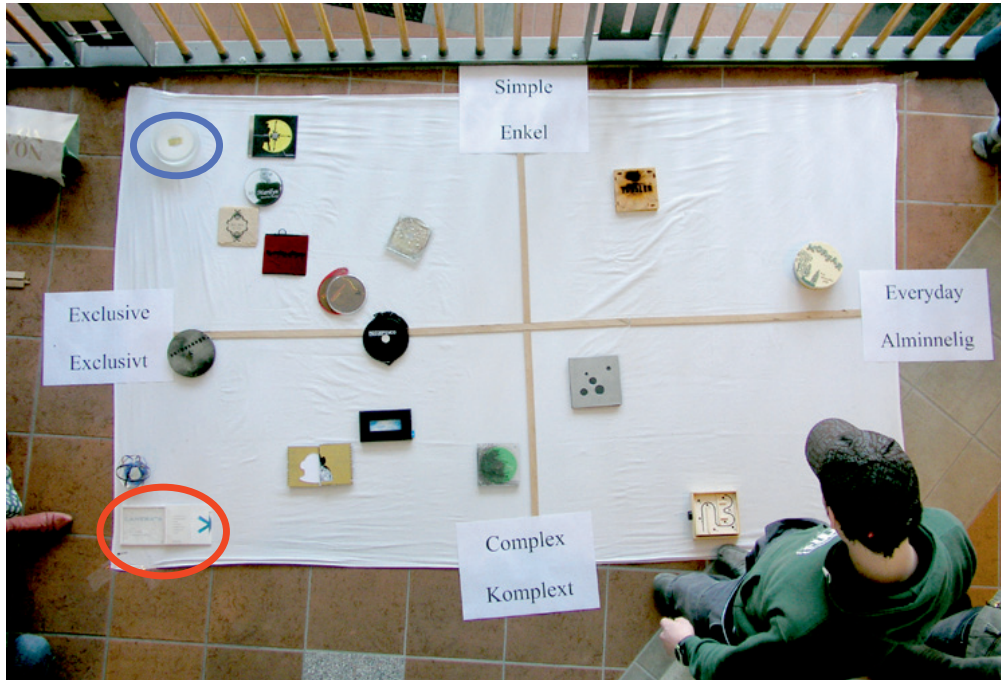
(Ragnhild's CD = red oval)

For the next variant, Ragnhild's CD cover was the only one to be presented in open form. This became a matter of discussion: the students could not agree whether to judge it while open or closed. When closed, one student exclaimed it was "super-Simple!" but when open, it was placed at the extreme combination of Exclusive and Complex. The students settled quickly on the location shown above. I suspected that the styrofoam channels might have led to the students' appreciation of its complexity rather than a strict interpretation of visual design. When I raised this issue, a few students said that they'd considered both aspects.

For comparison purposes, notice where the second CD cover (blue oval) was placed, at the extreme for Exclusivity and Simple. This cover and Ragnhild's were clearly deemed Exclusive, although they are not the only ones. The other two show completely different design strategies: one is composed of light pieces of bentwood woven into an orbital shape, and the second is composed of concrete spray painted with black. The materials and visual compositions of these four compositions were so different that it is nearly impossible to deduce any commonalities between them.

It became obvious that Ragnhild's CD cover had become a focus point, and the discussion began to revolve around her CD only. The students may have felt they could speak more openly about her CD because they knew that none of their fellow classmates had created it. However, recall that there were **two** CD covers that were unknown to the students, and the other one was more or less ignored. I had chosen both CD covers because they both represented white space, but the primary color on the other CD was black, not white.

3.3 Overall impression of CD cover:

At the point of this final variant, the students had become secure in their opinions of where Ragnhild's CD belonged. Upon beginning the new variant, her cover was one of the first to be moved. However, this does not mean it stayed in one spot — the dotted red lines represent two of the many locations where her CD was placed. The discussion became fascinatingly heated, and her CD was the focus of it. The debate almost seemed to pick up where it had left off from the previous variant. Please note that her CD cover was closed for this final part of the exercise.

Although the matrix words no longer included Exclusive and Simple, it became apparent that the discussion begun in the previous variant had not been concluded.

I had not told the students that her CD was one that I was watching specifically, but it became a natural focus point for the discussion. The students began to develop strong opinions about

what makes a CD exclusive or not. I was able to note down a small part of the group conversation regarding the placement of her CD. The quotes below are taken directly from the student discussion (my translation from Norwegian):

Student 1: That one is definitely exclusive, high quality

Student 3: I got an Ipod feeling from it

Student 1: Cardboard is a cheap material, but the white color gives it a feeling of exclusivity, it could have been perfume or wine

Student 2: I think it looks cheap, see; it's made of cardboard!

Student 1: The format is boring, but the white makes it exclusive

Student 4: I agree with Student 1, it does not look cheap or common

Student 2. It's so anonymous that it becomes common. There is no convention that says that things that are white are exclusive! In addition, it looks recycled, therefore, it can NEVER be expensive. I agree that the format is boring.

Student 3: What about Apple? Doesn't that mean simplicity?

Student 2: Does white automatically mean exclusive? What if this CD were red?

Student 1: The color white means purity, it gives me a feeling of silkiness…if it were red it wouldn't be exclusive!

It is important to note that I had not told the students my intentions for doing the exercise — I had not specifically discussed the emotional implications of visual white space with them at any point. I became fascinated by the appropriateness of this discussion for my research interests. Other than using the words on the axes, I had given the students **no idea** about how to proceed with the exercise or the discussion. All conversation was impromptu and occurred very naturally. The discussion lasted for about 10 minutes and became surprisingly intense.

The photo below shows where Ragnhild's CD cover eventually ended up, although a number of students voiced their complete disagreement with the placement.
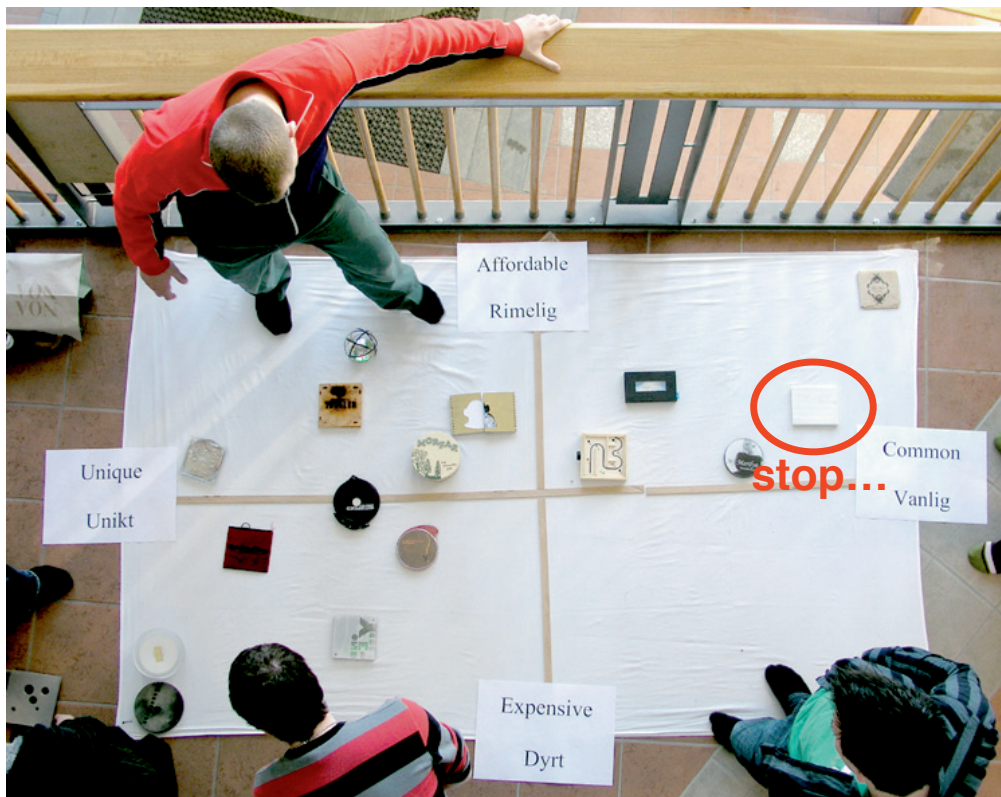
4. DISCUSSION

At this point, I decided to interrupt the discussion and ask the students what they thought the exercise had entailed. I explained that I'd been intrigued by the heated debate that had just occurred and that I was primarily interested in the relationship between what people see as white space and how they experience it emotionally. When I stated that I'd wondered about the associations of exclusivity, the discussion continued immediately, with the only exception that I was now involved. When I asked what it is that makes a CD cover (or any visual composition) appear exclusive, the focus turned immediately back to Ragnhild's cover. The discussion then revolved around materials and how her solution had been rendered physically:

Student 2: It looks like trash, something that someone throws away. Cardboard is a material intended to stiffen boxes, it's only a part of the packaging.

Student 4: Talk about something that creates different impressions: material vs. visual design!

Student 5: If something is plain white, the details become very important. What wrecks this for me is the imprecise edge on the outside.

Student 3: Can we please look beyond the materials?

Student 1: Very, very nice. This is one of the finest CD covers here. The color is pure, clean and exclusive. Black is exclusive too, but not pink.

Student 3: It's the overall impression that counts!

This dialogue clearly shows that some students interpreted Ragnhild's CD cover based purely on an overall visual impression, while others integrated the visuals with the choice of materials. At one point someone said that materials play a huge role: magnets give a very different impression than silk cord. Indeed, at various points during the exercise, it appeared that students made placement choices with as much regard to material use as to visual design.

Although Students 1 and 3 expressed views that were closest to my hypothesis, the students reflected a variety of opinions in which all were absolutely correct. From the discussion that transpired, it is obvious that there is no wrong answer in how people interpret visual media. Indeed, the students raised the very good point that materials ***do*** make a difference in how people interpret a visual composition, even if some of them did not agree.

5. CONCLUSIONS AND FUTURE WORK

The students demonstrated that white space is an important design consideration. The emotional relationship between white space and exclusivity became a charged and controversial discussion among 12 design students. Without knowing my research questions, these students clearly demonstrated that the primary research questions were on target:

• Do people consistently associate certain visual design characteristics with certain emotions (especially white space in particular)?

From this experience, it appears that people do not associate white space with certain emotions consistently. But because this was an experiment conducted by *a group* of students (where anyone could place the CD according to his/her opinion), it is impossible to determine individual emotional associations. Such findings could be accomplished by a different test format, whereby a student performed the same test, but only as a single participant. A single-

participant test method would better reflect individual associations of white space with certain emotions. That will very likely become a follow-up test.

• Do people agree on what constitutes simple vs. complicated design?
Definitely not for this study! It was clear that once the debate began, the students divided themselves into two groups: those who felt that white space reflects simplicity, and those who didn't. It became apparent to me that I was witnessing the students forming their individual opinions on this topic. As above, I intend to use a single-participant test method to see if people do agree more than they seemed to in this exercise. I wondered if some of the students were playing devil's advocate and simply creating a debate. I don't think so, but a single-participant test with averaged results would likely determine this better.

The students' debate raised a number of very specific questions, something that I'd hoped would arise from this exercise. Student 2 phrased my primary concern perfectly by asking "Is there a convention that says that white space automatically means exclusive?" There is clearly room for more research in this area. We may assume that a relationship between a design parameter (white space) and an emotional association (exclusivity) may be consistent and predictable, but the students showed that this is not the case.

Regardless of the emotions it triggers, white space is an active part of a composition, even though it is the space around, in between objects. When applied successfully, it is not simply negative space, which implies that it is an empty void and lacks purpose. Rather, it becomes a necessary, complementary aspect to positive elements. When used sensitively and conscientiously, white space is a powerful design parameter. When applied less successfully, it can appear empty, as though it lacks purpose and was designed as an afterthought.

Future work involves testing this phenomenon in more targeted, controlled manner. I am not sure that the dual-axis matrix is the ideal method to use, but it allows for subjective rather than specific interpretation. Another issue to be determined is the fine line between *intentionally designed* white space and that which is non-designed (an afterthought). Is there a way to test for people's interpretation of this? Can people tell the difference? Is there a way to help designers make the difference clear? Other questions also deal with very fine distinctions:

- How much white space does it take to push the object into the realm of being *exclusive*? Is there a fixed proportion?

- Why is this phenomenon apparently true? What does cognitive psychology have to contribute to understanding why?

Although there is clearly room for more research into the relationship between white space and exclusivity, this does not detract from the power of white space as an important tool in visual design. I firmly believe that white space must be given a proactive role in all types of compositional design, especially in electronic applications, where information must be relayed quickly and effectively. To do this, it is necessary to understand the relationship between white space and the various emotional associations it creates: particularly those that suggest exclusivity.

BIBLIOGRAPHY

1. Albers, Josef. (1963*) Interaction of Color — Revised.* Yale University Press

2. Apple Computer (1992). *Macintosh Human Interface Guidelines.* Addison-Wesley.

3. Berger, John (1977). *Ways of Seeing.* BBC/Penguin Books.

4. Bertoni, Franco. (2004) *Minimalist Design.* Birkhäuser-Publishers for Architecture.

5. Card, Stuart K. and Thomas P. Moran, Allen Newell (1983). *The Psychology of Human-Computer Interaction.* Lawrence Erlbaum Associates, Inc.

6. Dondis, Donis A. (1973). *A Primer of Visual Literacy.* MIT Press.

7. Götz, Veruschka (1998). *Color & Type for the Screen.* Rotovision/Grey Press.

8. Hofmann, Armin (1965). *Graphic Design Manual.* Van Nostrand Reinhold.

9. Hofmann, Armin & Dorothea. Individual interview conducted at their home in Luzern, Switz. April 8, 2005

10. Itten, Johannes (1961). *The Art of Color.* John Wiley & Sons.

11. Lipton, Ronnie (2002). *Information Graphics and Visual Clues.* Rockport Publishers Inc.

12. Maeda, John. URL: http://simplicity.media.mit.edu. June 2005.

13. Marcus, Aaron (1992). *Graphic Design for Electronic Documents and User Interfaces.* ACM Press.

14. Marcus, Aaron. *Globalization of User-Interface Design for the Web.* Proceedings. Conference on Human Factors and the Web (#5), June 3 1999.

15. Müller-Brockman, Josef (1981). *Grid Systems in Graphic Design.* Verlag Niggli AG, Zürich.

16. Mullett, Kevin and D. Sano (1995). *Designing Visual Interfaces.* Prentice Hall.

17. Nesbakken, Ragnhild. *Self Designed CD Cover.* 2004.

18. Nielsen, Jakob (2000). *Designing Web Usability.* New Rider Publishing.

19. Nielsen, Jakob & Marie Tahir (2001). *Homepage Usability — 50 Websites Deconstructed.* New Riders Publishing.

20. Pawson, John (1996). *Minimum.* Phaidon Press.

21. Rand, Paul (1985). *A Designer's Art.* Yale University Press.

22. Rand, Paul (1993). *Design, Form and Chaos.* Yale University Press.

23. Rand, Paul (1996). *From Lascaux to Brooklyn.* Yale University Press.

24. Resnick, Elizabeth (2003). *Design for Communication.* Wiley.

25. Schneiderman, Ben (1998). *Designing the User-Interface — Strategies for Effective Human-Computer Interaction.* Addison Wesley Longman Inc.

26. Thiel. Philip (1981). *Visual Awareness and Design.* University of Washington Press.

27. Tognazzini, Bruce (1992). *Tog on Interface.* Addison-Wesley.

28. Tufte, Edward (1990). *Envisioning Information.* Graphics Press.

29. Tufte, Edward (1997). *Visual Explanations.* Graphics Press.

30. White, Alex. (2002). *The Elements of Graphic Design.* Allworth Press.

31. Wildbur, Peter and Michael Burke (1998). *Information Graphics.* Thames & Hudson.

32. Wong, Wucius (1972). *Principles of Two-Dimensional Design.* John Wiley & Sons.

33. Wurman, Richard Saul (1996). *Information Architects.* Graphis Press Corp.

34. *You Are Here: Design of Information* (May 3, 2005). Exhibition at the Design Museum, London.

Paper 3

OBJECTIVE:

Focus on 'white space' in macro scale 3D public space

An Investigation into the Subjective Experience
of White Space in an Urban Environment

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ABSTRACT

Two-dimensional graphic design teaches us that white space, often known as negative space, is an important design parameter which when uncontrolled, can result in visual emptiness. This article describes an investigation into how this phenomenon works on a grand architectural scale: the urban landscape. The researchers conducted short personal interviews in two urban plazas in Bergen, Norway. One urban plaza, Festplassen, represents an open area that employs a great degree of three-dimensional white space. For comparative purposes, we interviewed pedestrians in a non-white space plaza, Torgallmenningen. From these subjective opinions, the authors extracted six categories which cover all the responses which were generated. The results show that white space in an urban area creates an aesthetically pleasing plaza, but is not considered a sociable place to be. Respondents emphasized the importance of an urban space's social aspects by saying that they appreciated the Festplassen most when it was filled with people, entertainment venues, etc. This article concludes with the observation that in order to avoid being associated with emptiness, white space must be applied very conscientiously and sensitively. Even though it is the space between other objects, white space is a powerful determinant of how a composition communicates to its viewers, both in 2- and 3-dimensions.

1. INTRODUCTION

Visual composition employs a number of different design parameters to communicate a message. This message gives the viewer a cumulative impression and often results in the attachment of emotional characteristics to the composition. How well those parameters are combined and controlled determines the overall communicability of the composition. This study focuses on one important parameter of visual design known as *white space*.

Alex White alludes to the difficulty of designing with white space (White 2002) when he acknowledges that it is ignored by all but a few who consciously manipulate it to create contrast, drama and rest. Composers, sculptors, artists and architects use it. Armin Hofmann elaborates on this crucial design aspect by saying that it is the space in between, often a by-product, is just as important as the element that produces it (Hofmann 1965). As a design parameter. white space can be defined as "…the empty but often active areas that are void of visual elements" (Resnick, 2003). Nielsen refers to it as "unused" (Nielsen 2001). Despite this seemingly negative approach to white space, cultural experience tells us that consumers associate white space with high quality and/or exclusivity. This is an emotional association that can be very powerful. It is important to learn more about the value of visual purity and whiteness and its emotional associations. It is our observation that prominent use of white space seems to promote consistent emotions and associations across various media (product packaging, small boutiques, user-interface design). For this reason we chose to investigate the emotional associations on a grand three-dimensional (3D) scale: architectural space. This study investigates people's subjective experience of white space in three dimensions on a grand public scale. The focus of the study was to research user opinions of two open plazas that represent two very different architectural layouts.

The availability of public space determines the pulse of the city or town. Public space is an especially important arena because it is where people meet, and where the city's current culture and history connect. Hopefully the public space encourages people's participation in recreational habits, feelings of comfort, familiarity, etc. The Norwegian city of Bergen is one example where many city development projects have been implemented. One urban space in particular (Festplassen) employs a conscientious amount of three-dimensional, architectural white space. We chose to collect data about people's experiences in Torgallmenningen for comparison purposes. The data collection for Festplassen would become richer when compared with a different architectural area.

1.1 Primary Research Questions

Our hypothesis combines the two very different backgrounds and interests of the authors: graphic design and sociology. When applied successfully in 2D graphic design, white space can denote characteristics of quality and exclusivity, but when applied unsuccessfully, it can exemplify visual emptiness. This phenomenon can be ascribed to the sociological experience of urban architectural space. When white space is applied successfully in landscape design, it can be considered beautiful yet antisocial at the same time. When applied unsuccessfully, it can be deemed an uninteresting public space. This study hypothesizes that people experience exclusivity on a grand architectural scale based on the amount of visual white space.

In this study, residents of Bergen were interviewed to determine their experience of white space in to two outdoor urban spaces. Through the project, the intention was to gain insight about the overall perception and emotional associations generated by the different architectural design of the two plazas. It was determined that grounded theory approach was the most appropriate research tool, and data was to be collected based upon interviews conducted on the two sites.

2. THE RESEARCH SITES

For this study, white space is relative. In order to see where white space *is used* in the urban arena, a second site was needed to characterize where white space *is not* used. For this reason, this study was devised to compare the relative engagement of white space between Torgallmenningen and Festplassen. The two urban spaces are conveniently located only 40 meters apart from each other. They provide an equivalent potential for pedestrian activity, and both plazas are equivalent in size.

2.1 Torgallmenningen

Identifying characteristics of Torgallmenningen include:

- Primary central location. Considered the reference point for *central*
- Often described as Bergen's living room.
- Enclosed by tall buildings and shops on three sides
- Long and narrow in shape
- Contains public benches which line each long side
- Contains a kiosk, trees, and several large statues
- The pavement is dark grey slate, especially when wet

Fig. 1: Torgallmenningen

Torgallmenningen is an old outdoor plaza located in the center of the city of Bergen and dates from 1582. It is both a non-motorized street and a public space. It was originally built as a buffer to prevent spread of fire: wide buffer streets maintain distance between buildings, especially old wooden buildings. Torgallmenningen is the largest of the numerous open plazas in Bergen, and its location in the middle of the city makes it one of the most visited public spaces in Bergen (Wathne and Bjørlykke 1998).

Torgallmenningen is located between the City Square to the east, to Olav V's Place to the west; it is closed for motorized traffic in the west. During the devastating city fire in 1916, Torgallmenningen was completely destroyed. Finn Berner, an architect from NTH in Trondheim, was given the responsibility to draw a new, improved Torgallmenning. Torgallenningen has remained spatially unchanged since 1916, with relatively minor adjustments to accommodate the changing aesthetic tastes. New materials were added to the street floor at a later date, and in 2002, Bård Breivik's new columns in front of the shopping center. Both structural changes lead to a heated political debate in Bergen.[1]

Torgallmenningen is surrounded by stone buildings with 5-6 floors. In most of the buildings there is a diverse mix of shops and offices, with shops on the 1st and 2nd floor. These buildings were built after the big city fire in 1916. The predominant architectural style at Torgallmenningen is New Classicism, and the only exception is the Functionalistic building Sundt Shopping Center, designed by Per Grieg in 1938 (Wathne and Bjørlykke 1998).

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[1] Information from http://no.wikipedia.org/wiki/Torgallmenningen, 01.04.06.

The floor on Torgallmenningen consists of plates of dark grey slate. There are two very large sculptures: Sjøfartsmonumentet (Seaman's Monument) and Blå Stein (Blue Stone). In addition, there are numerous fountains, oversized flower planters, and various street amenities such as benches, mail- and phone boxes. Sitting in Torgallmenningen is popular: 28 benches plus more than 100 sitting places provide plenty of space for lounging, when the weather permits. Several restaurants and other service offices line the three sides of the plaza (Wathne and Bjørlykke 1998).

Due to its wide range of services and provisions, Torgallmenningen does not represent what this project defines as white space in a public room. The architecture style and commercial activity make Torgallmenningen a busy and crowded place with little white space to separate buildings, street equipment and people.

