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From Skeuomorphism to Flat design: Investigating Older Adults Experience

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Abstract

Flat design became a widely used design technique among the interface design community, substituting the more classical one, skeuomorphic design. Although its increasing popularity, empirical studies have shown evidence that this may not be the best option. This simplistic approach to the design removes essential visual cues that might sacrifice usability. In the light of these results, material design was created to address the issues inherent to the latter. Design and aesthetic perception influence aspects such as user satisfaction, performance and perceived usability of the system. Despite its importance, the effects of these design approaches are still not well discussed, particularly in terms of users age.

In an ageing population, and a raise in technology acceptance and use, it becomes fundamental to understand better this user group (older people). This dissertation investigated the effect of age and other individual characteristics (related to familiarization with technology) and their interaction with the design approaches (skeuomorphic, flat and material). We concluded that both age and design have effects in both performance and aesthetic perception in the tasks involved. Older Adults (65+ years) were the ones where performance depended more on design. Aesthetic preference was also influenced by this factor: while younger adults perceived minimalistic designs as more aesthetically appealing, the older groups drew a more positive opinion towards a more detailed one.

These findings helped to create a set of user guidelines that vary according to the target age and to which is the goal of the designer (enhance efficiency, effectiveness or aesthetic preference).

Keywords: Older Adults, Interface, Aesthetics, Flat Design, Skeuomorphic Design, Material Design

Resumo

Atualmente, flat é uma técnica muito usada pela comunidade de design, vindo em substituição do clássico skeuomorfismo. Embora tenha tido uma crescente popularidade, estudos empíricos mostraram evidências que esta poderá não ser a melhor opção: a simplicidade deste design remove pistas visuais essenciais que podem sacrificar a usabilidade e experiência do utilizador. Para colmatar as falhas apresentadas do flat design, um novo design, material, foi criado.

Quer o design quer a apreciação estética são componentes essenciais à experiência de utilizador, influenciando aspetos como a satisfação, performance e a usabilidade percecionada do sistema. Apesar da sua importância, os efeitos das várias técnicas de design ainda não estão bem discutidos, em particular em termos de idade. Numa população cada vez mais envelhecida, e com um aumento da aceitação e uso tecnológico, passa a ser fundamental compreender melhor este grupo etário, quais são os designs mais eficientes, eficazes e esteticamente mais apelativos, de modo a construir diretrizes de design apropriadas. Esta dissertação investiga o efeito da idade e das três técnicas de design (skeuomorfismo, flat e material) na experiência do utilizador. Concluímos que quer a idade, quer o design, têm efeitos quer na performance, quer na perceção estética nas tarefas envolvidas. Quanto à idade, as pessoas de faixa etária mais alta (65+ anos) foram as que demoraram mais tempo na realização das tarefas e as que cometeram mais erros. Foram também o grupo cuja performance dependeu mais no design. Quanto ao design, para todos os participantes, de um modo geral, flat foi a condição que afetou mais negativamente a eficácia das tarefas. Em termos de preferência estética, as pessoas mais novas percecionaram os designs mais minimalistas como mais apelativos. Por sua vez, as pessoas mais velhas têm uma perceção mais positiva do design mais detalhado. Estes resultados permitiram criar um conjunto de guias de desenho de acordo com o grupo etário e objetivo pretendido (aumentar a eficiência, eficácia ou preferência estética).

Palavras-Chave: Idosos, Interface, Estética, flat design, Skeuomorfismo, material design

Contents

List of