2.2 Festplassen

Identifying characteristics of Festplassen include:

• Located centrally, 40 meters from Torgallmenningen

• Often described as Bergen's *living room*

• Butted up against a sizable man-made pond, Lille Lungegårdsvann

• Trees on outer edges

• No benches

• The pavement is light grey granite

Fig. 2: Festplassen

Festplassen is the name of the 7000 sq m open space between Lille Lungegårdsvann, Rasmus Meyers allé, Christiesgate and Kaigaten. Until 2002, Festplassen was used as an urban parking area, while only occasionally serving as a location for entertainment activities such as Tivoli, circus groups, exhibitions or big outdoor concerts. Festplassen is often used for the location for the celebration of the national holiday, 17th of May, since 1929. (Bergen Byleksikon 2006[2]).

In 2002, Bergen County decided to convert Festplassen into a permanently traffic-free arena for cultural activities. The Architect Office, CUBUS Arkitekter AS, had been working with different plans for the area since the 1980s, and together with Bergen County and Kalve-Smedsvig Landskapsarkitekter AS, became responsible for the redesign process.

The reopening of Festplassen took place in 2004. It was now designed to be a flexible place for large public assemblies, as well as for everyday use. It is shaped in the form of a large quadratic square, with solid granite plates on the floor and in the walls that separate the square from the City Park. The square meets the city park on one side, Ole Bulls Plass on the opposite side, and has an open view against the small lake Lille Lungegårdsvann. Above Lille Lungegårdsvann the view continues unimpeded towards the mountains that surround Bergen city. At night, Festplassen is lighted dimly, thanks to the work by Arne Selen, LandskapDESIGN. Fesplassen also provides a moderate amount of sitting area, there are eight benches designed by Elin Strandenes.

A kiosk and skateboard area have been planned, but are not yet complete. In 2002, the team consisting of Bergen County, CUBUS Architects AS, and Kalve-Smedsvig Landscape Architects AS were awarded the National Architectural Prize, Statens Byggekikkpris, for their combined work on Festplassen.

When not busy with an entertainment venue, Festplassen maintains a clean, sparse aesthetic style. It is characterized by the high quality of materials used in its decoration, and is a good representation of what this project defines as a white space in a public place. In three dimensions, Festplassen characterizes qualities of two-dimensional white space by being open,

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[2] Partly available at http://www.home.no/bergensiden/Leksikon.htm#F.

spacious and free of visual clutter. More importantly, it was conscientiously designed to communicate those primary values to its viewers.
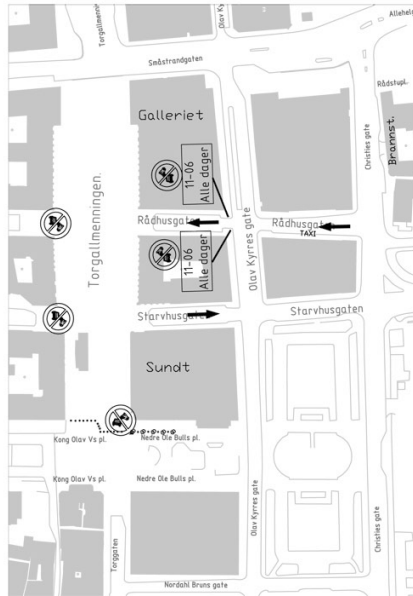
Fig. 3: The map used, very rarely, during the interviews

3. METHOD

The research study was carried out by the two authors in Bergen, Norway on Wednesday, 22 March 2006. Both researchers collected data from both urban spaces between 14:30 - 17:30 on a clear but cold winter day. To avoid potential interviewer bias, the researchers spent 1.5 hours interviewing pedestrians in both urban spaces *separately*, whereupon they switched places and spent another 1.5 hours in the opposite space. The researchers approached pedestrians randomly and asked an almost identical set of questions (see table below).

3.1 Interview Technique

64 subjects were interviewed — this number does not reflect the general population as a whole. Though not generalizable, this number provides an impression of how people *might* respond to the questions, and to how people *might* associate certain emotions with the respective urban spaces. The findings do not represent the opinion of all residents of Bergen, however, it is possible to extract predilections from the group of responses.

3.2 The Interview Questions

In the first two questions, the subjects were prompted to describe each plaza with three adjectives respectively. The prediction was that a majority of people would respond with neutral answers such as *nice*, or *large*. By then asking them to spend a few extra moments on the third question, we hoped to elicit more meaningful adjectives which might reflect their opinion more precisely. This was an effective technique which generated a large number of words outside of the neutral genre.

We asked the following questions as each plaza:

1.	If you were to describe Torgallmenningen/Festplassen, with three adjectives, what would you say?
2.	What do you like best about Torgallmenningen/Festplassen?
3.	What would you like to change about Torgallmenningen/Festplassen?
4.	Which public space to you prefer? (asked by one researcher only)
5.	Subject details: • Gender • Residence • Profession

It is important to note that both researchers inquired about *both* plazas, while located in each one respectively. This was done in order to test the influence of physical location upon the respondents' answers. We wanted to determine if there was a difference in responses from when people were physically standing in one plaza vs. the other. This resulted in being a highly determinant factor in the responses.

3.3 Circumstantial Conditions

It was a cold day, and the weather varied between partly sunny and light snow. It was chilly and moderately populated. We had predicted to find more people in Torgallmenningen than Festplassen, which turned out to be true.

The interview process proceeded as planned for both interviewers. Both researchers noted that people were easier to approach at Torgallmenningen, most likely because they were more likely to wander around without a specific destination in mind. However, it was more difficult to approach people at Festplassen. We noted that people seemed to use the space as a passageway, and were more likely to proceed intentionally from one point to another. We

both felt that pedestrians at Festplassen were less willing to be disturbed en route to their destination. In addition, the presence of a patch of snow in the middle inhibited pedestrian traffic there, but this melted during the interview session.

3.4 Evaluation

The interviews resulted in a substantial amount of responses which we knew had to be organized in some way. We tallied all adjectives/responses and wrote each one onto an individual sticky note. Doing this allowed us to easily place the responses in relation to each other. After we grouped the answers, identifying characteristics rose out of each group which allowed us to assign a category name. In this manner, the responses determined the category names, and not our presupposition of what the categories should have been. This process resulted in six different categories which embodied the diversity of answers. The categories of answers are:

- **Situational/Material Descriptors**
  Refers to words which describe the current situation and material qualities
  (e.g. *under construction, benches, open*, etc.)
- **Symbolic Descriptors**
  Refers to respondents' strong symbolic perceptions of the area
  *(*e.g. *a symbol of Bergen, essence of Bergen*, etc.)
- **Physical Attribute Descriptors**
  Refers to multiple visible parameters which affect the overall impression of the area
  (e. g. *dirty, clean, filled with litter,* etc.)
- **Social Descriptors**
  Refers to human activity in the area
  (e.g. *meeting place, living room, creates life*, etc.)
- **Emotional Descriptors**
  Refers to various feelings associated with the area
  (e.g. *I like it, it's dead, I enjoy the weather here*, etc.)
- **Service/Activity Descriptors**
  Refers to practical activities, provisions and events available in the area
  (e.g. *shopping, concerts, 17th of May, etc.*)

These category titles will be referred to in the Results section.

3.5 Respondent Details

Both genders were represented equally: 50 % women, 50 % men. The majority of respondents lived in Bergen and the immediate area. Respondents represented a diverse range of professions. Because the interviews were conducted during the afternoon of a normal workday, there was a large base of students, retirees and shift workers. This factor might have been reduced had the interviews been conducted during the weekend.

4. RESULTS & DISCUSSION

This section will address the results for each plaza respectively.

4.1 Descriptors for Torgallmenningen vs. Festplassen

In general, respondents appeared to have a strong connection to Torgallmenningen. A majority of respondents described the area with emotional and socially-oriented characteristics. With regard to Festplassen, people appeared to appreciate and enjoy Festplassen's aesthetic design. They responded that it was beautiful, stylish, and lovely. However, they did not respond with the same emotional connection descriptors that they did with Torgallmenningen.
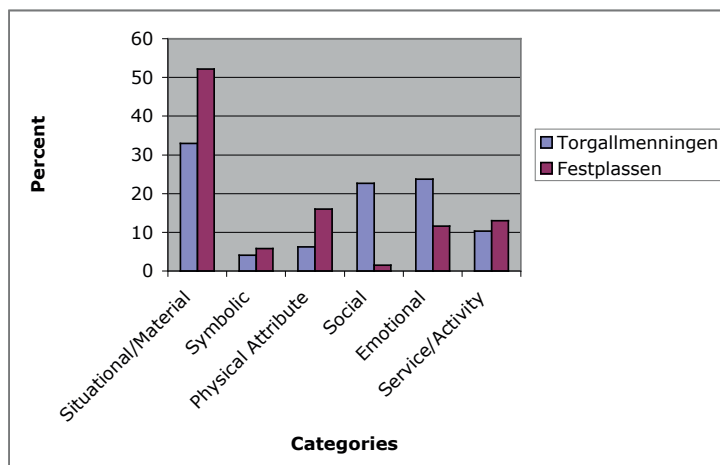
Fig. 4: Comparison of what respondents like best about Torgallmenningen and Festplassen

The following points reveal our insights into the responses of the emotional and the social descriptors.

Emotional Descriptors for Festplassen	Emotional Descriptors for Torgallmenningen
Contrary to Torgallmenningen, people described Festplassen with Situational/Materialistic and Physical Attribute descriptors (e.g. naked, too modern, gray, simple). Even still, many respondents said that they liked the minimalist and simple design, at least aesthetically. Surprisingly many described the space as new.	They said that it is welcoming and grand. Many said that it is nice, and one woman said she loves it, as if it were a person. Four respondents said that it embodies the essence of Bergen. For these people, Torgallmenningen carries a strong symbolic character. Many said they enjoy the sun/level of activity/weather/lifestyle there. Of all respondents, there were only two who described Torgallmenningen with negative descriptors: boring and most monitored place in Norway. Nine people could not come up with anything they would want to change.

The majority of people at Festplassen referred to Situational/Material categories to describe the urban plaza. Festplassen was described by the activities which are held there periodically. Some hoped that it was in the process of becoming a symbol of Bergen, but that it had not yet done so. Only one person mentioned sociable attributes and characteristics for Festplassen. People seemed to interpret the space as if it were a piece of art or sculpture, everyone referred to it as beautiful. Only a few thought of Festplassen as a grey, dull and empty public space.

Social Descriptors for Festplassen	Social Descriptors for Torgallmenningen
Many respondents described the area as important for entertainment and activities. The area was described as practical, nice to have, an ok living room, good to use — aspects which mean that it is nice under certain conditions. Only one person mentioned that it was a social area.	The majority of respondents consider the plaza to be an important social arena. Social-aspect descriptors often arose as one or more of the adjective list, whereas very few of those standing in Torgallmenningen used similar descriptors for Festplassen). Half of the respondents described the social aspect as that which they enjoyed best at Torgallmenningen.

No one seemed to mind the lack of commercial activity, but many noted the lack of a satisfactory amount of activity and cultural possibilities	When asked what they would improve, many answered with ideas that would improve/increase the social aspects even more: more benches, enclosed playground for children, permanent electrical wiring for traveling musicians.

The Social and Emotional descriptors revealed a pattern that follow the hypothesis. Very many people wished to change Festplassen to be more cozy and intimate, more green and nice and filled with more benches. People seemed to express the desire to use Festplassen in a more sociable manner, and implied that they would if the space were changed to accommodate social activity. These responses follow the pattern revealed by the Emotional descriptors.

In an attempt to remove the confounding factor of physical location, we asked the subjects a control question about the opposite plaza. When people stood at Torgallmenningen, they expressed more negativity to Festplassen and thought that it was a boring, uninteresting place. However, when they stood at Festplassen, the aesthetic and sculptural aspects came forth more clearly. It appears that the immediate physical experience of Festplassen gives stronger aesthetic associations than when people think of it as a remote location.

In addition, one researcher asked the respondents "*Which of the two urban spaces do you prefer?*". The great majority of people felt that Torgallmenningen was their favorite.

Control Questions

Two questions were included to extract more specific meaningful descriptors than neutral ones which were non-offensive to the researchers. This strategy also gave the subject more time to think and greater capacity to reveal their true opinion better than vague and ambiguous adjectives. The first question was: "*What do you like best about Festplassen/ Torgallmenningen?*".
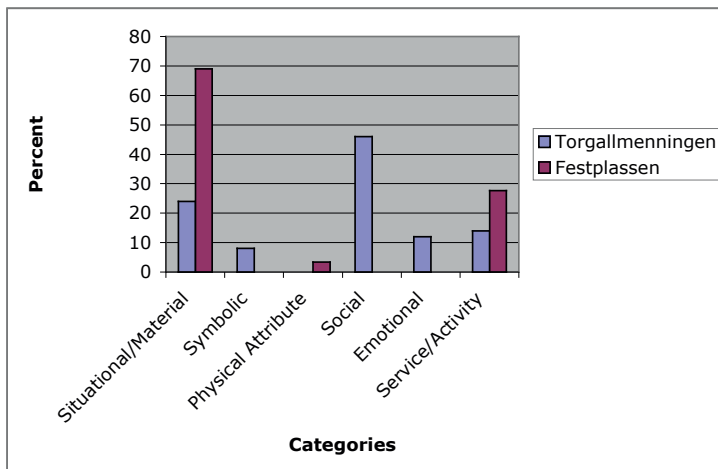
Fig. 5: Comparison of what respondents like best about either Torgallmenningen or Festplassen

At Festplassen, it was apparent that the physical attributes were in the forefront of people's experience. For the majority of respondents, the periodic activities held at Festplassen were an integral part of the respondents' experience. None of the subjects responded with Symbolic, Emotional, or Social aspects as a primary characteristic. Interestingly, the results were almost opposite for Torgallmenningen. Almost half of the respondents liked the Social aspects of Torgallmenningen best. These results reveal the most fundamental distinction between the two plazas. Peter Butenschön and Maren Hersleth Holsen conclude that a *place* is something different than a *public area.* A place gathers meaning due to its activities and cultural history, and provides a reference for both peoples' individual experience and their association to the city as a whole (Butenschön and Hersleth, 2003).

The second question was: "*What would you like to change about Festplassen/ Torgallmenningen?".* The responses for this question built upon and emphasized the established understanding. At Festplassen, most people described Situational/Material characteristics such as benches, more trees to make it cozy, flowers, and permanent art installations. Many respondents also expressed a wish for increased frequency of social and cultural activities such as dance exhibitions and concerts. In general, people wanted to change Festplassen into a more social public space. In general, people at Torgallmenningen wanted the place to either remain as it is today, or to intensify the current identifying characteristics

of the plaza. In contradiction to this, the respondents at Festplassen expressed a desire to radically alter the fundamental identity of the space.
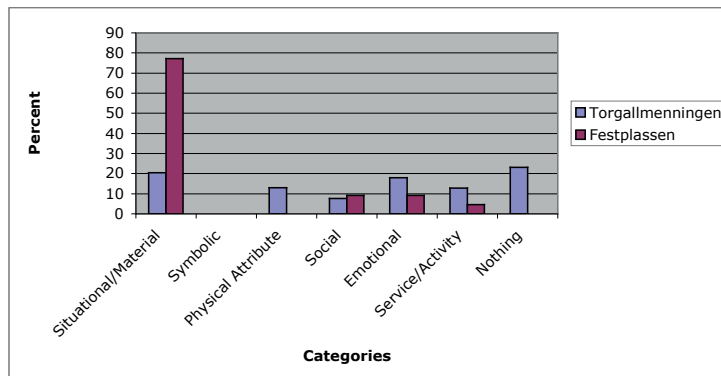
Fig. 6: Comparison of what respondents would like to change

The Danish architect Jan Gehl (2003) demonstrates that it is not the formal architectural of a space that determines its value, but rather its degree of integration into the existing urban structure and social life. The manner in which the space communicates with people is determined by the simplicity or the complexity. These aspects appear to be of vital importance to the pedestrians at Festplassen. Festplassen does not communicate its identifying qualities to the people as Torgallmenningen does. People seem to want to establish an emotional connection to places, including Festplassen.

4.2 Epilogue

The object for this study was to compare two spaces in order to find out more about one. Perhaps the best way to compare them is to listen to the residents who encounter both places on a regular basis:

Quotes about Torgallmenningen:
- "It's generally a nice place to be" Female student from Sogndal
- "The columns ruin it, both aesthetically and politically." Male shopkeeper
- "The sound is much too loud, especially when something is going on. The sound can be heard from Fløien!" Male retiree (NB: Fløien is the mountain closest to Bergen with a highly-popular observation deck that overlooks the city. The deck is quite far away)

Quotes about Festplassen:

- "It makes you want to dance tango" Female civil architect
- "A little too much asphalt" Female county administrator
  (NB: there is no asphalt on the site, only granite)
- "So nice but so slippery". Female retiree
- "Very, very, VERY ugly" Male shopkeeper
- "Its well-designed in relation to its surroundings". Male retiree

5. CONCLUSION

This paper investigates how/if a powerful design parameter (white space) can be translated from 2-dimensions into 3-dimensional experience of public space. It is important to keep in mind that white space is an active part of a composition, even though it is the space around, in between objects. When applied successfully, it is not simply negative space, which implies that it is an empty void and lacks purpose. Rather, it becomes a necessary, complementary aspect to positive elements. When used sensitively and conscientiously, white space is a powerful design parameter. When applied less successfully, it can appear empty, lacking in purpose and an afterthought.

In our study into white space in an urban arena, we found that (per our hypothesis) white space is considered *empty* at Festplassen, a space that represents graphic white space in three dimensions. Based on subject responses, we can conclude that white space does not create a socially attractive area. Rather, it creates a space where formal and informal recreational/entertainment activities can be held. From the respondent's descriptions, we can assume that if an urban space is intended to be a social meeting point, people want to see it filled with things: not only people but physical attributes and colors!

It is our opinion that white space must be given a proactive role in all aspects of design, in both 2- and 3-dimensional design. To do this, it is necessary to understand the relationship of white space to the associations it creates in people who see and/or interact with it.

REFERENCES

1. Albers, Josef. (1963*) Interaction of Color — Revised*. Yale University Press

2. Apple Computer (1992). *Macintosh Human Interface Guidelines.* Addison-Wesley.

3. Berger, John (1977). *Ways of Seeing.* BBC/Penguin Books.

4. Bertoni, Franco. (2004) *Minimalist Design*. Birkhäuser-Publishers for Architecture.

5. Butenschøn, Peter og Maren Hersleth Holsen (red) (2003). *Til stede. Byens rom*. Pax Forlag/ Norsk Form.

6. Canter, D (1976). *The psychology of place*. London: The Architectural Press Ltd.

7. Card, Stuart K. and Thomas P. Moran, Allen Newell (1983). *The Psychology of Human-Computer Interaction.* Lawrence Erlbaum Associates, Inc.

8. Cold, Birgit (1993a). *Physical Surroundings and the Person.* Work Notes taken during Techology Days in Northern Norway, Narvik 9-12 march 1993. seminar nr 3: The Town Center.

9. Cold, Birgit (1993b). *Space, Meetingplace and Quality*. Work Notes taken during Techology Days in Northern Norway, Narvik 9-12 march 1993. seminar nr 3: Eske 568, NTNU, Trondheim.

10. Dondis, Donis A. (1973). *A Primer of Visual Literacy.* MIT Press.

11. Gehl, Jan (2003). *Livet mellem husene. Udeaktiviteter og udemiljøer*. Arkitektenes forlag, København.

12. Hofmann, Armin (1965). *Graphic Design Manual.* Van Nostrand Reinhold.

13. Hofmann, Armin & Dorothea. Individual interview conducted at their home in Luzern, Switz. April 8, 2005

14. Maeda, John. URL: http://simplicity.media.mit.edu. June 2005.

15. Nielsen, Jakob (2000). *Designing Web Usability.* New Rider Publishing.

16. Nielsen, Jakob & Marie Tahir (2001). *Homepage Usability — 50 Websites Deconstructed.* New Riders Publishing.

17. Pawson, John (1996). *Minimum.* Phaidon Press.

18. Rand, Paul (1985). *A Designer's Art.* Yale University Press.

19. Rand, Paul (1993). *Design, Form and Chaos.* Yale University Press.

20. Rand, Paul (1996). *From Lascaux to Brooklyn.* Yale University Press.

21.   Resnick, Elizabeth (2003). *Design for Communication.* Wiley.

22.   Thiel. Philip (1981). *Visual Awareness and Design.* University of Washington Press.

23.   Tufte, Edward (1990)*. Envisioning Information.* Graphics Press.

24.   Tufte, Edward (1997)*. Visual Explanations.* Graphics Press.

25.   Wathne, Anna & Cecilie Bjørlykke (1998) *Bergen, byens liv; gaten som sosial arena.* Utgitt i samarbeid med Statens vegvesen Hordaland og Statens vegvesenVegdirektoratet. Trykk: Allkopi, Oslo.

26.   Webliography: http://no.wikipedia.org/wiki/Torgallmenningen

27.   White, Alex. (2002). *The Elements of Graphic Design.* Allworth Press.

28.   Wildbur, Peter and Michael Burke (1998). *Information Graphics.* Thames & Hudson.

29.   Wong, Wucius (1972). *Principles of Two-Dimensional Design.* John Wiley & Sons.

30.   *You Are Here: Design of Information* (May 3, 2005). Exhibition at the Design Museum, London.

Paper 4

OBJECTIVE:

First investigation into interpretation of GUI icons

Author: Martha Skogen

Full title: An Investigation into the Subjective Experience of Icons: A Pilot Study

Presented :   10th Int'l Conference on Information Visualization, IEEE London, United Kingdom (2006)

Is not included due to copyright

Paper 5

OBJECTIVE:

Categorization of verbal responses to GUI icons

Author: Martha Skogen

Full title: Say, what did you see?
A qualitative interview reveals how users interpreted GUI icons

Venue: 9th Conference on Design & Emotion—The Colors of Care
Bogotá, Columbia (2014)

SAY, WHAT DID YOU SEE?
A QUALITATIVE INTERVIEW REVEALS HOW USERS
INTERPRETED GUI ICONS

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ABSTRACT

A comprehensive user test was conducted with 29 participants, 11 of whom were aged five to twelve. The intention of the exploratory computer-based test was to collect both quantitative and qualitative information—this article reviews the qualitative data only. After the user test, each participant answered identical, open-ended questions regarding his/her approach(es) to the task. Data was split into <13 (Youths) and >17 (Adults). The age groups' responses are compared: Youths' responses were often succinct, direct, and confident compared with the long, detailed, and verbose responses from the Adults. Adults often contradicted themselves whereas Youths did not. In order to categorize the participants' diverse experiences, responses were analyzed for target words. The potential for design biases is highlighted. It is recommended that designers verbally test their specific user group—often—during the HCI/GUI design process in order to avoid designing from their own perspective and misunderstanding their user group entirely.

KEYWORDS: *Human-computer interaction, GUI design, user test, computer icons, visual design bias*

INTRODUCTION

This exploratory research focuses on how people interpret computerized visual stimulation. In this case, on-screen icons are the subject of investigation. The approach involves asking participants to view a fixed set of icons and collecting their responses, and determining if any patterns arise from the data. Of particular interest is if users respond that certain aspects of visual design are more influential than others (e.g. contrast, color, photorealism, perspective, number of metaphors, adherence to archetype, etc.). It seems logical that the more elements we are presented with onscreen, the more we are required to visually 'digest' those elements; and vast data in the field of attention has confirmed this. Two research groups say it well: 'Our environment contains much more sensory information than we can process at any given time' (Liu & Mance, 2011, p26), and 'people can respond to only a small amount of the sensory information present at any moment' (Corbetta et al., 1990, p. 1556). Visual processing takes valuable time and energy, especially when the extra visual elements are redundant and unnecessary. In this era where computers are becoming increasingly entwined in our everyday lives, our visual sense is immersed in ever-increasing amounts of stimuli. There surely must be a saturation point somewhere. Due to these factors, it becomes even more important for HCI/GUI designers to use streamlined visual interfaces to reduce cognitive load, reduce the potential for stress and increase a user's effectiveness when s/he interacts with a computerized device. In short, this researcher ascertains that visual information should be as simple and effective as possible in all human-computer interface tools.

Several studies support the use of simple visual design over complicated visual design: Chiu et al. (2012); Davis & Swezey (1983); Huang et al. (2002); Gittins (1986); McDougall et al. (2000); McDougall & Reppa (2008); Reppa et al. (2008); Yan (2011) etc. Byrne sums it up:

> for icons to be effective aids to visual search, they must be simple and easily discriminable ...

> They (icons) seem to clutter the display with information that participants are unable to employ to their advantage (Byrne, 1993).

There is a large amount of research regarding how icons affect the participant's experience and how to design icons effectively. However, these studies do not distinguish between all age groups. Studies with adults and seniors are prevalent, whereas studies comparing adults with children are virtually absent. This is not a good idea as children/youth's

computer experience is continuously on the rise (Rocheleau, 1995). Children and youths represent an important participant group (Chiasson, & Gutwin, 2005), and it is important that their needs be taken into account (Druin, 1999). Not all user groups are included regularly, despite such acknowledgments from researchers (e.g. Adams et al):

> Within HCI, there is also the recognition that the focus on tasks is not enough to design and implement an effective system. There is also a growing need to understand how user issues are subjectively and collectively experienced and perceived by different user groups (Adams et al., 2008, p. 138)

This article describes one data set of a computer-based user test that incorporated both quantitative (via participant ranking) and qualitative (via post-test interview) techniques. According to Adams et el. (2008), this multiple approach (i.e. gathering numerous sets of data simultaneously) embodies the true intention of grounded theory research. The user test was conducted in a modern computer laboratory setting (Jensen & Skov, 2005) where conventional computer-interface icons were used as an example of low-level visual stimuli. 'Low-level' in this context refers to the icons' relatively small size and **apparently** limited amount of two-dimensional visual information. This researcher considers computer-based icons as anything but visually limited—they are miniature, independent visual compositions. The research behind this article investigates the independent (albeit small) nature of computer icons' visual composition, not their meta-level position within applications or on the screen itself.

GUI designers face numerous challenges while designing apparently humble little compositions such as the computer icon. The question at the root of the design process is: What are the primary visual factors that GUI designers must control? A large body of literature attests to the importance of considering numerous aspects ('parameters') of the icon's visual design. Näsänen & Ojanpää (2003) found that contrast affects the speed of icon interpretation—the speed by which icons can be searched for—was clearly dependent on image contrast at small values, but relatively independent at high contrast values. Lindberg & Näsänen (2003) found that although icon spacing does not have an effect on search times, the size of the interface elements has a great effect. Huang (2007) showed that four visual variables significantly affected search performance: figure/background color combinations, type of computer icon, figure/background area ratio. Skogen (forthcoming) found that there are age differences in how simple and complicated icons are interpreted. In fact, interpretation of an icon appeared to be completely contradictory in many cases. Although there is abundant research regarding icons' visual parameters and how to design them, there is a lack of research on how these visual design parameters *are interpreted by children/youths*. Indeed, numerous HCI design studies use adults as test participants—as stated above, adults do not represent the full spectrum of computer users.

From a study from Skogen (forthcoming), Youths ‹thirteen years old seemed to recognize the detail-rich and highly realistic icons faster than the abstracted, rectilinear ones,

based upon their ranking of those icons first (equivalent to the "pickup order" described in Skogen, 2006). Adults responded initially to the icons that showed fewer details. Although there were no participants to demonstrate it, there appeared to be a shift between ages thirteen and seventeen, after which users began to respond similarly to the Adults. From this, we can deduct that the descriptors associated with the terms '*simple*' and '*complicated*' do not apply to all participant groups.

For this user test, participants of varying age groups did not interpret GUI icons in the same manner.

At the end of the user test, participants took a short post-test verbal interview intended to give them an opportunity to discuss, explain and/or clarify the criteria they thought about and the strategies they employed during the test. The fundamental point of the short, open-ended qualitative interview revolved around how participants interpret the visual icons. The study was exploratory, lacked a formal hypothesis, and gathered quantitative and qualitative data simultaneously. The fundamental purpose for the post-test qualitative interview was to gather verbatim information regarding:

- What particular words did participants use to a.) Describe their approach(es); b.) Describe the criteria they thought about; and/or c.) *Describe the strategies that they used to rank the icons?*

This final research topic forms the basis of this article.

METHOD

This exploratory user test was conducted at the National Center for Patient Journal Research computer lab at St. Olav's hospital, Trondheim, Norway. The equipment was conventional: a modern Microsoft PC with mouse and flat screen sat at a standard table with a comfortable chair. The room was airy, uncluttered, quiet and well lit (with windows to a natural setting outside). The test environment was intentionally set up to represent a basic computer room that a participant might have at home. Participants were given an identical set of instructions on a sheet of paper (to ensure consistency), which asked them to view sets of icons on a computer screen. If the participant was too young to read, then a parent read it for them.

The computer test included a set of icons (ten sets in total), where each set of icons represented one theme: e.g. *Home, PC, and Trash*. The icon sets were (in order): *Search, Edit, Document, Mouse, Mail, Home, Print, Book, Trash, PC*. This set (including its specific sequencing) was intended to duplicate the format of the pilot study (Skogen, 2006), with one major change: this user test would be conducted in the computer icons' native media, the computer. However, unlike the pilot study, this user test included two extra categories (*Search* and *Edit*) at the beginning. This gave the participant time to become familiar with the test format, so that when they encountered the original eight categories (i.e. *Document – PC*),

participants were seated comfortably, accustomed to computer/mouse's functionality, and familiar with the user test's format and progression. Each participant completed the user test individually, while the researcher was present at all times, seated discreetly to the side and behind. This provided the participant with a sense of security—the researcher was available for questions (particularly with the younger participants) and silently took notes. Although the researcher's presence may have influenced the users' responses, this is impossible to know. They said afterwards that they were undisturbed by her presence, and most participants stated that they'd forgotten she was there.

For each icon set, the participant saw eight icons of one theme appear on the screen at one time (see Fig. 1 below). The test consisted of ten sets/themes of icons, eight icons per set. The set of icons appeared in a circular format as shown below (Fig. 1). When the user was finished with one theme, s/he pressed *Next* to bring up the next theme. Time was not recorded and there was no time limit. To avoid potential bias due to an icon's placement in the circle, the computer repositioned the icons randomly with every reload. This means that each participant saw the icons in a randomized, unique relationship to each other, yet always in the same circular format. The other elements on the screen (instructional text, scale, button placement) remained constant for all participants. The participant was instructed to drag-and-drop each icon to one box on the scale. Each box could contain only one icon.

After completing the ranking for a set, the participant moved to the next icon theme by clicking '*Next*', whereupon the next circular set of icons appeared immediately. Participants were encouraged to respond quickly, not to think too much, and to trust their first reaction. Three types of data were collected for each participant:

1. Ranking of the icons (for quantitative data collection)
2. Video recording of the test in progress, with permission (for later reference/review)
3. Post-test interview responses for categorization purposes (for qualitative data collection)

The video apparatus was mounted very clearly on the top of the computer screen. Each participant granted permission to record prior to the test. The researcher's role was to be available as a 'guide' during the test, unobtrusive yet available. She served to help with computer formalities only, and avoided influencing any answers of the test itself. Only a few of the participants needed her assistance at all.

Quantitative Data—Participants Rank the Icons

As stated earlier, the quantitative results (Skogen, forthcoming) revealed an unforeseen age difference: detail-rich icons termed *Complicated* were often ranked lower on the scale (i.e. closer to *Simple*) for the Youths. The Adults responded in a predictable way, however the Youths did not. The results imply that designers unwittingly carry inherent biases regarding how icons and their visual parameters appear to various users across all age groups. It appears that one design does not fit all, and designers should not presume that they do. This will be discussed in the section, 'Discussion' below.

Qualitative Data—Post-Test Interview

The researcher spoke the native language of the participant (English or Norwegian), and each participant responded in his/her native language. The intention of the post-test interview was to gather participants' descriptive words regarding (in order of importance):
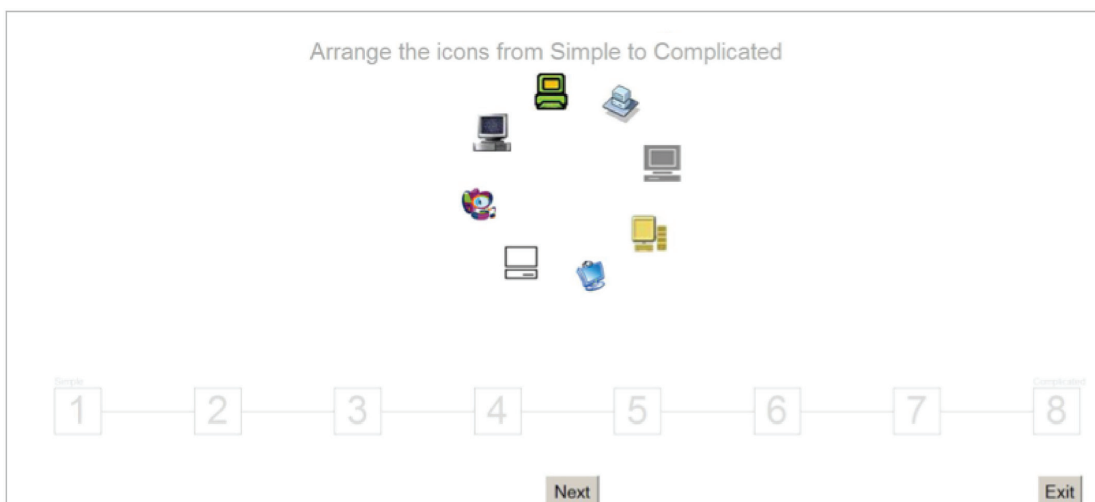
Figure 1. "PC" themed-icons: a screenshot from the user test

a. The criteria and strategies each participant used to rank the icons

b. How each participant defined the words "Simple" and "Complicated"

c. Closing the test in an appropriate & natural manner (rather than the participant leaving the room immediately).

The five Open-Ended Interview Questions were (in order):

1. Did you enjoy the test?

2. Can you describe the criteria and/or strategies you used to place the icons—what did you think about? *Rephrased for the Youths*: How did you choose where each icon should go—what did you think about?

3. How did you define *Simple* and *Complicated*?

4. Did you find anything particularly easy or difficult?

5. When asked to think of one single icon from the test, which one comes to mind?

At the end of the test, the participants often pushed their chair back and paused... some of them had used only four minutes to take the entire test so they were slightly out of breath. The difference between Youths' and Adults' responses began to appear at this moment of test completion: almost all of the Adults started talking immediately upon finishing the test, whereas all the Youths looked quietly back towards the researcher and waited for instructions on what to do next. Regarding the answers themselves, very often the Adults' responses were obtuse and self-contradictory. For the Adults, the researcher frequently needed to prompt the participant to be more specific in his/her response, give examples, or try to describe more clearly what they were thinking. Regarding question two, the Adults often answered in a confusing or wordy manner, almost as if they were trying to impress the researcher. Youths responded very directly and concisely. This also will be addressed in detail in the section 'Discussion' below.

ANALYSIS

Limits of Language

It is important to recognize that everything—including open-ended responses—is open to interpretation.

By the very act of using language, a person already filters the type of information that their mind's eye can see.

This phenomenon can be described with an example from an eight year old's responses to the interview questions. When asked which icon he recalled from the test, he said 'the computer'. When asked 'Which one?', he answered, 'The one that looks like a simple one!' In his mind's eye, he knew exactly which one he was talking about, but the nature of linguistics prevented this researcher from understanding which one he meant. Language is a crude tool for seeing into another person's inner thoughts. This is contrary to Munslow's postulate that:

History owes its very nature to the fact that language is an incredibly rich medium for describing and explaining the meaning of objects in the world. (Narrative and History - Theory and History. James, 2007, p.34).

Categories

For analysis of the five Open-Ended Questions, we used grounded-theory techniques described by Bryant et al. (2007); Charmaz (2006); Clarke & Friese (2007); and Seale et al., (ed.) (2004). Kvale & Brinkman (2009) provided numerous helpful tips on interviewing techniques in general. Ryghaug (2002) offers a nice outline of various methods of text analysis, including structuralism, semiotics, and 'linguistic-based analysis methods', but she does not go into specific detail regarding exactly how to do it.

As per the quantitative data set (Skogen, forthcoming), verbal responses were first split into two age groups: <13 (Youths) and >17 (Adults). This was done to maintain consistency across both sets of data.

For the qualitative/interview data set, analysis began with dividing all responses into two major groups, '*Criteria*' and '*Strategy*'. Criteria was regarded as noun-based and referred to 'what' the user did, whereas *Strategy* was more verb-based and referred to 'how' the user did it. After this division, words were allowed to rise out of the two groups. Although seemingly diverse, participants' responses showed that common words were often used (regardless of native language). All responses were analyzed, and sorted according to those word commonalities. These commonalities quickly revealed 'target words': i.e. words that arose more often than other descriptors. Upon scoring of the target words, the titles of the categories became evident. The specificity of the target words grew outward to encompass the words that participants (collectively) had used to describe a particular visual parameter of the icons. These target words were then codified into larger categories.

RESULTS & DISCUSSION

Emotional Value of Responses

After documentation of every word of the post-test interview, the emotional value of the responses became noticeable, based upon age. The Youths displayed an unassuming self-confidence, chose direct words, and answered the questions bluntly, sometimes monosyllabically. Adults often (but not always) responded in a verbose, complicated manner, and their answers were sometimes self-contradicting or did not make sense at all. The Youths answered the question, without pause or second thought, and then waited for the next—they responded to the open-ended questions very clearly. Not once during the Youth's interviews did the researcher sense an awkward pause, yet this was almost common with the Adults.

During the interview, it was important to avoid offering deeper clarification of the five Interview Questions due to:

1. Need to maintain consistency
2. Not wanting to impose vocabulary upon the participant
3. Avoidance of leading questions.

On a few occasions the researcher was compelled to expand upon the questions, but this only occurred in the rare instances where the extended pause felt too awkward for both the participant and the researcher. In these cases, she repeated the question, with slight rewording and/or encouragement to continue. For the few instances where it did happen, it occurred only with Adults. With the Youths, there was no need to clarify.

There were no pauses where the Youths seemed to fail to understand the question, nor did the Youths hesitate or take time to prepare an answer. This shows yet another level of age differences between *Simple* (i.e. Youths') and *Complicated* (i.e. Adults') responses. The researcher was often caught off guard by the Youths' verbal responses because there was no way to be prepared for the succinctness and clarity of their answers. Due to the Youths' concise, clear, direct answers, the interviews with the Youths went very quickly. Although she realized the Youths responded effectively at the time, it was not possible to fully experience the Youths' confident directness until she analyzed their videoed responses.

Contrarily, some of the Adults' descriptions of their criteria, strategies, and other answers seemed to flow into each other, and for some participants, answers became almost interchangeable. Even upon review of the videos, some of the Adults' sentences were convoluted to the point that it was difficult to discern what they were trying to say. Indeed, categorizing the use of language proved to be more difficult than anticipated. Still, the words were tallied and specific usage was documented. The words were important, and the general communicability of the participants' answers did not affect the categorization. However, it served as an interesting observation (between Youths and Adults) only.

Categories

i. Color

The target word '*color/farge*' came up often, and there didn't seem to be another word that participants used to communicate that particular aspect of the icons' design. One 9-year-old pinpointed *color* (while simultaneously using the word *simple/enkel* on two occasions):

> ...det var noe med enkelte som jeg likte veldig godt. Jeg likte dem med farger.
>
> Farger var litt enkelere.
>
> *(There was something about the simple ones that I liked very much. I liked those with color. Color was a little more simple.)*

COLOR became one of the codified categories because the participants used it often. However, as the quantitative/rank-ing data from this user test revealed, there may be an inherent bias lurking in the use of the word 'color'. Some participants had very different interpretations of color: a few participants decided icons were *Simple because* they contained color, whereas other participants decided that icons were *Complicated* because they contained color. Those who said color made an icon *Complicated*, also said that black & white icons were more *Simple* than the colored ones. Regardless, it was only the Youths who considered color to be a simplifying parameter (perhaps making the icon appear more realistic). Contrarily, the Adults considered color to be a more complicating parameter. This disparity in interpretation of this one parameter—COLOR—between Youths and Adults is perhaps one of the most important results of this study.

ii. Recognizability

Many participants described another parameter of the icons' visual impression: its ability to communicate meaning quickly—it's recognizability. This refers to an icons' ability to represent what it was supposed to represent, i.e. whether it was easy/difficult to understand what the icon described. The terms used for this became coded as RECOGNIZABILITY.

iii. Detail

Many participants described the icons' richness of detail, which quickly became coded as DETAIL.

Again, target words were easy to identify due to '*detail*' being used in a consistent manner. Only one person mentioned '*perspective*', while another person mentioned '*photorealism*' only once.

iv. Degree of Abstraction

Many participants found it difficult to describe the concept of visual simplicity without using the word 'simple'.

From this user test (particularly the quantitative data herein) we may deduce that each participant carries an individualized idea of what 'simple design' means, and this term's interpretive emotional value might be linked to the user's age. Simplicity appears to be in the eyes of the beholder. Indeed, a 'simple' icon means something different when viewed from an Adult's viewpoint when compared with a Youth's or a child's viewpoint. This researcher states: the presumption that 'simple' means lack of detail is inherently biased and implies that an adult's viewpoint is the only one that exists. McDougall showed that an icon's concreteness (i.e. the extent to which icons pictorially represent objects, places, or people) primarily affects the grasp of meaning (McDougall et al., 2000), as well as correlates strongly with the ease of an icon's interpretation (McDougall et al., 2006). For this study, the concept of concreteness became expanded and termed as DEGREE of ABSTRACTION.

All of the categories can very easily meld into each other, yet Adult participants seemed to switch quickly between two specific categories, DETAIL and DEGREE of ABSTRACTION.

This quick switching could even occur mid-sentence. One adult participant stated: 'Line drawings are easier than photorealistic ones and less items makes it easier, makes it simpler'. This participant felt he needed to elaborate on his first sentence (DETAIL) by supporting it with another (DEGREE of ABSTRACTION). Although DETAIL and DEGREE of ABSTRACTION can easily overlap, this researcher intends to keep them separate as much as possible.

Other Creative Descriptors

Some descriptions did not fit into any categorical sorting, yet they became interesting because of their insightfulness and uniqueness. One unforgettable example came from the youngest participant (five years old):

> I think the simpler things are harder to break.

> The most simple things are the most hard to break, they are!

This was such a profoundly new and unpredicted approach to the task, that it took a few moments to actually comprehend it. Imagine a category entitled Breakability! This participant was a big, strong five-year-old, who (his mother mentioned later) was prone to breaking his toys, so this made perfect sense to him—this ideology of breakability fit into his world seamlessly. He was accustomed to it.

Historicity. A second example is the thirteen-year-old who used a unique technique—historical reference—to determine his definition of *Simple/Complicated*. He was the only one who did so:

> Enkle var de som var historiske... kompliserte var moderne.

> *(Simple were those that were historical, Complicated were modern.)*

Replicability. When one eleven-year-old was asked what he thought about during the test, he responded:

> Det jeg tenkte på var hvis du skal lage... tegne de tingene der... hvor lang tid skal du ta?

> *(What I thought about was if you were to make...draw those things there...how long would it take?)*

This participant's strategy had been to convert each icon into an estimation of his time required to replicate it by drawing it. This idea was actually conveyed by two of the youths, completely independent of each other. This participant was eleven years old and the other individual who used this approach was seventeen years old. Unfortunately this study did not include enough participants to determine how likely would it be for an adult to employ a similar strategy. A criteria/strategy could become its own category if there were enough respondents to support it.

Finally, three of the Adults (all female) strategically interpreted how the icons would appear to others. This was unique among the Adults... none of the Youths used this tactic.

The final four categories were:

1. COLOR

2. RECOGNIZABILITY

3. DETAIL

4. DEGREE of ABSTRACTION

Icon Recall

The fifth Interview Question asked for the participant to recall one specific icon from the test. The intention here was to see which icon made enough of an impression to remain memorable beyond the conclusion of the test. Interestingly, there was only one icon that was recalled by more than one participant (five in total: four Adults and one Youth). It was a highly unusual, detailed and colorful rendering of a house ('home'). It was also the icon deemed most '*Complicated*' by all Adults. Table one below shows the icon with its corresponding ranking scores for both Adults and Youths (on a scale of 1=*Simple* to 8=*Complicated*).

	ADULTS (>16)	YOUTHS (<13)	ALL AGES COMBINED
Home	7.6	4.8	6.4

Table 1. The most-recalled icon with ranking scores

All other participants recalled only one instance of other icons.

CONCLUSION

In describing the criteria used to rank the icons, participants in this user test revealed numerous strategies regarding what they thought about while ranking the icons on a scale of *Simple-Complicated*. Some participants used unique and highly insightful approaches whereas the majority showed commonalities among their responses. The fact that we could identify, group, and extract four categories from those target words shows that there were similar approaches to interpreting the icons. Although people used the same target words, (e.g. COLOR), this does *not* infer they interpreted or defined that word similarly.

This is the most important point of the qualitative aspect of this user test, perhaps the largest contribution: designers cannot presume that users will see their designs in the exact same manner. This study showed that there appeared to be age and individual differences in how people interpreted the visual parameter of COLOR. As this one example shows, the viewer's definitions might be contradictory. If this is the case, how many other visual parameters do we misjudge? It is important for those involved with computer interface design to know the potential for this discrepancy among their users.

This user test incorporated a small sample size (n=29) and although all ages were not represented, it does accomplish a very important task for GUI/HCI designers: it highlights the potential for inherent biases. As adults, we tend to design

from our own perspective, and this means that our designs potentially carry a quiet, unintentional bias. We presume that our definitions of the numerous aspects of visual design apply equally to all age groups (children, adults, and seniors, across cultural boundaries), while this study shows that such presumptions may be highly incorrect.

Designing from one's own adult perspective is a trap into which many GUI designers fall. The only way to avoid this trap is to test the user group repeatedly to ensure that it is the user group's interpretation of the design that is being met, not the designer's. In order to avoid this pitfall, a GUI designer must test often, particularly during the beginning phases of the design process. The most effective time to test is as early as possible, when design changes are easily made. Otherwise, a designer has the potential to miss his/her target user group entirely. Repeated user testing, during *all* phases of the design process, is the only insurance that the designer has—it's the only way s/he can be sure to meet the needs of the intended user group. According to Thomson (2008, p.1):

> Indeed, the perspectives of children and young people are of interest to contemporary social scientists precisely because they offer specific and unique insights…which can easily slip below the horizons of older inquirers. The omission of these perspectives can easily lead to researchers making interpretations and representations that are very shortsighted and which miss the point.

This study shows that youths' do not share the same visual design needs for GUI/HCI applications as adults. In addition, people's interpretation of visual information changes as we age. It appears that a GUI icon's visual design—its simplicity and/or visual complexity—is in the eye of the beholder.

REFERENCES

Adams, A., Lunt, P., and Cairns, P. (2008) A qualitative approach to HCI research.

Bryant, Anton.y & and Kathy Charmaz, K. (2007). *The SAGE Handbook of Grounded Theory*. London: Sage.

Byrne, M. D. (1993) 'Using icons to find documents: simplicity is critical', *Proceedings of the INTERACT'93 and CHI'93 Conference on Human Factors in Computing Systems*, (May), pp. 446-453, ACM.

Charmaz, K. (2006) *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. London: Sage.

Chiasson, S., and Gutwin, C. (2005) 'Design principles for children's technology', *interfaces, 7*, 28.

Chiu, S., Koong, C. S., and Fan, S. H. (2012) 'Icon Design Principles for Preschoolers: Implications Derived from Child Development', *Procedia-Social and Behavioral Sciences*, 64, pp.228-237.

Clarke, A. and Carrie F. (2007) 'Grounded Theorizing Using Situational Analysis', in A. Bryant and K. Charmaz (eds), *The SAGE Handbook of Grounded Theory*, London: Sage. pp.363-397

Corbetta, M., Miezin, F. M., Dobmeyer, S., Shulman, G. L., and Petersen, S. E. (1990) 'Attentional modulation of neural processing of shape, color, and velocity in humans', *Science*, 248 (4962), pp.1556-1559.

Davis, E. G., and Swezey, R. W. (1983) 'Human factors guidelines in computer graphics: A case study', *International Journal of Man-Machine Studies*, 18, (2), pp.113-133.

Druin, A. (1999) *The Design of Children's Technology*. San Francisco: Morgan Kaufmann Publishers.

Huang, S. M., Shieh, K. K., and Chi, C. F. (2002) 'Factors affecting the design of computer icons', *International Journal of Industrial Ergonomics*, 29, (4), pp.211-218.

Gittins, D. (1986) 'Icon-based human-computer interaction', *International Journal of Man-Machine Studies*, 24, (6), pp.519-543.

Huang, K. C. (2008) 'Effects of computer icons and figure/background area ratios and color combinations on visual search performance on an LCD monitor', *Displays*, 29, (3), pp.237-242.

Jensen, J. J., and Skov, M. B. (2005) 'A review of research methods in children's technology design', *Proceedings of the 2005 conference on Interaction design and children*, (June), pp.80-87 ACM.

Steinar, K., and Brinkman, S. (2009) *InterViews – Learning the Craft of Qualitative Research Interviewing*. London: Sage.

Lindberg, T., and Näsänen, R. (2003) 'The effect of icon spacing and size on the speed of icon processing in the human visual system', *Displays*, 24, (3), pp.111-120.

Liu, T., and Mance, I. (2011) 'Constant spread of feature-based attention across the visual field', *Vision research*, 51, (1), pp.26-33.

McDougall, S. J., de Bruijn, O., and Curry, M. B. (2000) 'Exploring the effects of icon characteristics on user performance: The role of icon concreteness, complexity, and distinctiveness', *Journal of Experimental Psychology: Applied*, 6, (4), p.291.

McDougall, S. J., and Reppa, I. (2008) 'Why do I like it? The relationships between icon characteristics, user performance and aesthetic appeal', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 52, (18), pp.1257-1261.

McDougall, S., Tyrer, V., and Folkard, S. (2006) 'Searching for signs, symbols, and icons: effects of time of day, visual complexity, and grouping', *Journal of experimental psychology: Applied*, 12, (2), p.118.

Munslow, A. (2007) *Narrative and History (Theory and History)*. Place of publication: Palgrave Macmillan.

Näsänen, R., & Ojanpää, H. (2003). Effect of image contrast and sharpness on visual search for computer icons. Displays, 24(3), 137-144.

Reppa, I., Playfoot, D., and McDougall, S. J. (2008) 'Visual aesthetic appeal speeds processing of complex but not simple icons', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 52, (18), pp.1155-1159.

Rocheleau, B. (1995) 'Computer use by school-age Youths: Trends, patterns, and predictors', *Journal of Educational Computing Research*, 12, (1), pp.1-17.

Ryghaug, M. (2002) 'Å bring tekster i tale—mulige metodiske innfallsvinkler til tekstanalyse i statsvitenskap', *Norsk Statsvitenskapelige Tidskrift*, 18, pp,303-327.

Seale, C., Gobo, G., Jaber, F., Gubrium, (initial), and Silverman, D. (ed). (2004) *Qualitative Research Practice*. London: Sage.

Skogen, M. G. (2006), 'An investigation into the subjective experience of icons: a pilot study', *Information Visualization, 2006*, Tenth International Conference on (what?), (July), pp.368-373.

Thomson, P. (ed.) (2008) *Doing Visual Research with Youths and Young People*. UK and USA: Routledge.

Yan, R. (2011) 'Icon Design Study in Computer Interface', *Procedia Engineering*, 15, pp.3134-3138.

Paper 6

OBJECTIVE:

Comparison of responses across three types of visual stimuli

Author: Martha Skogen & Helle Kristine Hoem

Full title: What Can GUI Designers Learn from 2D Poster Art?

What Can GUI Designers Learn from 2D Poster Art?

Viewers Responses Reveal Consistencies Across Diverse Media

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ABSTRACT

The design of current graphical user interfaces (GUIs) is the result of the ability to crowd increasing amounts of information into limited space plus a powerful cultural trend that strives for richness in detail. The authors propose that at some point, the abundance of visual information and/or interplay of aesthetic elements on a computer screen can potentially disturb the user's level of understanding. Counter-intuitively, stripping the design can be undesirable. This explorative study builds on prior work investigating the fundamental factors that underlie viewers' experiences of visual information, including what constitutes "too much" or "too little" in GUI design. This study also leads to a larger study currently investigating the formation of visual archetype in GUI icon design.

Using social science/humanities methodology to compare GUI design with 2D poster design, participants ranked three types of non-digital visual stimuli on a 1-7 scale: home icon (ICONS), miniaturized poster art (POSTERS), and introductory screens for an online booking application (GUI). Results demonstrated general consensus among the users in judgment of the stimuli's compositional design. Viewers experienced numerous visual parameters simultaneously and consistently. We apply six parameters from graphic design and discuss them along with their implications for software development. Innovation in GUI design is constantly evolving, making design research a valuable tool that is often underutilized. This study shows that many types of visual communication incorporate common aesthetic principles, regardless of media. Ultimately, 'good' design is not so much an aesthetic value judgment as the multileveled experience that the designer conscientiously intended.

Keywords: Graphical user interface (GUI) design, poster art, 2D visual design, social science/humanities research, computer icons.

1   INTRODUCTION

The aim of this explorative study was twofold: i) To discover if users' judgments of visual information was consistent across different types of media including icon design, user interface design and poster art, and ii) To gain deeper understanding about what constitutes "too little" and "too much" visual design in users' experiences. Overall, the intention of the study was to learn more about the visual factors that underlie the experience of visual simplicity or complexity—an aesthetic value judgment that is appropriate for software developers to understand and be able to control conscientiously.

Research in GUI design is imperative so that our increasingly integrated computer interfaces reflect the most optimal design for our busy lifestyles. Computer users are subject to a constant flow of innovations through new upgrades, technologies and/or ways in which computers are integrated into our lives. With each new software release, developers engage their users by asking them to learn and/or respond to new aspects and changes in their already-familiar computing tool. Extensive pre-release software research is essential to determine how those changes might be understood and received. Often software tools utilize visual effects and/or compositional layouts that create unintended responses in their users. The computing community is accustomed to updates

and changes in the GUI interfaces they use, yet sometimes those changes are more embraced than others.

The most recent Apple© iOS 8 ("Yosemite") operating system is an example of a tool that received conflicting feedback when it was recently released. The design was stripped of many levels of detail and numerous extraneous design elements were removed. Many distracting, redundant and/or unnecessary aspects of the design were reduced to their absolute minimum while still maintaining communicability. The reaction was mixed, demonstrating that even Apple©, a company renowned for "intuitive" interfaces and GUI innovation, can make an interface that is perceived as less intuitive/innovative. Some opinions on their new interface are reflected in the brief interviews conducted with university students below. The students provided responses in three distinct categories, from *Dislike, Like*, to *Don't Know*.

User reactions for *Like* included 'It's cleaner & easier', and a neutral 'It's ok'. Their for *Dislike* were more numerous, stronger and included words such as: 'Ugly', 'Boring', 'Tacky', 'Weird', 'Annoying', 'Childish'. The most revealing verbatim quotes include:

Like:

  • 'I was a beta tester, I really like it. You can stream films 2x faster. They took away shadows and other unnecessary stuff'

Dislike:

  • 'Ok functionally but I liked the design better before'

  • 'What were they thinking?'

  • 'I don't like it'

Don't know:

  • 'I'm going to wait for the next upgrade'

One university student used the term "childish"—a term that reveals a strong, pervasive bias that can come from an adult's perspective. Adults *presume* that detail-scant designs represent what are most efficient for children and/or what youths want to see. This is hardly the case as this researcher is finding in a study currently in progress. [29].

From the brief gathering of opinions described above, there seems to be a preference for more detail-rich designs of the iOS user interface. We wonder if the new iOS demonstrates a gap, on numerous levels (including emotional association) between what users expect and what the new update presents. Perhaps the Yosemite update provided *too large* a departure between what the user is accustomed to, and what the new graphical layout presents. Since the concept of 'intuitivity' is highly subjective, the authors suggest employing two visual descriptors instead: simple and complicated.

By adult age, most people have built experience, history and personal association with these two terms. After years of computer experience, adults develop a personal history with what constitutes the visual, functional, experiential and emotional understanding of "simple" and "complicated". In short, they have established a 'visual archetype' for each concept. Because

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these archetypical associations are based on personal history and experience, the visual associations connected with these terms may be subject to change. For this reason, this study employs the terms Simple and Complicated in order to learn more about their meanings. This research explores the fundamental, experiential associations connected with these value judgments. Research questions for this study include:

• How do users rank three types of analogue, visual stimuli on a single axis scale ranging from Simple to Complicated?

• Is there consistency: i) between users and ii) across various media (i.e. 2D poster art and GUI elements)?

• Do the visual parameters employed in 2D graphic design apply to those used in GUI design?

• What are the underlying design parameters [28] that are associated with those value judgments termed "Simple" & "Complicated"

• What do the terms "Simple" and "Complicated" actually mean for user-interface designers and how do they relate to "good" design?

Our hypothesis is that the images that contain less visual detail and fewer design parameters will be considered (and thus ranked on the scale 1-3) as Simple, whereas the images that contain more detail and parameters will be considered (and ranked 5-7) Complicated. This will allow us to determine if users' aesthetic value judgments of the terms 'simple' and 'complicated' refer to amount of visual detail in an image.

2   BACKGROUND

Aesthetically, sophisticated desktop design programs provide a wealth of opportunity for programmers and designers to dramatically increase the level of visual richness in graphical user interfaces. To the average viewer, it appears that the number of onscreen visual elements, as well as the degree to which they are designed, has increased in recent years. The new iOS 8 provides a distinct departure from that trend—does it represent "good" design?

There is a vast amount of information on how to design "good" interfaces. "Good" is a subjective term, yet there are fundamentally understood general design principles that are common for all visual compositions, regardless of media. This study attempts to discover more about the underlying design principles that end up being determined as "good" or "bad". This research focuses on two terms: "simple" and "complicated". These terms were chosen as a continuation of research begun earlier [28]. This study reduced the dual-axis matrix to a single axis that consisted of Simple and Complicated only. Explorative in nature, this study's aim was to discover how well the value judgment of Simple-Complicated is related to amount of visual information in a defined area. Ultimately the purpose is to use this research to help the software industry adopt principles of useful, effective, enjoyable visual design. Visual parameters are those aspects of design that can be manipulated to change the appearance of a visual stimuli. Some examples that will be discussed include Density, Negative (or White) Space, Colour, Detail, etc. The six parameters discussed below are a continuation of the previous study [28].

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There are numerous authors who help us design 'good' GUI [1, 3, 13, 16-20, 26-27, 30, 35-37 etc.]. Ware's textbook describes virtually every aspect of GUI design, from the physiology of perception to how to present information effectively [35]. Mullet and Sano applied basic graphic design principles of printed media to GUI design because all visual design is concerned with communication. They present that the same visual principles *should* (and often do) apply from print to GUI. Mullet and Sano provide a foundation for this researcher's hypothesis that the same visual design parameters apply to numerous aesthetic realms, from the largest posters (e.g. print) to the smallest icons (e.g. GUI design).

Useful, effective, and enjoyable visual communication often incorporates aesthetic simplicity [19]. Nick Chater provides the argument that not only is visual simplicity more appealing, it is more reliable—this makes it have crucial practical importance [5], Cheon & Grant provide a good overview of the variables to be taken into account when designing GUI's including learning effectiveness, cognitive load, and usability. Importantly, they provide a useful summary of recommendations based upon graphic design principles [7]. The most important design aspect is to use a bottom-up approach and begin with the data, and then design it appropriately. Tufte tells us that often visual displays suffer from too much ink in proportion to the data being communicated [33], Pretorius & Van Wijk suggest looking for the specific characteristics of the data and presenting it in ways which have not been considered before [25]. Regardless, design of visual information and GUI's requires an iterative design process where the goal is to arrive at a list of usability issues with suggestions for interface improvements [21].

The literature regarding how users respond to different types of visual information is varied. Plaue, Miller & Stasko conducted a relevant study whereby they tested three types of visual information (highly graphical, web portal and text based) and found that users responded to (and recalled) more information from the highly graphical interface even though they had to learn the codings associated with it. [24]. Cheon and Grant conducted another test including three types of information (metaphorical, graphical and text-based) but found that none of the user interfaces aided learners. The metaphorical (most visual) did however increase users' attention [7].

Research in Attention attempts to describe how our eyes & brains focus on particular elements vs. others. Those elements we focus upon (regardless of media) must be picked out and visually digested in an overall composition, and some elements can be visually distracting, redundant and unnecessary.

Digesting complicated visual information takes up precious time and energy on the part of the viewer [2, 4, 31], and it is highly restrictive [18]. This is true from a psycho-physiological perspective [8, 10]. This is applicable to human-computer interface design [12], making it imperative that we understand the fundamental visual factors at work. For this study, we interpret and summarize this collective research as: the time needed to absorb extra design elements detracts from the primary goal of functional applications. We suggest that too many redundant, distracting, unnecessary visual elements detract from the primary goal of a GUI to convey information as quickly and easily as possible, and adversely affects the user's ability to use the computer tool optimally. The question is: what constitutes 'too much'? Or, how do we know if a design element is distracting, redundant and unnecessary? If 'good' GUI design

incorporates being useful, effective, and enjoyable, how does one design for that? This research attempts to shed some light on those questions.

3   METHOD

Methodologically, the test setup was reflective of basic social science practice rather than conventional GUI testing. Primarily, the test was analogue—there was no computer used. The ranking scale was a long wooden board with seven frames in which the visual stimuli (images mounted on blocks) were to be placed. This setup was designed intentionally to encourage the participant to respond as quickly as possible without needing to learn and operate an unfamiliar GUI interface. The analogue test setup directed the participants' focus entirely to the compositional layout of the stimuli and the task of placing them quickly on the scale. By asking users to act as quickly as possible, we tried to capture the immediacy of participants' initial reactions.

Upon arrival, each participant was introduced to the test individually with a brief explanation. We explained how to use the analogue, seven-level scale that ranged from Simple to Complicated, and emphasized that they could go as fast as they wished. Time was not being calculated. We asked each participant to place the blocks in the squares as quickly as possible, and to not analyze too much while placing them. We encouraged this by reiterating that there can be no wrong answers in people's subjective interpretations of visual media. Each showed seven variations of a theme which ranged from simple to complicated, based upon our aesthetic judgment alone.

Fig. 1. The single-axis scale with the study in progress.

Ten subjects participated: two women, eight men. The subjects were all permanent employees of a Norwegian company affiliated with the petroleum industry. The ages ranged between 25-45 years old, and each subject was highly educated with a minimum eight years of computer use. This sample size was small and not at all representative of the larger population. All were native Norwegian speakers, and conversation during the test was conducted in Norwegian. In order to obtain reflective information about what the user thought

during the test, we conducted individual post-test verbal interviews that lasted approximately ten minutes.

We did not describe the terms "Simple" or "Complicated" for each participant, nor did we impose any opinions on how the terms should be interpreted, even when we were asked to do so. We indicated that defining the terms for themselves was a part of the test, and that upon completion of the test, they would have time for discussion.

Before starting the test, each participant understood they were to define the semantic meaning of the words SIMPLE-COMPLICATED themselves ("Enkel – Komplisert" in Norwegian) and rank the visual stimuli accordingly. Both the Norwegian and English words were visible on the scale, with the English being more prominent. This was to maintain consistency with regard to previous and future testing formats.

The subjects were asked to pick up the blocks as quickly as possible and place them on the scale, one item per frame. There were seven frames total, with the word Simple (Enkel) on the left edge and Complicated (Komplisert) on the right. To change categories, the subjects turned around while we set up the next set of blocks. All blocks were positioned consistently for each subject (we used photos of the original layout for each category). The participants' test times ranged from 10-40 seconds across all categories.

3.1 Home Icon (HOME)

The first category served as a warm-up, and involved seven representations of the HOME icon only: archetypical due to all having an inverted V-shaped roof (see Fig. 2 below and Fig. 6). The icons presented all incorporated multiple parameters including colour, contrast, detail, perspective and photorealism [28]. The images in the POSTER and GUI categories did not incorporate as many parameters as the HOME category. The icons were taken from free collections available on the internet.
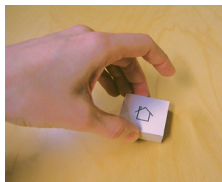
Fig. 2. HOME image mounted upon a block.

3.2 Miniaturized Poster Art (POSTERS)

The second category consisted of seven posters from Armin Hofmann's extensive career (see Figure 3). They ranged from text only, to highly abstracted, to photorealistic. Armin Hofmann is an internationally recognized graphic designer whose posters populated the Swiss urban landscape from the

1960´s to the mid-1980´s. As a master of form and positive- and negative space, Professor Hofmann's poster art reveals his exquisite manipulation of the basic principles of visual design. We chose them based on the categorization system originated by Prof. Hofmann to document his work portfolio. At a personal interview, Prof. Hofmann demonstrated the organizational system he'd devised for his own purposes. His posters were mapped out and grouped together based upon visual parameters, including: negative space, colour, detail-density, etc.

The posters chosen for this study represent Prof. Hofmann's evaluation of his own posters on a Simple-Complicated scale. Two examples are shown below (Fig 3). In his own words, the poster on the left is "simple" while the poster on the right shows "complicated-ness" (sic). Note the difference between the "flat" design on the left and the depth represented by the photorealistic imagery on the right. This will be addressed more in the Discussion.

Fig. 3. Two examples of Armin Hofmann's poster art used for the test.

3.3 Introductory Screens for Online Booking Application (GUI)

The third category consisted of seven conceptual layouts for an electronic application that allows users to book meetings online. Each design was "flat" without extraneous visual details. While each GUI representation was derived from the same informational architecture, each showed a different conceptual model for how the application might look. The concepts reflected an increasing degree of visual density, showing the content up front rather than via drop-down windows. Because the test blocks were made of wood and paper, users were not able to click and/or electronically interact with the booking application as they might if the test were in its native format (i.e. on the computer). Intentionally, our test eliminated the interactivity of the application and thereby required the participant to make judgments based upon the layout and visual composition only.

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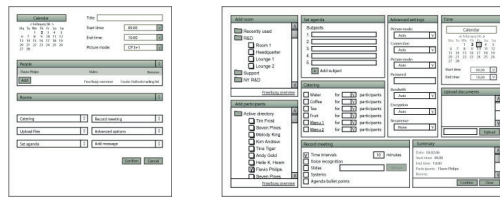
Fig. 4. Two examples of the GUI stimuli.

4   EVALUATION AND RESULTS

The boxes on the ranking scale were numbered 1-7, and each block containing a visual stimulus was coded A-G. During the user test, we noticed that almost everyone employed a similar strategy when placing the blocks. Extremes were placed almost immediately while with only one exception, the subjects slowed down considerably when placing blocks in the middle. This is an interesting cognitive strategy that warrants further research.

We recorded all responses and averaged all ranked scores for each block in each category. For the GUI category, we averaged all responses and then mapped the results for each category to the scale itself for easy comparison (see Fig 5 below).

Results showed that overall, users ranked the visual information consistently for the HOME and GUI categories, but ranked the POSTERS blocks less consistently. In general, users ranked images with fewer design parameters in the Simple end of the scale, and ranked images with more design parameters in the Complicated area. Each category's results follow below.

4.1 Icons

The icons were intended as a warm-up for GUI and POSTERS categories, but the ICONS category provided consistent results as well. The range of scores reflected our hypothesis as well as the research conducted earlier. Colour, detail, perspective and photorealism were the major parameters. The black & white line-art icons were ranked at the Simple end (1-3) of the scale whereas the detail-rich, colourful, photorealistic images were ranked at the Complicated (5-7) end of the scale.

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4.2 Posters

The posters with the most negative space (in our examples, the negative space was coloured black) were consistently considered simpler. The posters judged Simple contained fewer elements in the composition than those judged Complicated. We have termed this amount of visual information "density". The two posters with rich photographic detail were consistently placed towards the Complicated end. The range of answers varied in this category much more than the other two categories. Even though all users agreed that this was the most difficult test, the results still showed that the posters with increasing number of elements (greater visual density) and level of detail were consistently considered increasingly more complicated.

Everyone in this test agreed that the posters were the most challenging to rank. One subject even commented that the participants in the test all were technical engineers and therefore, "Not very good at art". Although we presume this test has very little to do with being good at art, other user groups (e.g. design students) might respond differently to the posters. For future studies, the sample group will be larger and hopefully more representative of the population at large with regard to age, gender, nationality, profession and computer proficiency.

4.3 GUI Design

The results for this category are shown below (Fig. 5). This illustration shows the placement of the averaged results for the GUI category, with the major visual design parameters specified underneath.
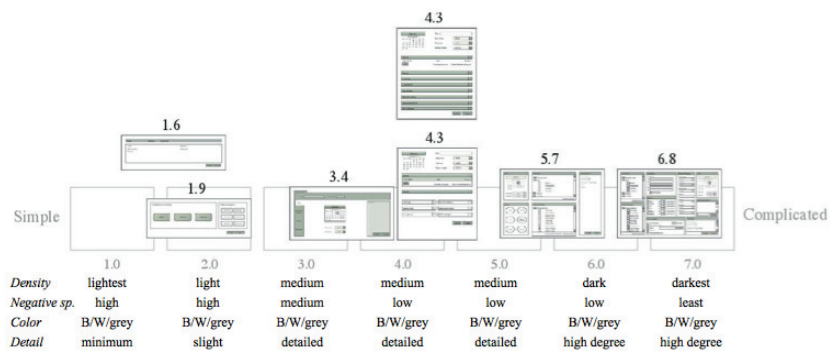
Fig. 5. The averaged results for placement of the GUI blocks. The parameters indicated underneath are our summarizations based upon previous work [28].

4.4 Results of Post-test Interviews

The post-test interviews focused on two questions:

• How did you define simple/complicated?

• Can you describe what makes an a visual image appear simple/complicated?

9/10 subjects commented that if the image was unfamiliar or abstract, it was difficult to understand—making it difficult to place on the scale. One person even said during the test that the designs were "easy to place if they were familiar". 7/10 subjects remarked that colour determined whether the image was "Complicated or not". 7/10 subjects also confirmed that the number of objects was an important determining factor for where they placed the objects. Other responses included (all translated from Norwegian):

• "The design is complicated when you spend time understanding the message"

• "The more detail-rich, the more complicated"

• "There is a lot of white in this one..."

• "The design is good if I 'get' it quickly"

All of the participants said they'd enjoyed the test, and three mentioned that it had caused them to "think". One mentioned she was sure she would "see things differently" after taking it. The researcher heard some time later that having taken the test had allowed some of the participants to be more observant of the interfaces they used on a daily basis. One participant even stated that the test had caused him to "notice things he'd not seen before".

5   DISCUSSION

Due to the small sample size, results of this study should be interpreted as points of interest rather than absolutes. We presume that there were many factors behind peoples' subjective experience of the visual information we presented. Almost all of that experience was beyond our ability to measure, identify or control. Despite being unable to account for people's subjective interpretations (other than their ranking and verbal responses), participants consistently ranked designs that contained fewer parameters (e.g. density, colour, contrast, high degree of white space), as Simple, whereas those designs with more parameters were considered Complicated. This test shows that visual information often contains multiple parameters simultaneously, and although these parameters overlap each other somewhat, they have distinguishable characteristics. Although results were not 100% consistent, the users (all adults) in this test responded in a manner which shows there was agreement in their interpretations of Simple-Complicated. From this study we can associate less visual detail/parameters in an image with the term Simple, and more visual detail/parameters in an image with the term Complicated.

What follows is a description of the major parameters that appeared to play a role in the images placed on our Simple-Complicated scale.

5.1 Density

Visual density is the cumulative amount of information that the user sees on a first impression. It refers to the amount of information reflected by the positive

1

graphic elements in a composition. Tufte calls this the Data-Ink proportion, whereby the amount of ink dedicated to the information should not outweigh the information itself [33]. We found that visual density is a powerful parameter in determining if the imagery was considered Simple or Complicated. This study showed that images consisting of minimal visual density were consistently considered Simple, whereas increased visual density was consistently considered Complicated.

Density is perhaps one of the visual parameters that is most easily taken for granted by designers. It is tempting to add a feature without careful consideration of its placement within numerous contexts including: visual, conceptual, experiential and structure/architecture of information. We propose that every visual element resides within a context on many levels, regardless of media. The deliberate handling of the visual density created by elements creates an immediate first impression. For each user, this first impression instantly establishes a powerful, emotional association regarding the design. This immediate emotional association then determines how the user approaches and engages with the GUI, and ultimately results in how they determine the GUI (e.g. useful, effective, enjoyable). First impressions happen fast, and they make a lasting impact.

5.2 Negative Space (also referred to as "white space")

Closely intertwined with density, negative space is the area between objects in a composition—it is sometimes referred to as visual "air". Jakob Nielsen judgmentally calls this negative space "unused" [22], which implies that it is something that needs to be filled. In non-design arenas, the prevailing understanding about white space seems to be that it is devoid of any meaning and therefore not a valuable visual parameter in its own right.

We argue that white space is a powerful design parameter and should be incorporated into the GUI design vocabulary. When used conscientiously, white space provides the user with an immediate impression of the interface's ease-of-use. The amount of white space in any composition makes an impact—often as the first impression. Armin Hofmann explained this vital aspect of design [11]:

> *Two straight parallel lines produce a third enclosed between them. The relationship of negative-positive, one of the most important encounters between opposites in all design work, arises automatically. The space in between, which is a by-product, is just as important as the element producing it.*

The controlled use of both density and negative space is paramount to the experience and perception of the integrity and functionality in any GUI. Based on responses from this test, Density and its counterpart White space are extremely important design parameters in determining the user's overall experience of Simplicity/Complexity. How the user perceives the ease-of-use of the GUI determines their approach and whether (or not) they choose to use it again.

The fundamental rules of human perception help us to understand that people react extremely quickly to certain parameters of design. High contrast makes certain designs jump out more than others. Saturated colours have the same effect. We are aware that the strength of these parameters combine to affect

the overall interpretation of an image. In a personal interview, Armin Hofmann stated that "contrast is the most powerful parameter of visual design". Contrast is hereby designated as the strength of interplay between elements in a composition. Contrast can be achieved via numerous parameters that include: colour, placement, shape/form, angle and the dynamic between positive and negative space, etc. Conscientious control of contrast is imperative for good design, regardless of media, even at the smallest compositional level (e.g. icons) [9].

5.3 Colour

Human stereoscopic vision dictates that saturated colours come forward, desaturated ones recede. This is a condition that allows humans to determine distances. Colour is an extremely powerful design parameter [14], and it became a potentially determining factor in the ICON section of the test. The less colourful the icon, the more likely it was to end up on the Simple side of the scale. More colourful icons were considered more Complicated, with one participant stating during his interview that "Colour makes it complicated".

Fewer colours were represented in the images in the POSTER section; they included black/white, grey, and one large instance of red. To eliminate the power of colour for the GUI section, we chose to use only very quiet tonal values in the images used. This restricted the participant to view the level of detail, density and varying amounts of white space.

Because people are highly sensitive to colour (and 1/12 have some sort of colour deficiency [38], it is mandatory for software designers to 1) design colours in harmonizing palettes that reflect the integrity and intention of the GUI. It is equally imperative that the visual communicability of a design **not** be dependent upon colour alone. On the other hand, colour should not be used so generously that it annoys the viewer via overly contrasting or saturated elements. In any composition (art or other), colour should always be intentionally, deliberately and carefully controlled.

5.4 Gestalt Principles

The Gestalt Principles describe the fundamental psychological processes in how we interpret our visual world. They describe four basic phenomena of how objects interact with each other, and are relevant for every type of design, particularly GUI design. These principles are: closure, continuity, proximity and similarity. These parameters are vital in creating meaningful relationships among visual elements in the GUI composition—it is imperative that the software designer understands their ever-present effects.

Although not tested specifically in this study, we theorize that the Gestalt principles apply to every aspect of GUI design, including the tiny icon. Visual elements relate to each other and to the context in which they reside, regardless of size, media or intended use. Gestalt aspects of human perception always apply to visual compositions, in any theme, context, media or environment.

5.5 Detail

Also highly related to density, the level or amount of detail reflects the range of richness in the image. The elements used in forming detail richness can be text, pattern, line, shapes, figures, etc. Some images can be very communicative without being detailed, whereas others might show detailed information that may or may not be necessary for understanding. Photorealism is the most extreme aspect of visual detailing. Our user test showed that people consistently ranked more detailed information as complicated, including photographic imagery. Images that comprised the least amount of detail were consistently ranked as Simple. Regarding the iOS 8 Yosemite interface mentioned above, the question remains if it became too lacking in detail. Was it the 'flat', detail-scant design and stripped-down visual layout that many users didn't like? Was it too detail-scant—was it *too simple*? Why were so many users disgruntled by the new version's lack of detail? These are questions for further research.

5.6 Photorealism

Two photorealistic images were placed consistently in the Complicated side of the scale: the HOME icon (see Fig. 6 below) and the photomontage of hands in the poster by Armin Hofmann (see Fig. 3). For the poster, this could either be due to its immediate recognizability (i.e. closer representation to the real world), or the multiple levels of detail and visual arrangement in the composition. This study was not able to determine which of these factors weighed most in each participant's answer. There is room for study regarding photorealistic imagery: does the nearness to reality render the image easier to recognize and hence more Simple, or more detail-rich and thus more Complicated?

For the HOME icon, the same phenomenon applied and was demonstrated even more convincingly. In fact, every participant ranked the following two icons in the exact same positions.

Most Simple (Rank 1)   *Most Complicated (Rank 7)*

(From pixelgirlpresents.com)

Fig. 6. HOME icons with 100% ranking scores

No other visual stimuli achieved 100% consistency among all participants. Because this study included adults only, the question remains if this phenomenon applies to younger people (including children) as well. This is currently being researched [29].

Screen resolutions have advanced to the point where we can show even the smallest unit of information visualization (e.g. the icon) in photorealistic detail. Additionally, user interfaces can be designed to contain almost limitless amounts of visual information. As this amount of information visualization expands, the necessity to address the user's needs expands in parallel. Indeed, just because

we are able to design informational interfaces in very complicated ways, does not always mean that we should do so. Simple design is not just about removing elements and reducing visual density. We know from graphic design that fewer elements in a composition means that those elements gain greater visual weight and power. If/when simple design is appropriate for a GUI, it is necessary that the software developer be able to conscientiously manipulate those remaining elements and the relationships between them.

5.7 Summary

Computers were developed to make our lives easier, and in doing so, they are supposed to be easy to use. However, as computers become more intertwined with our lives, the range of their functionality expands, and the complexity in using them grows dramatically. This is especially true when developers are encouraged to pack more functionality into each system they construct. Often, visual designers are left out of the design process, which results in interfaces that make visual aesthetics an afterthought. This is unfortunate. Chatty et al highlighted the importance of working with graphic designers during software development, but acknowledged that it is not always a viable option. This is often due to economic considerations, scheduling conflicts, incompatible design processes, and even the inability of designers and developers to communicate with each other [6].

In some respects, this small, explorative analogue study revealed the obvious. People reacted consistently to one fundamental parameter of design: the amount of visual information in a composition. How visual elements interplay within a context is something that most people, including interface designers, assume is easy to do. It's not, which is why masters such as Armin Hofmann stand out above the rest of us. Therefore, it is all the more important that we develop a methodological system of analysis for determining the appropriate amount of visual information for each user interface we build. This requires targeted user testing to define the parameters at work in visual GUI design, which include Density, Colour, Gestalt Principles, Detail, and Photorealism. We understand the delicate interplay between these parameters ultimately results in the user's connection to the visual composition (either poster art or GUI) on an emotional level.

6   CONCLUSIONS AND FURTHER WORK

This small study attempted to learn more about the relationship between the amount of visual information in a 2D composition and the viewer's evaluation of that composition. We have drawn inspiration from the field of graphic design, particularly 2D poster art to identify and systematically analyze the parameters involved in how people perceive various amounts of information. We attempted to identify and analyze some of the fundamental visual parameters underlying people's reactions to 2D visual compositions. We did this for the purpose of relaying that knowledge to another media: the design of onscreen visual information in its contextual graphical user interface (GUI). It is our hope that software developers study and adopt these parameters to design innovative products that are based in deep understanding of how people respond to visual

information, regardless of media. The design principles present in Armin Hofmann's posters are as relevant for GUI design as they are for all visual compositions. By comparing simple and complicated visual stimuli in 2D poster- and GUI design, we hope to help software designers utilize them appropriately, conscientiously and intentionally.

This study demonstrated that people are sensitive to design aspects of visual communication and when asked to evaluate them, often (but not always) do so similarly. In addition, this study showed that principles of visual composition are applicable and appropriate across various types of media [15, 19]. The weakness of the study is the methodology's inability to capture, measure and identify fine details of interpretation. For that, physiological data gathering techniques such as eye trackers and scanning techniques may give further insight into neurological phenomena. Human perception is a difficult field to measure, particularly when user's interpretation is involved.

Future studies will delve into the relationship between photorealistic imagery and its rate of understanding. This will involve a more intricate and consistent scaling/measuring system. It is also imperative to use native media—the user-interface information must be presented in its appropriate context (i.e. a computer user-interface).

GUI design employs the same visual principles that have been manipulated by all artistic masters, including the renowned graphic designer Armin Hofmann. Comparing art with GUI design allows us to apply the foundational concepts from one media to another. We hope that in coming closer to identifying the underlying visual parameters common to all visual compositions, we can encourage developers to employ them confidently in the earliest stages of GUI development. Regardless, the value of research in design can only benefit the field and shed light on principles at work across various media. We compel designers in every field to understand how their works are being viewed and experienced and remembered. Perhaps most importantly, the designer needs not ask if the design is 'good' (or not), 'simple' (or not), but whether the design will be experienced as s/he intended.

7   REFERENCES

[1]   Apple Computer. Macintosh Human Interface Guidelines. Addison-Wesley, 1992.
[2]   Bennett, K. B., & Flach, J. M. (1992). Graphical displays: Implications for divided attention, focused attention, and problem solving. Human Factors: The Journal of the Human Factors and Ergonomics Society, 34(5), 513-533.
[3]   Card, Stuart K. and Thomas P. Moran, Allen Newell. The Psychology of Human-Computer Interaction. Lawrence Erlbaum Associates, Inc., 1983.
[4]   Carrasco, M. (2011). Visual attention: The past 25 years. Vision research, 51(13), 1484-1525.
[5]   Chater, N. (1997). Simplicity and the mind. The Psychologist, 10(11), 495-98.
[6]   Chatty, S. Sire, etc. Revisiting Visual Interface Programming: Creating GUI Tools for Designers and Programmers..Proceedings of the ACM UIST. ACM Press, October 2004. Pages 267-276.
[7]   Cheon, J., & Grant, M. M. (2009). Are pretty interfaces worth the time? The effects of user interface types on web-based instruction. *Journal of Interactive Learning Research,* 20(1), 5-33.
[8]   Corbetta, M., Miezin, F. M., Dobmeyer, S., Shulman, G. L., & Petersen, S. E. (1990). Attentional modulation of neural processing of shape, color, and velocity in humans. *Science*, 248(4962), 1556-1559.

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[9]   Dreyfus, Henry. Symbol Sourcebook: An Authoritative Guide to International Graphic Symbols. Wiley, 1984.
[10] Huang, W., Eades, P., & Hong, S. H. (2009). Measuring effectiveness of graph visualizations: A cognitive load perspective. Information Visualization, 8(3), 139-152.
[11] Hofmann, Armin. Graphic Design Manual, Principles and Practice. Van Nostrand Reinhold, 1965.
[12] Hollender, N., Hofmann, C., Deneke, M., & Schmitz, B. (2010). Integrating cognitive load theory and concepts of human–computer interaction. Computers in Human Behavior, 26(6), 1278-1288.
[13] Isaacs, Ellen and Alan Walendowski. Designing From Both Sides of the Screen. New Riders Publishing, 2002.
[14] Itten, Johannes. The Art of Color. John Wiley & Sons, 1961.
[15] Maeda, John. URL: http://lawsofsimplicity.com/ (per March 2014)
[16] Marcus, Aaron. Graphic Design for Electronic Documents and User Interfaces. ACM Press, 1992.
[17] Marcus, Aaron. Globalization of User-Interface Design for the Web. Proceedings. Conference on Human Factors and the Web (#5), June 3 1999.
[18] Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological review, 63(2), 81.
[19] Mullett, Kevin and D. Sano. Designing Visual Interfaces. Prentice Hall, 1995.
[20] Nielsen, Jakob. Designing Web Usability. New Rider Publishing, 2000.
[21] Nielsen, J. (1993). Iterative user-interface design. Computer, 26(11), 32-41.
[22] Nielsen, Jakob & Marie Tahir. 50 Homeages Deconstructed. New Riders Publishing, 2002.
[23] Petterson, Rune. Information Design — An Introduction. John Benjamins Publishing Co., 2002-
[24] Plaue, C., Miller, T., & Stasko, J. (2004, May). Is a picture worth a thousand words?: an evaluation of information awareness displays. In Proceedings of Graphics interface 2004 (pp. 117-126). Canadian Human-Computer Communications Society.
[25] Pretorius, A. J., & Van Wijk, J. J. (2009). What does the user want to see? What do the data want to be?. Information Visualization, 8(3), 153-166.
[26] Resnick, Elizabeth. Design for Communication. Wiley, 2003.
[27] Schneiderman, Ben. Designing the User-Interface — Strategies for Effective Human-Computer Interaction. Addison Wesley Longman Inc., 1998.
[28] Skogen, M. G. (2006, July). An investigation into the subjective experience of icons: a pilot study. In Information Visualization, 2006. IV 2006. Tenth International Conference on (pp. 368-373). IEEE.
[29] Skogen, Martha. Simple Design…for Whom? User Tests Reveal Age Differences in Interpretation of GUI Icons (to be submitted for publication March-April 2015).
[30] Thiel. Philip. Visual Awareness and Design. University of Washington Press. 1981.
[31] Treue, S. (2003). Visual attention: the where, what, how and why of saliency. Current opinion in neurobiology, 13(4), 428-432.
[32] Tufte, E. Envisioning Information. Graphics Press. 1990.
[33] Tufte, E. R., & Graves-Morris, P. R. (1983). The visual display of quantitative information (Vol. 2). Cheshire, CT: Graphics press.
[34] Van Orden, K. F., Limbert, W., Makeig, S., & Jung, T. P. (2001). Eye activity correlates of workload during a visuospatial memory task. Human Factors: The Journal of the Human Factors and Ergonomics Society, 43(1), 111-121.
[35] Ware, C. (2012). Information visualization: perception for design. Elsevier.
[36] White, Alex W. The Elements of Graphic Design. Allworth Press, 2002.
[37] Wong, Wucius. Principles of Two-Dimensional Design. John Wiley & Sons, 1972.
[38] http://www.iamcal.com/toys/colors/stats.php (per Feb. 2015)

Paper 7

OBJECTIVE:

Large investigation into GUI icons in different user scenarios

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Author: Martha Skogen

Full title: An Investigation into the Subjective Experience of GUI Icons:
                    Age Differences Revealed

Submitted: To be submitted

AN INVESTIGATION INTO THE SUBJECTIVE EXPERIENCE OF GUI ICONS: AGE DIFFERENCES REVEALED

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ABSTRACT

This article describes a multi-phase, exploratory research project (n=833) that continues a previous investigation into how participants rank graphical user interface (GUI) icons on a scale from 'Simple' to 'Complicated'. After qualitative and quantitative analysis, results demonstrated that Youths (aged ≤13) ranked some icons differently than Adults (aged >13). Adults consistently ranked detail-scant 'archetypal' icons as 'Simple' whereas for Youths, this was not always the case.

Findings reveal a potential window of transition during which people adjust their interpretation of minimalized amounts of information ('visual archetypes'). Results suggest that as people mature and gain experience, they learn to interpret and understand visual representations that adopt reduced, abstracted information. This article is appropriate for professionals who help children interact with computers as well as those who design for applications that rely on GUI understanding, e.g., smart devices. Educators, developers and designers should consider that users may interpret minimized GUI icons differently than intended based on their age.

1

INTRODUCTION

The computerized desktop metaphor was envisioned in the 1930's (Jansen, 1998) and icons have been an integral part of the graphical user interface (GUI) experience since the mid-1970's (Reimer, 2005). Currently, the computer screen is bursting with enormous amounts of detail-rich visual information in which GUI icons function as highly essential forms of communication. The use of visual iconography is increasing in this era of international trade and expanding multiculturalism (e.g. Marcus & Gould, 2000; Pappachan & Ziefle, 2008; Piamonte, Abeysekera, & Ohlsson, 2001), and it is imperative that all aspects of their use be understood. Despite the widespread use of visual icons, they are far more diverse and complicated than normally realized (Familant & Detweiler, 1993), and it is essential for system designers to know what makes them easy to use and interpret (McDougall, de Bruijn, & Curry, 2000).

Graphic design teaches us that being small does not compromise a GUI icons' visual design, rather, the icons' small size *enhances* the importance of the compositional elements—internally within its compositional design as well as contextually. Although much has been written about icons' visual design (e.g. performance, meaning, comprehensibility, etc.), the literature lacks insight into how individuals develop an understanding of GUI icons from childhood to adulthood. This research is a step towards filling that void. The author has conducted an ongoing research project that investigates how people interpret 'simple' vs. 'complicated' design. The broader research motivation working underneath the three studies described here investigates simplicity as an aesthetic approach in GUI design and asks the question: What constitutes "simple" vs. "complicated" GUI icon design? Previous research was conducted with adult participants who demonstrated significant consistency in ranking a set of identical GUI icons based on their own interpretation of the terms *Simple* and *Complicated* (Skogen, 2006; Skogen & Hoem, 2015). The aim of the study described here expanded upon earlier research in three ways:

  i) moving the pilot test to its native format, the computer,
  ii) gathering responses from a greater range of participants in terms of age, contexts and experiences, and
  iii) determining if the responses revealed any observable patterns.

This article examines two questions: 1) Do users of various ages interpret the terms *Simple* and *Complicated* similarly with GUI icons as a stimulus, and 2) Do patterns arise from their responses? The tests described here were conducted over a number of years, and used three different testing contexts. The first tests took place in a formal, laboratory user setting (Study I), which prompted the researcher to investigate a larger youth audience through testing conducted on-site in schools (Study II). This led to a follow-up study based on crowdsourced, web-based research via the internet (Study III). The research involved children directly because researchers have realized that the opinions, attitudes and behavior of children should be surveyed and collected directly from children themselves (Borgers, De Leeuw & Hox, 2000). Punch (2002) suggests that children's accounts are considered valid because they originate from children's unique perspectives regarding how they see the world.

In our information technology (IT) culture, it is important to investigate how users in all age groups interpret visual stimuli, including GUI icons. Beginning with a presumption that people of all ages interpret visual stimuli similarly may create unintentional confusion for

certain audiences. By comparing responses from youths and adults, it is possible to observe how diverse populations interpret identical computer-based visual stimuli. These observations can help educators, developers and designers gain insight into foundational visual parameters that are commonly used in GUI icon design. By understanding how different age groups interpret identical GUI icons, educators are better equipped to assist their students while education embraces more types of computer-based learning. Additionally, designers can use the information to design icons for optimal communication with their intended audience.

BACKGROUND

Icons

As computer tools increasingly penetrate our daily lives in all realms (e.g. school, office and home), it is necessary for educators, developers and designers to understand how users interpret and respond to computer-based information. This is particularly true for children whose exposure to computers in schools has created a surge—and a need—for research regarding the impact of IT in education (Collis, 2013). GUI icons are an essential aspect. According to Bennett & Flach (2011), GUI icons are: i) small, often-static visual metaphors that represent various objects or actions in a domain, and ii) initiate actions and can range visually from pictorial to abstract. This definition of a GUI icon forms the basis for the research described here.

Well-designed icons and symbols have the ability to convey large amounts of information at a glance, even to those who cannot read or have vision problems (Wolff & Wogalter, 1998). Icons are important tools to assist users' performance when using software tools, and people's interactions depend on how they perceive, interpret, absorb and understand icons (Kunnath, Cornell, Kysilka, & Witta, 2007). Because icons are condensed, symbolic representations that communicate message and meaning, it is imperative that they can be interpreted quickly and effectively by viewers of all age groups and abilities. Lin & Kreifeldt (1992) found that an icon's quality and effectivity depends on its design, which cannot be improved in post-design evaluations. This means that attention needs to be given to helping designers develop icons that meet design requirements initially. Lin (1994) identifies three visual features of an object—its shape, image and function—in order to help designers choose the correct visual approach early in the design process.

GUI icons come with challenges as Rogers (1989) describes: "on some occasions it is relatively easy to interpret the intended meaning of an icon, for others a whole range of different meanings can be attributed to a single icon—each being as valid as the other" (p. 106). For Rogers, the interpretation of ambiguous symbols can be narrowed by the symbols' context coupled with the viewers' experience. When converting 3D objects to a 2D representation of that object, the representation is always somewhat stylized because no 2D visual representation can fully mimic the object itself. According to Kurniawan (2002), an icon's "distinctiveness" can be subdivided into two aspects: i) physical distinctiveness—recognizing the object that the icon communicates, and ii) perceptual distinctiveness—understanding the object that the icon represents. Only when these two aspects are sufficiently aligned can the icon be considered 'successful'. In helping visual designers construct successful icons, DeLoache, Uttal, & Pierroutsakos (1998) have discovered many

areas in which children from infant to school ages can misunderstand symbols and how they relate to their referents.

Icon Archetype

Despite the vast amount of literature dedicated to GUI computer icons, there is little focus on how people's interpretation of icons develops and/or changes from an early age. The dictionary defines 'archetype' as an original pattern or model from which all things of the same kind are copied or on which they are based (Random House©, 2015). Lin (2003) used the term "archetype" to refer to the symbols and images that have potentially unlimited communicable power and are common to all individuals.

The studies described here were influenced by Winkielman, Halberstadt, Fazendeiro, & Catty's three-phase ranking study from 2006. They found that people's fluency (i.e. speed and efficiency of cognitive processing) in interpreting visual stimuli is linked to a preference for "prototypical" visual stimuli. Further, Schröder & Ziefle (2008) categorized the results of studies with icons on mobile devices according to 'stereotypicality' (high & low). The terms "stereotype" and "prototype" are used seemingly interchangeably in the literature. In this research, 'visual archetype' is preferred as it accentuates using the least amount of necessary visual form (with no extraneous detail) required to render an icon 'successful' for the majority of the intended user population. In their examples, Schröder & Ziefle (2008) come closest to describing this researcher's concept of 'archetypality'.

Classification and Categorization

Gatsou, Politis, & Zevgolis (2011) devised a succinct classification of types (i.e. stylistic categories) that progress from pictographic and/or "concrete" representations to abstracted/minimalized designs. Concreteness refers to the degree to which the icon visual represents its referent, as defined by McDougall et al. (2000). Gatsou et al. describe how concrete-to-abstract icons affect user performance as well as how user interpretation becomes easier as the representation becomes more 'schematic' or diagrammatic. Some researchers have found that participants identified concrete icons better over abstract icons (García, Badre, & Stasko, 1994; McDougall & Isherwood, 2009). This research and the terms used herein are based upon Gatsou et al.'s terminology as illustrated in Table 1.

Table 1. Gatsou et al.'s (2011) classification of icons (adapted from Nadin).

Further, Wang, Hung, & Liao (2007) describe nine taxonomic systems and how the current terminologies correspond and overlap. Lin & Kreifeldt (1992) present an overview of

the research according to various researchers and three types of icon design style: representational, abstract, and arbitrary. It is important to note that studies on taxonomy and/or categorization of icons omit a fundamental aspect of design consideration: the age of the viewer.

Children/Youths Often Overlooked

There is ample research regarding GUI icons, yet with few exceptions, the GUI icon research community has overlooked an important user group: children/youths. With children/youths' computer experience continuously on the rise (Rocheleau, 1995), children are growing up immersed in technology that was unavailable to young people in earlier generations (Markopoulos, Read, Hoÿsniemi, & MacFarlane, 2008). This younger age sector represents a growing participant group (Chiasson & Gutwin, 2005) whose needs should be addressed (Druin, 1999). Chiasson & Gutwin (2005) demonstrate full appreciation that children are a unique user group with unique needs and goals—they are not just miniature adults. Guidelines for interface design are not difficult to find, but they typically address adult rather than juvenile users (Large & Beheshti, 2005). Markopoulos & Bekker (2003) observe that research into the age-specific interaction styles (e.g. how to structure menus, the size of the on-screen objects, fonts etc.) is very sparse. Even less frequent is the study of how children's interpretation of GUI icons can change as they age.

There are some exceptions. Philleo (1993) studied graphics on buttons and hotspots in HyperCard® media with middle school children (ages 11-13), but the research created numerous unanswered questions. Zammit (2000) studied 11-12 year olds' responses to text vs. pictorial icons and found that not all pictorial icons are easy to interpret—sometimes a text-based icon serves better. If pictorial icons are seen over multiple contexts, their interpretation rate increases. However, among her age group and small sample size, the difficult-to-understand icons included those that were highly abstracted, seen only in the context of the test itself, and very realistic, pictorial icons that did not represent the content or pathway. As demonstrated in Figure 1, Huang, Shieh, and Chi (2002) describe how children might interpret icons by suggesting, "children may prefer the left arrow to the right, although the right arrow is simpler than the left" (p. 217). They go no deeper into either the stylistic or interpretive aspects of this assertion.
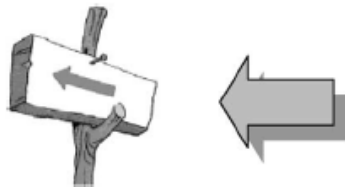
Figure 1. Children may prefer the left arrow according to Huang *et al*., 2002

Nesset & Large (2004) provide an extensive review of children in the technology design process, and note that the users, whether adult or child, are only involved *after* the technology has been designed (Nesset & Large, 2004). This is not ideal. In attempting to fill the need for guidelines, Chiu, Koong, & Fan (2012) suggest three icon design principles: the principle of

obvious visibility, the principle of visual resemblance, and the principle of conceptual resemblance in order to improve young children's interpretation. Druin (1999) found that involving children at different stages of software development brought significant benefits, including taking inspiration from their design ideas. Importantly, Druin found that children's inputs helped to differentiate between what the researchers thought was 'good' and what the children found to be effective and motivating.

These studies highlight various aspects of children's growth stages when conducting research with them, particularly when comparing their responses with adults'. This is important when researchers study children to discover how they are different from adults (Scott, 1997 via Borgers et al. (2000). Jean Piaget's (1969) theory of the developmental stages of children provides a framework for understanding how children might respond to visual stimuli. Piaget's stages include: I. Sensory-motor intelligence (age 0-2), II. Preconceptual Thought (age 2-4), III. Intuitive Thought (age 4-7/8), IV. Concrete Operations (age 8-11), V. Formal Thought (age 11-15/16) (Piaget, 1959, 1969). After age 16, children are considered fully developed with regard to cognitive capacity (Borgers et al., 2000). These stages should be regarded as a gradient based upon individual factors including ability, heredity, education, socio-environmental factors and history. Hourcade's (2008) extensive review of interaction design with children highlights (and critiques) the Piagetian stages of development. For this research, Piaget's stages served as a starting point for interpretation of data described later in the paper.

The Simple-Complicated Visual Parameter in GUI Icons

McDougall et al. (2000) describe how users are able to classify an icon's distinctiveness into ten categories, including *simplicity* and *complexity*. According to Jones (1983), successful, creative solutions are sometimes effective due to their ability to simplify what appears complex to a larger population. Byrne (1993) compared simple and complex icons with 45 adults and found that simple icons outperformed complex ones, particularly with larger set sizes. Icons were even more efficient when they were unique and easily discriminable.

Karvonen (2000) found that clarity or 'clean design' and 'visual pleasantness' can be associated with valid emotional states, e.g. 'simple' design conveys a sense of trust. Forsythe (2009) found that the amount of detail or intricacy within an icon influences the rate at which an icon is detected. Specifically, very simple and/or abstract icons are detected faster than those in the mid-range. Ferreira, Noble, & Biddle (2006) found that when computer icons graphically resemble their underlying functionality, participants are better able to recognize them. McDougall S., Reppa, Smith, & Playfoot (2009) linked aesthetic appeal with usability and found that simplicity/complexity directly affected user performance in search tasks. In her studies on complexity and familiarity, Forsythe calls for an exploration into our understanding of what is perceived as complex or simple (Forsythe, 2009).

For the studies described in this article, the term *simplicity* utilizes Hochberg & McAlister's (1953) principle regarding a given stimulus: "the less the amount of information needed to define a given organization as compared to the other alternatives, the more likely that the figure will be so perceived" (p. 361). The research uses *complicated* over *complexity* because while *complexity* describes the state of the world, *complicated* refers to the state of the mind and can also include *confusing* (Norman, 2011). This article uses the terms *Detail-scant* and *Detail-rich* to describe the continuum from Simple to Complicated.

RESEARCH DESIGN

This section describes the fundamental aspects of the user test that were common for all three studies reported in this article. It concludes with a description of the tool (Icon Comparison Chart, or *ICC*) used as the basis for quantitative analysis of all of the data. Qualitative measures (see Appendix C) are discussed in this paper to supplement the quantitative data.

The Icons in the User Test

In total, 80 GUI icons were included in the user test; eight icons, in each of ten categories, see Table 2. The icons were used in previous research (Skogen, 2006). All were selected from free, arbitrary online image sources based on multiple visual parameters or characteristics in their composition. Table 2 presents the GUI icons in organized in a progression from Detail-scant to Detail-rich for the reader only—this is not how the users experienced the test.

Table 2. All icons presented in the user test. This table is for ease of the reader's overview.

Category										
	Search	Edit	Docu-ment	Mouse	Mail	Home	Print	Book	Trash	PC
Detail-scant										
Detail-rich										

In Table 2, each descending row presents an increase in the icons' richness of detail. Detail-scant icons showing few 'visual parameters' (Skogen, 2006) are located towards the top whereas the icons become more Detail-rich towards the bottom. The icons in the top row for Search and Edit are designed by the researcher because it was not possible to find icons with a sufficiently minimum level of detail for the desired themes.

The Computer-Based User Test

Participants in the user test were asked to rank icons on an 8-point scale from *Simple* to *Complicated* (see Figure 2). The ranking scale was designed to show 1 as the most simple, progressing up to 8 for the most complicated. Ranking methodology for this (and previous)

research was inspired by Winkielman et al.'s study (2006) combined with Pedell's (1996) assertion that ranking studies may be valuable to reflect users opinions.

While previous studies used analogue tools (Skogen 2006, Skogen & Hoem, 2015), the three studies described here used a custom-made, computerized user test that was based upon a single-axis ranking scale. The test could be accessed from any computer with an internet connection. Children and adults took the same test such that it was possible to make direct comparisons between responses from all participants. This research proceeded on the premise that children are competent social actors (Morrow, 1998, Punch, 2002) whose interpretations of GUI icon design are worthy of observation. The user test included an introductory instructional text so that each participant received the same written instructions. Participants' anonymity was protected and their responses were used for this research only.
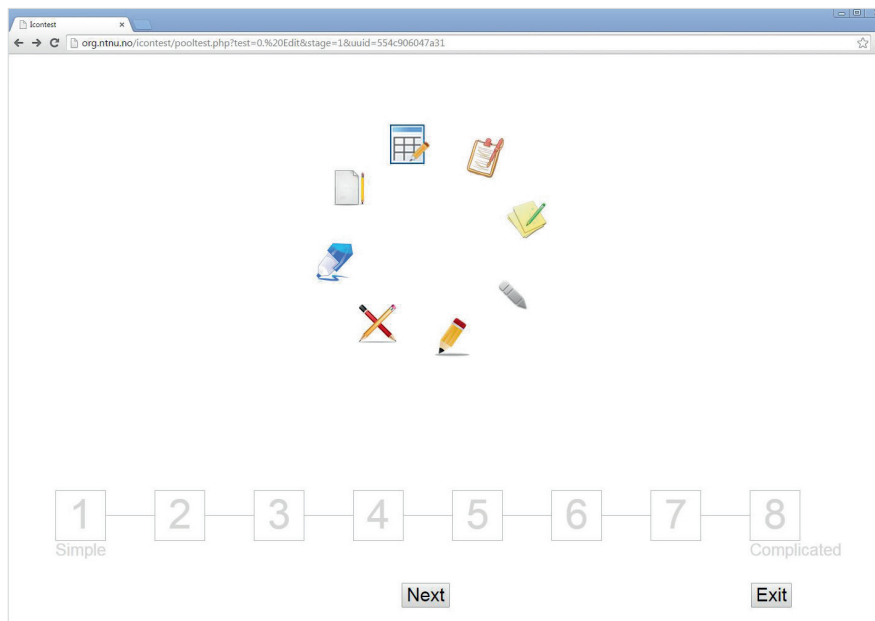
Figure 2. "Edit" screenshot from the computer-based user test showing how the participants viewed the icons.

In the user test, participants were presented with ten sets of icons, organized by theme (e.g. eight versions of the Edit icon only). After the participant ranked the icons by dragging and dropping one-icon-per-box on the 8-point ranking scale, they pressed 'next', whereupon eight icons for the following category appeared. This testing strategy continued for all 10 sets of icons, or until the user chose to Exit. The icons' categories were ordered as: Search, Edit, Document, Mouse, Mail, Home, Print, Book, Trash, PC. To avoid potential bias due to an icon's placement in the circle, the computer randomly repositioned the icons in the circle upon each reload. This meant that each participant viewed the icons in a random position, yet always in a circular format. The user test was seen using conventional internet browsers

including Chrome®, Firefox® and Explorer®. Once the user progressed to the next category, they were not able to go back to any previous category.

Upon completion of the final icon category, each participant was presented with a short computerized questionnaire to collect their age, gender, amount of computer usage per day, and number of years they had used a computer. A comment field was provided for limited written input. All participants in Study I completed the questionnaire, 90% completed it for Study II, and approximately 70% completed it for Study III. When it was possible post-test, the researcher asked participants to verbally describe the criteria they used while ranking the GUI icons, and these qualitative results can be found in another article (Skogen, 2014). All participants were instructed to take the test one time only.

Data Analysis

All data was controlled for quality and completeness. 100% of Study I responses were included for Study I whereas approximately 95% of the responses were included for Studies II and III. Data were removed permanently if input lines were: i) incomplete (i.e. did not have answers for all icon categories), ii) lacked the age of user, and/or iii) revealed irrelevant, identifying or personal information that might compromise the user's complete anonymity.

Age Division

For this research, Piaget's developmental stages provide insight into how children might interpret GUI icons. In *Psychology of Intelligence* (1959), Piaget specifies that children aged 11-12 are capable of reflective thought and reasoning. For Study I, Piagetian stages were used to suggest age grouping. Despite the small sampling of young people in Study I, the data hinted there were observable differences in the responses with regard to Piaget's stages. Hence, age 13 was selected to differentiate Youths from Adults. This also may be attributed to the absence of participants in the 14-16 age range. Studies II & III were conducted in order to investigate the unforeseen phenomenon further.

To ease data analysis, preliminary visual charts were constructed (see Figs. 3-4), where the data was split into Adults >13, Youths ≤13 for comparison on the Icon Comparison Chart. In this way, the age split reflected Piaget's organizational stages combined with indications from the collected data based upon age. The differentiation in responses between Youths and Adults becomes clearer in Study II data (See Appendix A).

The Icon Comparison Chart ('ICC')

Statistical analyses (Mann-Whitney, or 'MWW') were performed for each of the three data sets. Mann-Whitney is a nonparametric statistical analysis that determines whether the distributions of two groups differ. In order to aid comparison and allow for quick overview of the data, the researcher devised a color-coded table that showed all the numerical MWW results for each icon simultaneously. This table, the Icon Comparison Chart ('ICC', see Table 3 for partial example), contains a dense amount of information for each icon including:

- Icon in its category, in order from Detail-scant to Detail-rich
  (as interpreted by the researcher)
- Correct sequencing of icon categories as presented in the user test (1-10)
- 'Archetypal' icon, positioned first and highlighted by light grey background
- Study I, II, III grouped into row sections, with age divisions and
  number of participants (n)
- Color-coded main MWW numerical results (i.e. p-value), per icon, per study
- Median placements for each icon, in grey text designated per age group
- Median gap scores, in black italicized text (only when the score was ≥2)

The p-value forms the main MWW numerical result, and all p-values were color-coded to indicate each icon's level of significant difference between the two age groups: participants aged ≤13 (Youths) and >13 (Adults). See Appendix B for the complete ICC for all GUI icons according to their categories.

After Study I, null and alternative hypotheses were devised for Studies II & III. The null hypothesis (H0) states that there is no difference in the distributions between the two age groups, whereas the alternative hypothesis (H1) states that there is a difference between their distributions. For the analysis of the entire data set, the significance level was set to p=0.05. Hence a p-value less than or equal to 0.05 (i.e. p≤.05) demonstrates a significant difference in response between the two age groups. Table 3 shows only two categories of the ICC, Home and Print. The median placement represents the ranking box for which half of the participants ranked the icon above—and half ranked below. The median placement numbers were useful particularly when there was a large difference ('median gap') between the two groups.

The ICC became invaluable for all types of comparitive analysis. Most importantly, it revealed clear patterns in the response sets. In the ICC, numbers that are color-coded green indicate a significant difference in responses between Youths and Adults (p≤.05). Yellow indicates a slight score over p≤.05 for marginal non-significance, and red indicates non-significance between the two age groups. If the icon is coded green (dark or light), the participants ranked it on the scale relatively consistently amongst their own age group, and significantly different from the other age group. If the icon shows a yellow or red coding, the users ranked them somewhat randomly on the scale and not significantly different from the other age group. When viewing the coding for all three data sets comparatively, patterns become noticeable. Responses for each data set will be discussed in detail below.

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Table 3. Example of the Icon Comparison Chart ('ICC'). Home & Print categories are shown only.

			Home (6)								Print (7)							
		Icon:																
Study I:	*n=*	*p =*	.0022	.0404	.0617	.8153	.6591	.4517	.0313	.0240	.0274	.0486	.0582	.0917	.0693	1.000	.0457	.1462
Age ≤13	11	*median:*	6	3	3	4	4	6	5	4	6	5	6	4	4	5	2	4
>13	15	*median:*	1	2	5	4	5	4	7	8	1	3	3	5	6	6	7	6
total	26	*gap:*	*5*		*2*			*2*	*2*	*4*	*5*	*2*	*3*		*2*		*5*	*2*
Study II:		*p =*	.0000	.0000	.0002	.2187	.5462	.0008	.1323	.0000	.0034	.0012	.6043	.7627	.0002	.8796	.2053	.1475
≤13	242	*median:*	5	5	3	5	4	4	7	5	6	6	6	3	3	5	4	4
>13	61	*median:*	1	2	4	5	4	5	7	7	3	3	6	4	6	4.5	4	5
total	303	*gap:*	*4*	*3*						*2*	*3*	*3*			*3*			
Study III:		*p =*	.0075	.0019	.0096	.2242	.5129	.3579	.3492	.0014	.4230	.1536	.3492	.5037	.1033	.5847	.1946	.1734
≤13	20	*median:*	2	3	3	5	4	5	7	5.5	5.5	6	5.5	4	4	5	4	4
>13	484	*median:*	1	2	4	5	4	5	7	7	4	3	4	4	5	5	5	5
total	504	*Gap:*											*3*					

key:		
	.0000	significant difference between the two age groups
	.0001 - .0499	approaching significant difference "
	.0500 - .0999	marginal non-significant difference "
	.1000 - .9999	non-significant difference "
	1.000	non-significant outlier " (one occurrence only)

Limitations of Studies I, II, & III

Few participants aged 10-13 completed the user test in Studies I and III. Additionally, few senior users (60+) participated in Studies I and III. It would be interesting to gain insight into seniors' interpretations compared to midlife and younger users, but there were not many participants in that age group.

The 'www' data (Study III) inherently lacks experimental control—a known disadvantage with crowd-sourced data (e.g. Reips, 2000; Schmidt, 1997; Wright, 2005). Other disadvantages include uncertainty of validity of the data and sampling issues, i.e. the inclusion of users who had access to a computer as well as those who understood how to use one (Wright, 2005). Finally, it was not possible for the researcher to determine if there were repeat participants in the crowd-sourced data.

STUDY I

Method

Participants

26 participants total (aged 5-59). Ages: ≤ 13 n=11, >13 n=15

Table 4. Participants in Study I.

Age	n=	Male	Female
5-11	7	2	5
12-13	4	4	0
14-16	0	0	0
17	2	2	0
18-39	0	0	0
40-49	8	5	3
50-59	5	2	3

Table 4 shows the breakdown for participants in Study I. Recruitment occurred by invitation and word-of-mouth. Participants granted consent verbally for themselves and their children onsite. The youngest participant (age 5) had no regular computer usage and little experience, yet his understanding of how to successfully operate the mouse was intact after approximately one minute of practice. Young children are capable of using a computer mouse and able to click precisely on small objects, especially when they are presented within a context of other objects (Donker & Reitsma, 2007). In general, as the age of the participant increased, so did his/her computer usage and history.

For computer usage, the following averages apply: ≤ 13 year olds used a computer 0-2 hours per day and had been using a computer since age 6. Older adults used 5+ hours per day and had been a computer user for an average of 15 years. For those who responded, most had been computer users from the age of 6 (first grade).

Procedure

The methodology for Study I was the most controlled of all three data sets. The user test was conducted at a highly equipped, professional, dedicated computer laboratory in St. Olav's Hospital in Trondheim, Norway. The participants visited the laboratory and took the test individually. Each participant sat comfortably with a modern Windows®-based PC with mouse. The test room was airy, uncluttered, quiet, well lit, and furnished to resemble a basic home environment. In this scenario, the researcher was present and seated discreetly near the participant at all times. Her note-taking behavior provided a non-disturbing, supportive presence while being available for assistance (rarely needed).

Preliminary Results of Study I—Initial Test at St. Olav's

When glancing at Figure 3 (Adults), the icons appear to progress from detail-scant (*Simple*) on the left to the detail-rich (*Complicated*) on the right side of the chart. The icons deemed by the Adults to be *Complicated* tend to show detail-rich, colored, shaded, abstracted references that incorporate multiple metaphors. Adults (> 13) consistently ranked icons with minimal details as *Simple* whereas they ranked detail-rich icons with numerous visual parameters as

Complicated. One example is "PC": every Adult agreed that this icon: was the most complicated of the entire user test.
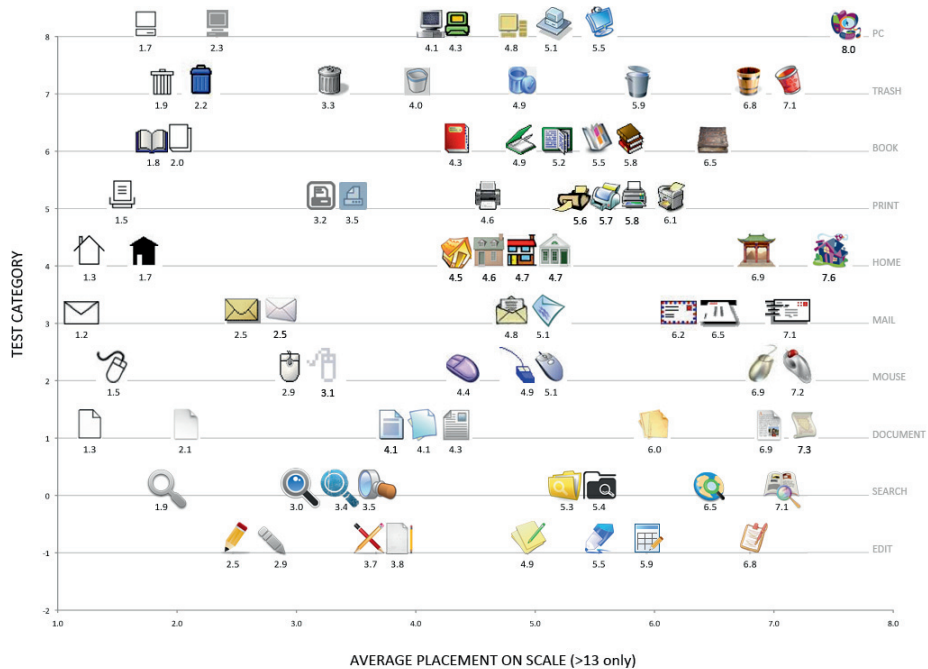
Figure 3. Averaged responses per icon for Study I — **Adults Only (n=16).**

At a glance, the chart in Figure 4 (Youths) is quite different from the Adults' chart. To some, this might indicate a lack of task comprehension in the Youth age group. However, such an inference projects an unfortunate presumption onto younger participants in that the Youths' responses were different because they did not understand the task. During the user test, the Youths (including the youngest children) gave no indication whatsoever that they might have misunderstood the task.

The icons are clustered centrally on the chart in Figure 4 indicating that the Youths responded less consistently than the Adults. This means that participants in this age group agreed less amongst themselves regarding how the icons should be ranked. In the Youths' chart, no distinct design style immediately stands out, and the archetypes are spread

throughout the scale unlike their adherence to the left side in the Adults' (Fig. 3) chart. The researcher noted that the youngest children spent considerable time trying to discern what some of the archetypal icons represented, often by leaning into the screen for closer inspection, saving them for last, and/or taking considerably longer to rank them. These behaviors suggest that those particular icons' meaning was not understandable or interpreted quickly. Alternatively, the detail-rich icons with numerous visual parameters (e.g. color, detail, stylization) appeared to help the Youths' understanding—even if the meaning was relatively unfamiliar (e.g. Edit).
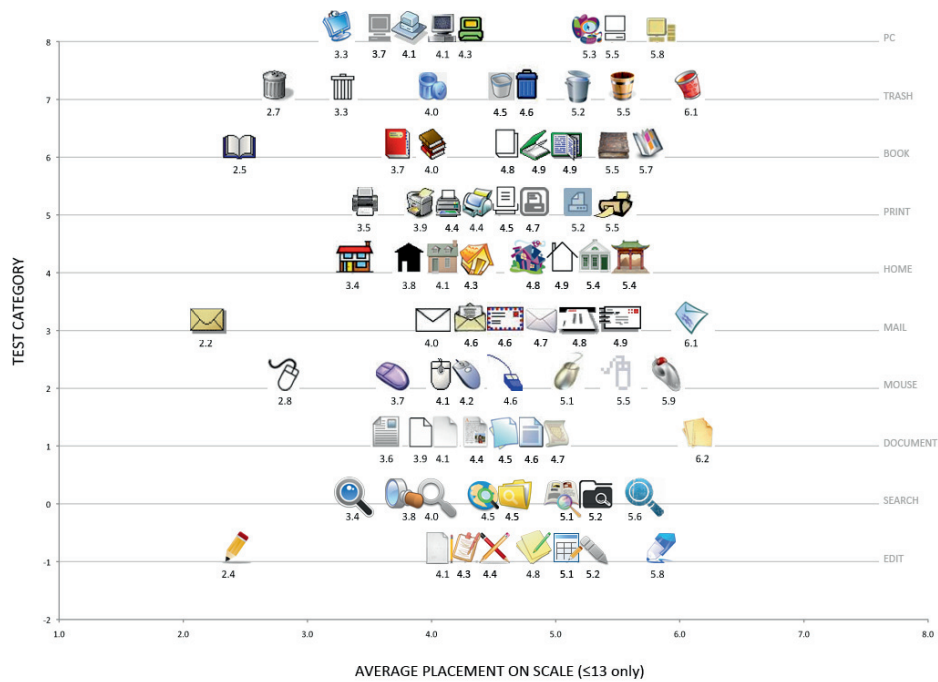
Figure 4. Averaged responses per icon for Study I — **Youths Only (n=10).**

The difference between the charts in Figures 3 & 4 motivated the researcher to gather more data from a broader range of participants (i.e. Studies II & III) and to analyze the data statistically rather than merely qualitatively. The intention was, if possible, to discover at which age the suggested change in interpretation occurred and to determine if the response sets (based upon age) were statistically different from each other.

Results & Discussion of 'ICC': Study I

Although this data set had the smallest number of participants (n=26), there was a wide range of ages represented. The variation in responses across the data set might reflect the diversity

of participants' experience, exposure and history of understanding of the GUI categories presented.

When viewing the ICC as a whole (Appendix B), the responses for Study I appear to alternate in color-coding more than the other data sets. Despite this mixing, there is a noticeable 'sandwich' pattern that appears: the red (non-significant) icons tend to reside in the middle of their respective categories whereas the significant icons (green) for that category tend to reside on the outer edges. Table 5 shows this pattern for the 'Home' category—it demonstrates that the two age groups responded differently to both the archetypal icons and the most detail-rich icons.

Table 5. Example of Color-coded 'sandwich' pattern in Study I (Home).

			Home							
		Icon:								
Study I:	n=	p=	.0022	.0404	.0617	.8153	.6591	.4517	.0313	.0240
Age ≤13	11	median:	6	3	3	4	4	6	5	4
>13	15	median:	1	2	5	4	5	4	7	8
total	26	gap:	5		2			2	2	4

This data set also included one anomaly; an icon with a MWW result of 1.000, (Print), which reflects the maximum difference for responses between the two age groups. In another example, the median placement for (Mouse) was in ranking scale box 2 (highly *Simple*) for Adults and 7 (highly *Complicated*) for Youths, resulting in a median gap of 5. This shows that Youths and Adults in Study I ranked this icon almost inversely from each other. The following icons also had a median gap of 5:

Edit: *Home:*   *Print:*   *PC:*

It is worthy of note that 3 out of 5 icons with a median gap of 5 were archetypal for their category. Additionally, Study I contains one icon that scored the maximum median gap of 6 (, Book archetype) across all responses. This means that for the Youths, the median placement for the icon was in ranking scale box 7 (close to most *Complicated*) whereas for Adults, the median placement for the icon was in ranking scale box 1 (most Simple). This median gap of 6 occurred one time only.

STUDY II

Method

Participants

302 participants total (aged 5-23). Ages: ≤13 n=238, >13 n=64

Table 6. Breakdown of participants in Study II.

Age	Grade	n=	Male	Female	ngs*
6	1	48	24	21	3
7	2	13	2	11	-
8	3	23	12	11	-
9	4	87	49	38	-
10	5	52	30	22	-
11	6	15	5	9	1
12	7	0	0	0	-
13	8	0	0	0	-
14	9	47	27	19	1
21-24	Univ.	17	7	10	-

*no gender specified

Table 6 shows the breakdown for participants in Study II. Recruitment occurred by pre-arranged visitation to schools. Consent was granted according to each school's protocol—each student's participation was 100% voluntary with no effect on their academic record. For computer usage, the following averages apply: Computer use (per day): ages 6-7: 0-1 hours, ages 8-9: 1-1.5 hours, ages 10+: 2 hours, ages 20+: 2-3 hours. For those who responded, most had been computer users from the age of 6 (first grade).

Procedure

The methodology for Study II was semi-controlled compared with the formal laboratory setting of Study I. The researcher visited a number of schools in the city of Trondheim, Norway that spanned a variety of learning approaches including International Baccalaureate, Norwegian standard, and Steiner educational systems. Whole classes participated (often in rotation) on their premises, using equipment provided by the school. Groups between 6-60 students participated simultaneously. In addition to the Youths aged ≤13, Study II also includes 17 university students (aged 21-24).

The researcher was present at all times with the students. For the younger students, the researcher translated the English instructions into Norwegian verbally to the group at large. This was done to save time as many participants were native Norwegian speakers—reading in English would have taken substantial amounts of time and effort, particularly for the youngest participants. For almost all of the school testing scenarios, the students' primary teacher, or another school representative, was present during the testing.

Results & Discussion of 'ICC': Study II

When the results from Study II were statistically analyzed using MWW, 46 out of 80 icons were ranked significantly differently, which was the highest for all three Studies.

When viewing the ICC as a whole (Appendix B), the responses for Study II are noticeably distinct when compared with Studies I & III. This data set showed the clearest 'sandwich' patterning. In addition, this study shows the most examples of this 'sandwiched' color-coded phenomenon shown in Table 7. Eight out of ten icon categories demonstrated the 'sandwich' pattern for Study II. Importantly, there are considerably more green icons strewn across the whole set of data.

Table 7. Example of Color-Coded 'Sandwich' Pattern in Study II (Search).

The data shows that respondents in the two age groups ranked the icons on the outer edges significantly differently from each other, whereas the two middle icons were not ranked significantly differently. Interestingly, Search category also included one icon that

participants often referred to as "the camera": . A number of participants wondered aloud why there "was a camera located with the other icons". Such comments reveal the degree to which users are sensitive to metaphorical representations and whether or not the metaphors match the user's criteria for that concept.

STUDY III

Method

Participants
504 participants total (aged 6-78). Ages: ≤ 13 n=21, >13 n=483

Table 8. Breakdown of Participants in Study III.

Age	n=	Male	Female	ngs*
6-11	13	7	6	-
12	6	3	3	-
13	2	0	2	-
14	20	12	8	-
15	0	0	0	-
16-19	16	11	5	-
20-29	137	67	70	-
30-39	130	41	88	1
40-49	92	37	54	1
50-78	88	36	51	1

* no gender specified

Table 8 shows the breakdown for participants in Study III. Recruitment occurred through distribution of the user test's public URL over social media. Consent was granted by virtue of the participant completing the online user test itself. For computer usage, the following averages apply: Computer use (per day): aged 6-11: 1 hour, ages 12-14: 2-2.5 hours, ages 16-19: 4.5 hours, ages 20-78: 5+ hours. Considering that most participants in this data set were aged 20+ and taking the test via the internet, it is not surprising that these measures were higher than for Studies I & II.

Procedure

Since the invitation to participate in Study III was distributed via social media/email with a publicly available URL link, anyone with a computer and an internet connection could access the user test for the duration of six weeks that it was available. The researcher was not present during this phase of data gathering and had no way of knowing who, where, or under what circumstances the participants were taking the test. The identical written instructions as for Study I and II were available upon accessing the user test.

Results & Discussion of 'ICC' : Study III

When the results from Study III were statistically analyzed using MWW, 16 out of 80 icons were ranked significantly differently between Youths and Adults. This was the smallest number of significant icons across all three studies.

When viewing the ICC as a whole (Appendix B), this large data set was visibly different when compared with Studies I & II—namely, it contained the fewest number of green (i.e. significant) responses across all icon categories. This means that the two age groups' median rankings were less distinct from each other than what was demonstrated by the participants from the two other studies.

Because the web-based methodology for this data set provided the least amount of research control, it is not possible to determine whether the dominance of red in the ICC was due to the methodology, or the test content. Reips (2000) calls this disadvantage 'lack of experimental control' and is typified by multiple submissions, self-selection and dropout. It is possible that multinational interpretations of the icons had an influence—this phenomenon must be tested further in a controlled, rigorous manner. For the purpose of drawing conclusions about the perception of the icons, global web-based experimentation may not be the most effective methodology due to its difficulty controlling for confounding factors (Schmidt, 1997; Reips, 2000; Wright, 2005). For this study, self-selection is reflected in a data set with statistical bias of middle-aged users. More instances of dropout occurred in this study compared with the others, shown by numerous incomplete answers in the data—approx. 5%, all were removed prior to data analysis.

For 3/10 of the categories (Mouse, Print and Book) in this data set, every icon was ranked non-significantly (red). Two more, Search and Edit, contained only one significant icon each. Only two categories in this data set somewhat reflected the 'sandwich' pattern.

Table 9. Example of color-coded 'sandwich' pattern in Study III (PC)

		PC							
	Icon:								
Study III:	p =	.9375	.0046	.9713	.6493	.4934	.1687	.0479	.0374

Table 9 shows that this 'sandwich' pattern for Study III is less clear-cut than in Studies I & II. This data set also includes one distinct icon: the leftmost icon (i.e. the archetype) for this category. For Studies I & II, the PC archetype icon was strongly significant (green), but in Study III, the MWW score was highly non-significant.

The Study III user test gathered data anonymously—there was no way for the researcher to determine where the participant was located when s/he took the user test. This was truly a global test—after data collection was complete, it was reported by a posting to have been shared via email to participants living on all seven continents.

USER COMMENTS

In the comment field at the conclusion of the user test, many participants took the opportunity to reflect upon how they felt about the user test, how they had judged the icons, and/or how they had interpreted the terms *Simple/Complicated*. Unfortunately, the input field was limited to 100 characters—this meant that many potentially insightful comments and descriptions were incomplete and thus rendered unusable. Table 10 shows a sampling of verbatim comments that were complete. Study II (Schools) reflected a far larger distribution of 6-14 year olds' comments, whereas the Study III was filled with almost exclusively adult comments. Male-female proportion was approximately 50-50 for both data sets.

Although the User Comment data set included many irrelevant inputs (hence removed), there were insightful comments regarding the broader research question of the study (i.e. What constitutes "simple" vs. "complicated" GUI icon design?). The responses from Study II and III are shown in Table 10 (some translated from Norwegian).

Table 10. Sampling of insightful user comments for Studies II & III only

	Age	M/F	Comment (sic)
	9	M	*For me, "simple" means it was easy to understand.*
Study II	10	F	*Complicated means for me that it was difficult.*
	10	M	*Simple is something we know how to do. Difficult means it is something I don't know how to do.*
(n= 157)	11	F	*To me, Simple means that the symbols look like reality.*
	11	F	*Simple is something I have done, seen or known before.*
302 commented	14	M	*I looked for what was most detailed. I put those that were 3D as Complicated and those with simple lines as Simple.*
	23	F	*Simple icons were those without so much nonsense around them. Preferably low use of color.*
	23	M	*Difficult to really get what was meant by Complicated vs. Simple.*

	23	F	*Some of the most simple icons were those that were difficult to immediately understand.*
Study III (n=110) 504 commented	8	F	*Simple to me means things with very little drawing strokes because they have very little things on them.*
	16	M	*Simple is better but too simple can be difficult to understand.*
	19	M	*Simple linear icons are clearer.*
	21	M	*Icons should only include the most necessary elements. Too many extra features can confuse.*
	22	M	*When the icons are complicated it tends to be because of too many colors and shapes mixed together.*
	39	F	*I tend to associate simplicity with modernity and complexity with antiquity.*
	54	M	*To be honest, they all confused me initially.*
	65	F	*I had no idea what some of these icons were.*

This sampling of user comments shows a range of diversity in how the terms 'Simple/Complicated' were interpreted. All interpretations of the terms were considered valid. For example, each term might refer to the icon's amount of visual detail, or its iconic/indexical/symbolic mapping to the concept (Gatsou et al., 2011). It is important to note that despite participants using individualized, unspecified interpretations of the main terms, data results showed clear patterns in how participants (of similar age groups) ranked the icons.

CONCLUSION AND FURTHER WORK

The data from this large study revealed a variety of discussion points regarding how Youths and Adults ranked GUI icons. Because this research was exploratory and patterns arose only during data analysis, implications drawn from the studies are intended to increase awareness and not to serve as formalized or definitive conclusions. Using a familiar adage, one image does not say the same thousand words to each viewer (Ferreira et al., 2006). This article reveals how GUI icons, contrary to what many designers may presume, are not 'one size fits all'. The three studies described in this article collectively showed that Adults' (>13) responses and Youths' (≤13) responses were sometimes contradictory. For example, Youths often ranked the following detail-rich icons as most "Simple":

Document: *Home:*   *Print:*   *PC:*

whereas Adults often ranked the following detail-scant icons as most "Simple":

Document: *Home:*   *Print:*   *PC:*
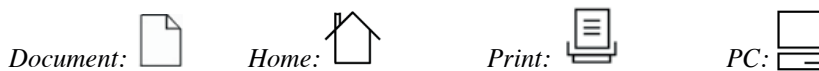
The results from this research showed that there were significant differences in how Youths and Adults ranked abstracted, minimalized line-drawn icons. This finding confirms the premise of the alternative hypothesis (H1). Results suggest that a person's fundamental

interpretation of minimalized, abstracted visual forms ('visual archetypes') in 2D GUI icon design may be learned rather than innate. People's understanding of visual archetypes appears to take root in youth, gain reinforcement over time, and continue to develop with an individual's accumulation of experience, exposure and history. Confirming the concept of visual archetype as aligned with detail-scant presentations is worthy of additional study.

Until further research reveals how people interpret GUI icons *as they age*, it is important for professionals who work with children (e.g. educators, medical practitioners, designers etc.) to understand that children and adults do not always interpret visual information similarly. Because children's responses might vary from adult's responses, they are equally valuable considering children's exposure and engagement with IT from an early age. Although this research did not include seniors as an individual age group, the results from these studies imply a need for sensitive treatment of seniors' interpretation of GUI icons as well. This is as an area that may deserve continued future research.

Implications for Theory and Application

The studies described here are beneficial and may be of particular interest to educators, developers and designers in the IT sector. The research elucidates an important issue for educators, developers and designers: children do not always interpret visual stimuli in the same way that adults do. The solution may seem straightforward: user testing needs to be conducted with the target group as early and as often as possible, yet sometimes this is not always possible. Regardless, user testing should remain a high priority in the development process. This applies to all age groups, in all realms of software development. Indeed, a minimal and rather pragmatic requirement for user-centered design is to involve children as testers of products, i.e. as participants in user tests (Markopoulos & Bekker, 2003).

As computers become more integrated into our daily lives and are used by children in academic settings, it is particularly important for educators to understand the fundamental ways in which people of younger ages interpret visual information. These studies suggest that people's understanding of abstracted information does not originate from inherently innate or tacit knowledge, but rather it is gained and learned through repeated reinforcement that changes as we mature in exposure and experience.

REFERENCES

Bennett, K. B., & Flach, J. M. (2011). *Display and interface design: Subtle science, exact art*. CRC Press.

Borgers, N., De Leeuw, E., & Hox, J. (2000). Children as respondents in survey research: Cognitive development and response quality 1. *Bulletin de methodologie Sociologique*, 66(1), 60-75.

Borkin, M. A., Vo, A. A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H. (2013). What makes a visualization memorable? *Visualization and Computer Graphics*, IEEE Transactions on, 19(12), 2306-2315.

Byrne, M. D. (1993). Using icons to find documents: simplicity is critical. In *Proceedings of the INTERACT '93 and CHI'93 Conference on Human Factors in Computing Systems* (446-453). ACM.

Chiasson, S., & Gutwin, C. (2005). Design principles for children's technology. *interfaces*, 7, 28.

Chiu, S., Koong, C. S., & Fan, S. H. (2012). Icon Design Principles for Preschoolers: Implications Derived from Child Development. *Procedia-Social and Behavioral Sciences*, 64, 228-237.

Collis, B. A., Knezek, G. A., Lai, K. W., Miyashita, K. T., & Pelgrum, W. J. (2013). *Children and computers in school*. Routledge.

DeLoache, J. S., Uttal, D. H., & Pierroutsakos, S. L. (1998). The development of early symbolization: Educational implications. *Learning and Instruction*, 8(4), 325-339.

Donker, A., & Reitsma, P. (2007). Young children's ability to use a computer mouse. *Computers & Education*, 48(4), 602-617.

Druin, A. (1999). *The design of children's technology*. San Francisco: Morgan Kaufmann Publishers.

Familant, M. E., & Detweiler, M. C. (1993). Iconic reference: Evolving perspectives and an organizing framework. *International Journal of Man-Machine Studies*, 39(5), 705-728.

Ferreira, J., Noble, J., & Biddle, R. (2006, January). A case for iconic icons. In *Proceedings of the 7th Australasian User interface conference-Volume 50* (97-100). Australian Computer Society, Inc.

Forsythe, A. (2009). Visual Complexity: Is That All There Is? *Engineering Psychology and Cognitive Ergonomics*, 158-166.

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.

Gatsou, C., Politis, A., & Zevgolis, D. (2011). From icons perception to mobile interaction. In *Computer Science and Information Systems (FedCSIS), 2011 Federated Conference on* (pp. 705-710). IEEE.

Hochberg, J., & McAlister, E. (1953). A quantitative approach to figural" goodness". *Journal of Experimental Psychology*, 46(5), 361.

Hourcade, J. P. (2008). Interaction design and children. *Foundations and Trends in Human-Computer Interaction*, 1(4), 277-39).

Huang, Shih-Miao and Kong-King Shieh, Chai-Fen Chi. (2002). Factors Affecting the Design of Computer Icons, *International Journal of Industrial Ergonomics*, Volume 29, Issue 4, April, 211-218.

Isherwood, S. J., McDougall, S. J., & Curry, M. B. (2007). Icon identification in context: The changing role of icon characteristics with user experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 49(3), 465-476.

Jansen, B. J. (1998). The graphical user interface. *ACM SIGCHI Bulletin*, 30(2), (22-26).

Jones, S. (1983). Stereotypy in pictograms of abstract concepts. *Ergonomics*, 26(6), 605-611.

Karvonen, K. (2000). The beauty of simplicity. In *Proceedings on the 2000 conference on Universal User* (pp. 85-90). ACM.

Kunnath, M. L. A., Cornell, R. A., Kysilka, M. K., & Witta, L. (2007). An experimental research study on the effect of pictorial icons on a user-learner's performance. *Computers in human behavior*, 23(3), 1454-1480.

Kurniawan, S. H. (2000). A rule of thumb of icons' visual distinctiveness. In *Proceedings on the 2000 conference on Universal User* (pp. 159-160). ACM.

Large, J. A., & Beheshti, J. (2005). Interface design, web portals, and children. *Library Trends*, 54(2), 318-342.

Lin, M. H. (2003). Archetypal icon and delightful design. *In Proceedings of the 2003 international conference on Designing pleasurable products and interfaces* (pp. 40-44). ACM.

Lin, R. (1994). A study of visual features for icon design. *Design Studies*, 15(2), (185-197).

Lin, R., & Kreifeldt, J. G. (1992). Understanding the image functions for icon design. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 36, No. 4, 341-345. SAGE Publications.

Marcus, A., & Gould, E. W. (2000). Crosscurrents: cultural dimensions and global Web user-interface design. *interactions*, 7(4), 32-46.

Markopoulos, P., & Bekker, M. (2003). Interaction design and children. *Interacting with computers*, 15(2), 141-149.

Markopoulos, P., Read, J., Hoÿsniemi, J., & MacFarlane, S. (2008). Child computer interaction: advances in methodological research. *Cognition, Technology & Work*, 10(2), 79-81)

McDougall, S. J., de Bruijn, O., & Curry, M. B. (2000). Exploring the effects of icon characteristics on user performance: The role of icon concreteness, complexity, and distinctiveness. *Journal of Experimental Psychology:* 6(4), 291.

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.

McDougall, S., Reppa, I., Smith, G., & Playfoot, D. (2009). Beyond emoticons: Combining affect and cognition in icon design. *Engineering Psychology and Cognitive Ergonomics*, 71-80.

Morrow, V., & Richards, M. (1996). The ethics of social research with children: An overview1. *Children & society*, 10(2), 90-105.

Nesset, V., & Large, A. (2004). Children in the information technology design process: A review of theories and their applications. *Library & Information Science Research*, 26(2), 140-161.

Norman, D. (2011). *Living with Complexity*. MIT Press.

Pappachan, P., & Ziefle, M. (2008). Cultural influences on the comprehensibility of icons in mobile–computer interaction. *Behaviour & Information Technology*, 27(4), 331-337.

Piaget. J. (1959). *The psychology of intelligence*. Routledge & Kegan Paul, Ltd. London.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child*. Basic Books.

Piamonte, D. P. T., Abeysekera, J. D., & Ohlsson, K. (2001). Understanding small graphical symbols: a cross-cultural study. *International Journal of Industrial Ergonomics*, 27(6), 399-404.

Pedell, B. (1996). Toward a declaration of icon independence. *ACM SIGDOC Asterisk Journal of Computer Documentation*, 20(2), 18-21.

Philleo, T. (1993). Icon Images in HyperCard: An Exploration of Visual Concepts with Middle School Students.

Punch, S. (2002). Research with Children. The same or different from research with adults? *Childhood*, 9(3), 321-341.

Random House©, (2015). Online website based on the Random House©, Inc. Dictionary. URL: www.dictionary.com Retrieved April 2015. *Archetype: The original pattern or model from which all things of the same kind are copied or on which they are based; a model or first form; prototype*.

Reimer, J. (2005). A History of the GUI. *arstechnica*. com, May, 5.

Reips, U. D. (2000). The Web experiment method: Advantages, disadvantages, and solutions. *Psychological experiments on the Internet*, 89-117.

Rocheleau, B. (1995). Computer use by school-age Youths: Trends, patterns, and predictors. *Journal of Educational Computing Research*, 12(1), 1-17.

Rogers, Y. (1989). Icons at the interface: their usefulness. *Interacting with Computers*, 1(1), 105-117.

Schmidt, W. C. (1997). World-Wide Web survey research: Benefits, potential problems, and solutions. *Behavior Research Methods, Instruments, & Computers*, 29(2), 274-279.

Schröder, S., & Ziefle, M. (2008). Making a completely icon-based menu in mobile devices to become true: a user-centered design approach for its development. In *Proceedings of the 10th international conference on Human computer interaction with mobile devices and services* (pp. 137-146). ACM.

Skogen, M. (2006). An investigation into the subjective experience of icons: a pilot study. In *Information Visualization, 2006. IV 2006. Tenth International Conference on* (pp. 368-373). IEEE.

Skogen, M. (2014). Say, What Did You See? A Qualitative Interview Reveals How Users Interpreted GUI Icons. In *Proceedings of the Colors of Care: The 9th International Conference on Design & Emotion* (pp. 332-339). Universidad de Los Andes, Bogotá, Columbia. ISBN 978-958-774-070-7.

Skogen, M. & HK Hoem (2015). What Can GUI Designers Learn from 2D Poster Art? In *Proceedings of The Value of Design Research: The 11th European Academy of Design (EAD) conference*. April 2015, Paris, France.

Wang, H. F., Hung, S. H., & Liao, C. C. (2007). A survey of icon taxonomy used in the interface design. In *Proceedings of the 14th European conference on Cognitive ergonomics: invent! explore!* (pp. 203-206). ACM.

Winkielman, P., Halberstadt, J., Fazendeiro, T., & Catty, S. (2006). Prototypes are attractive because they are easy on the mind. *Psychological science*, 17(9), 799-806.

Wolff, J. S., & Wogalter, M. S. (1998). Comprehension of pictorial symbols: Effects of context and test method. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 40(2), 173-186.

Wright, K. B. (2005). Researching Internet-based populations: Advantages and disadvantages of online survey research, online questionnaire authoring software packages, and web survey services. *Journal of Computer-Mediated Communication, 10*(3), 00-00.

Zammit, K. (2000). Computer icons: A picture says a thousand words. Or does it? Journal of Educational Computing Research, 23(2), 217-232.
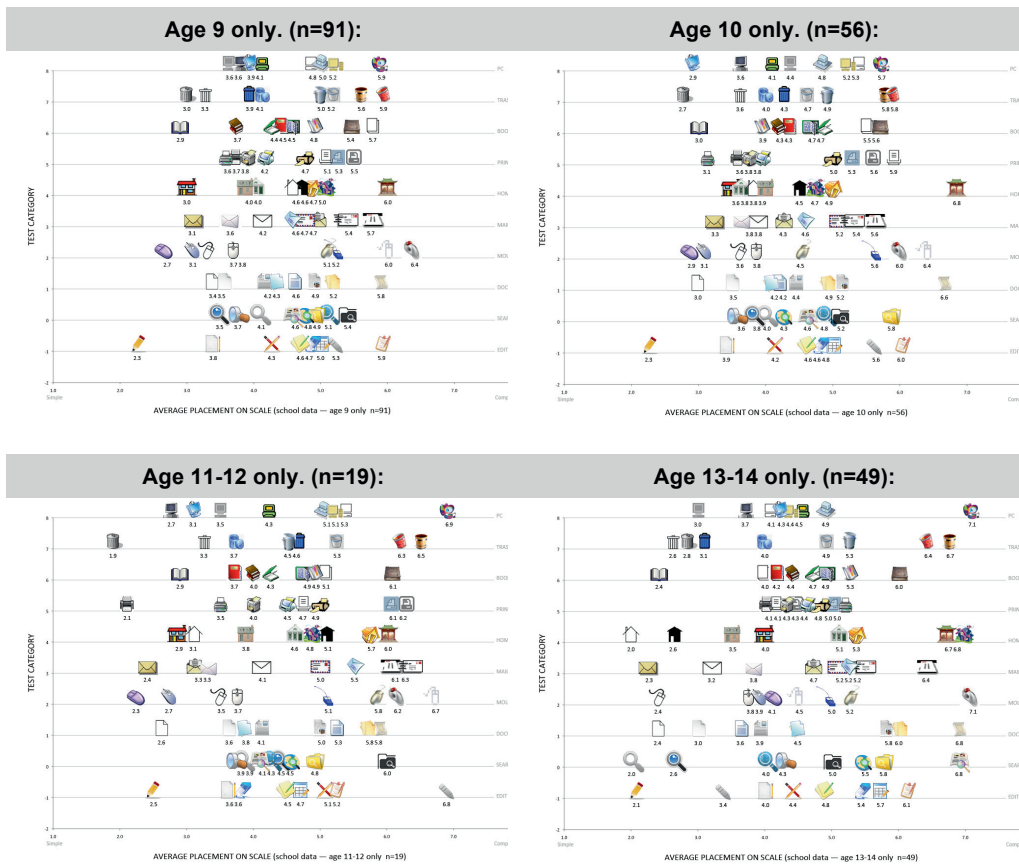
APPENDIX A

The four charts in Figure i. show a subset of Youths' responses broken down into smaller, more precise age brackets. Many of these preliminary visual charts were constructed—this appendix shows only the most decisive ones regarding the splitting of the data into "Youths" (≤13) and "Adults" (>13).

This type of mapping indicates visually how responses changed, according to age. The chart for ages 11-12 shows a noticeable distinction in earlier-aged responses, particularly regarding the archetypal icons. By age 14, the Youths seemed to show responses consistent with older ages. This is why the age split was set at age 13.

Figure i. Averaged responses per icon for Study II (Schools).

APPENDIX B

The Complete Icon Comparison Chart (ICC):

			Search (1)								Edit (2)							
		Icon:																
Study I:	*n=*	*p =*	.0147	.0012	.7555	.9793	.3918	.8355	.0170	.0821	.0693	.6780	.8559	.4835	.5165	.4363	.0028	.9173
Ages ≤13	11	*median:*	5	6	3	6	4	3	4	5	6	2	6	5	4	4	3	5
>13	15	*median:*	1	3	3	5	6	4	7	8	1	2	6	4	6	3	7	5
total	26	*gap:*	*4*	*3*			*2*		*3*	*3*	*5*				*2*		*4*	
Study II:		*p =*	.0000	.0140	.0014	.5623	.6850	.0086	.0010	.0000	.0000	.0393	.0044	.5161	.0026	.8810	.0325	.6980
≤13	242	*median:*	4	5	3	6	6	3	5	4	6	2	4	4	5	4	6	5
>13	61	*median:*	1	4	2	5	6	4	7	7	2	1	6	4	7	4	7	5
total	303	*gap:*	*3*						*2*	*3*	*4*				*2*			
Study III:		*p =*	.8402	.7001	.2525	.8605	.0396	.9406	.1291	.6175	.6735	.2693	.6099	.0210	.7195	.5325	.6306	.2607
≤13	20	*median:*	1	3	3	6	6	4	5	6	2.5	2	5.5	3.5	6	4.5	7	4
>13	484	*median:*	1	4	3	5	5	4	7	7	2	2	6	5	6	4	6	4
total	504	*gap:*							*2*									

key:
- .0000 significant difference between the two age groups
- .0001 - .0499 approaching significant difference "
- .0500 - .0999 marginal non-significant difference "
- .1000 - .9999 non-significant difference "

			Document (3)								Mouse (4)							
		Icon:																
Study I:	*n=*	*p =*	.0240	.4675	.2645	.0240	.6404	.0486	.6404	.0064	.1258	.0548	.0274	.8355	.2535	.3370	.0379	.3241
Ages ≤13	11	*median:*	3	4	3	4	4	6	6	4	2	7	4	5	3	5	6	7
>13	15	*median:*	1	4	5	2	3	8	6	7	1	2	3	5	4	5	7	8
total	26	*gap:*	*2*		*2*	*2*		*2*		*3*	*5*							
Study II:		*p =*	.0000	.0000	.7672	.0042	.2931	.0006	.0202	.0137	.0000	.0022	.4147	.5593	.0007	.0142	.2935	.0038
≤13	242	*median:*	3	5	5	3	4	5	5	7	4	7	4	6	2	3	5	7
>13	61	*median:*	1	3	4	2	5	6	6	7	2	6	4	5	4	4	5	8
total	303	*gap:*	*2*	*2*							*2*				*2*			
Study III:		*p =*	.2902	.0182	.0164	.1340	.3211	.6417	.0278	.0746	.2651	.1459	.9565	.5439	.3574	.6184	.5443	.7684
≤13	20	*median:*	2	5	5	2	3.5	6.5	5	7	2.5	6	3	5.5	3	3.5	5.5	7.5
>13	484	*median:*	1	4	4	2	4	7	6	7	2	5	3	6	3	4	6	8
total	504	*gap:*																

			Mail (5)								Home (6)							
		Icon:																
Study I:	n=	*p =*	.0055	.3918	.8153	.0333	.0088	.0548	.1076	.1772	.0022	.0404	.0617	.8153	.6591	.4517	.0313	.0240
Ages ≤13	11	*median:*	3	2	5	6	5	4	5	6	6	3	3	4	4	6	5	4
>13	15	*median:*	1	2	5	3	7	6	7	5	1	2	5	4	5	4	7	8
total	26	*gap:*	*2*			*3*	*2*	*2*	*2*		*5*		*2*			*2*	*2*	*4*
Study II:		*p =*	.0039	.0018	.7410	.5119	.8728	.0288	.0048	.5436	.0000	.0000	.0002	.2187	.5462	.0008	.1323	.0000
≤13	242	*median:*	4	3	5	3	6	5	6	5	5	5	3	5	4	4	7	5
>13	61	*median:*	2	2	4.5	3	6	6	7	5	1	2	4	5	4	5	7	7
total	303	*gap:*	*2*								*4*	*3*						*2*
Study III:		*p =*	.0947	.2516	.0018	.7943	.1013	.1921	.2889	.6738	.0075	.0019	.0096	.2242	.5129	.3579	.3492	.0014
≤13	20	*median:*	3	2	5	3	6	5	7	5	2	3	3	5	4	5	7	5.5
>13	484	*median:*	2	2	4	3	6	6	7	5	1	2	4	5	4	5	7	7
total	504	*gap:*																

			Print (7)								Book (8)							
		Icon:																
Study I:	n=	*p =*	.0274	.0486	.0582	.0917	.0693	1.000	.0457	.1462	.0582	.3370	.5858	.0256	.9173	.5506	.4835	.6780
Ages ≤13	11	*median:*	6	5	6	4	4	5	2	4	7	4	4	5	6	2	5	6
>13	15	*median:*	1	3	3	5	6	6	7	6	1	4	5	7	5	2	7	5
total	26	*gap:*	*5*	*2*	*3*		*2*		*5*	*2*	*6*			*2*			*2*	
Study II:		*p =*	.0034	.0012	.6043	.7627	.0002	.8796	.2053	.1475	.0022	.2395	.0784	.2041	.9400	.0002	.0208	.0006
≤13	242	*median:*	6	6	6	3	3	5	4	4	6	4	4	4	5	3	6	4
>13	61	*median:*	3	3	6	4	6	4.5	4	5	3	3.5	5	4	4.5	2	7	6
total	303	*gap:*	*3*	*3*			*3*				*3*							
Study III:		*p =*	.4230	.1536	.3492	.5037	.1033	.5847	.1946	.1734	.5254	.8818	.1595	.1732	.9776	.0913	.5627	.1571
≤13	20	*median:*	5.5	6	5.5	4	4	5	4	4	6	4	6	3	5	2	7	5
>13	484	*median:*	4	3	4	4	5	5	5	5	3	4	5	4	5	2	7	6
total	504	*gap:*		*3*							*3*							

key:

color	range	description
(dark green)	.0000	significant difference between the two age groups
(light green)	.0001 - .0499	approaching significant difference "
(yellow)	.0500 - .0999	marginal non-significant difference "
(red)	.1000 - .9999	non-significant difference "
(blue)	1.000	non-significant outlier " (one occurrence only)

			Trash (9)								PC (10)							
	Icon:																	
Study I:	*n=*	*p =*	.2226	.0055	.4211	.1857	.3241	.4211	.1391	.0868	.0022	.0158	.1258	.8968	.8559	.2429	.0195	.0031
Ages ≤13	n=11	*median:*	2	5	4	3	4	5	6	6	6	3	6	3	4	4	3	6
>13	15	*median:*	1	2	4	4	5	6	8	7	1	2	5	4	4	5	6	8
total	26	*gap:*		*3*					*2*		*5*						*3*	*2*
Study II:		*p =*	.0000	.0004	.5700	.9171	.6850	.0793	.0683	.0002	.0100	.0012	.0013	.8847	.6069	.7130	.0039	.0000
≤13	242	*median:*	3	4	5	2	4	5	6	6	5	3	5	3	4	5	3	7
>13	61	*median:*	2	3	5	2	4	6	7	7	4	2	4	3	4	5	5	8
total	303	*gap:*															*2*	
Study III:		*p =*	.3929	.0307	.0483	.4591	.3580	.3627	.6147	.0029	.9375	.0046	.9713	.6493	.4934	.1687	.0479	.0374
≤13	20	*median:*	2	4	5	2	4	6.5	7	6	3.5	3	5	4	5	6	3	8
>13	484	*median:*	1	3	5	2	4	6	7	7	4	2	5	3	4	5	5	8
total	504	*gap:*															*2*	

The ICC tables can be formatted to provide an overview of all tests:
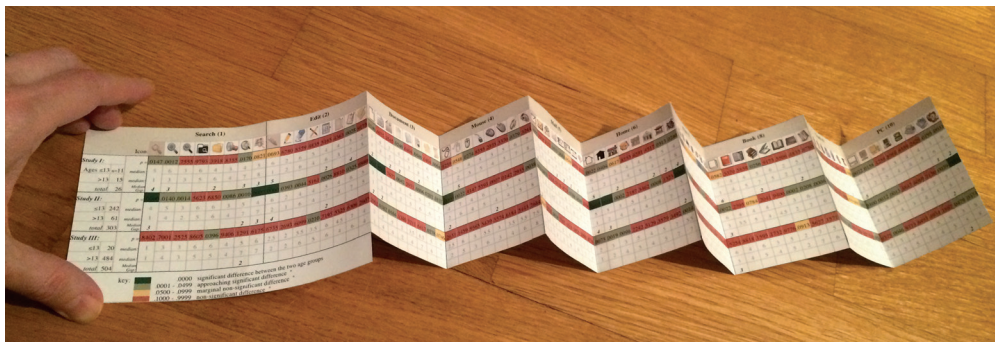
APPENDIX C

Additional Data Measures (Qualitative)

Three informal measures were taken in addition to the computer-based ranking data. The extra data described in this section were collected for the sake of curiosity as well as a potential lead-in to a future study. No statistical analyses were performed on these data sets and their results are intended for general information only. Participants were never shown their prior ranking results.

1. Time Interval

The research described up to this point was not conducted as a continuous, longitudinal study where individuals were followed from childhood through the 'window of transition', and into adulthood. For Studies II & III, participants took the test one time only. However, there are some participants who took the test twice: thirteen of the Study I participants took the user test originally at the Initial Test/St. Olav's (Study I), and then again four years later. This section describes the second time that some of the Study I participants took the test. Nine youths and four adults took the test four years after the original test—this was done so that comparisons could be made with the same users over time. Some of the icons were ranked in almost inverted order from earlier ages to later. Some examples are shown in Tables i-vi, with each example's point of interest described underneath each table.

Table i. Participant 1, Ranking Switch

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
F	12								
	16								

Note two icons in Table i: the yellow envelope and the compound black envelope+small magnifying glass (often referred to as the 'camera') that seemed to move dramatically on this person's ranking scale. The yellow envelope inverts almost completely resulting in a "split" in responses for that icon.

Table ii. Participant 2, Ranking Switch

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
F	6								
	10								

Many of the icons in Table ii have moved from one side of the ranking scale to the other despite the yellow envelope remaining in the same place. Here, note the 'camera' split, the brown and blue icon in deep perspective that almost splits, and the plain grey archetype changes places as well.

Table iii. Participant 3, Ranking Switch

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
F	12								
	16								

Table iii shows that despite almost identical responses for the black house and the purple house, the 'archetypal' detail-scant, abstracted, line drawn icon performs a complete split, moving from highly-ranking ('complicated') at age 12 to lowest-ranking ('simple') at age 16. The detail-rich yellow and orange houses invert positions as well.

Table iv. Participant 4, Ranking Switch

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
M	5								
	9								

As in Table iii, the Table iv archetypal house performing almost a complete split, while the black house with minimal detail stays constant. In addition, the purple house moves to a lower rank ('simple'), while the Chinese pagoda later moves to a higher rank ('complicated').

Table v. Participant 5, Ranking Switch

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
M	46								
	50								

Mostly, adults answered consistently from the first to the second testing session, demonstrating that the participants had defined their criteria for the icons. This did not change despite four years of advancement in computer experience. However, one user answered differently regarding the archetypal line drawing as well as the bright blue, 3D icon. Table v shows the only example of 'archetype split' from an adult.

Table vi. Participant 6, Exceptional Consistency

Gender	Age	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
M	13								
	17								

Not everyone changed their opinions after four years, as this participant showed in Table vi. His answers across all categories were almost equally consistent.

2. Memory Recall Survey

Highly informal, this qualitative measure was conducted for Study II *only* (aged 6-14), post user test. The methodology involved asking randomly selected students to recall the first icon that jumped into their mind's eye whereupon they flagged it on a poster. Figure ii shows results from the qualitative survey that was intended to gather opinions only.

Figure ii. Results of icons recalled by participants in Study II

Borkin found that for visualizations larger than GUI icons, higher memorability scores were correlated with visualizations containing pictograms, more color, low data-to-ink ratios and high visual densities' (Borkin et al., 2013). Further, familiarity eases icon identification and has lasting effects on access to long-term memory representations (Isherwood, McDougall & Curry, 2007). Isherwood et al.'s considerations become interesting with particular regard to the following icons:

 'that funny/weird/strange purple house'   'clock' (10x or more)

 'house with the cowboy hat'   'eye' (10x or more)

 'robot', 'alien', 'bug', 'rocket', 'tampon'

The last icon was referred to as the 'upside down rocket' on five separate occasions and the 'tampon' (4x) from students at different schools where it was impossible to for them influence one another. Although context clues may help to identify confusing icons in some circumstances, it is clearly in a designer's best interest to use all measures to insure that their target group understands the icon in the manner in which they intend.

STATEMENT FROM CO-AUTHOR
(cf. section 10.1 in the PhD regulations)

Martha Skogen   applies to have the following thesis assessed:
Name of candidate

Do You See What I See?
Investigations into the Underlying Parameters of Visual Simplicity
....
Title

Statement of co-authorship on joint publications to be used in the PhD thesis of Martha Skogen:

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1. An Investigation into the Subjective Experience of White Space in an Urban Environment

Both authors participated in data collection in Torgallmening, Bergen Norway, and contributed to the research in equal amounts.

I declare that these contributions are correctly identified.
I agree that this work is to be used as part of the PhD thesis.

Trondheim 26/6-2015
Place, date

Hilde Østerås Berntsen

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2. What Can GUI Designers Learn from 2D Poster Art?
Viewers Responses Reveal Consistencies Across Diverse Media

Both authors participated in data collection in a corporate setting in Trondheim, Norway and contributed to the research in equal amounts.

I declare that these contributions are correctly identified.
I agree that this work is to be used as part of the PhD thesis.

Oslo 26/6-2015
Place, date

Helle Hoem-Martinsen

Afterword

Sometimes the sincerest attempts to show one's appreciation only barely suffice. Such is the case when trying to express my deepest, heartfelt gratitude to my husband Erik, and son Falk.

You've helped me more than you'll ever know

You inspire me every day

Life is fully complete

                    because we share it together.

This sentence is by far the simplest to compose because without your eternal love, support, and patience, none of the previous ones would have been written.

Life is simple

…we choose to make it difficult.

Confucius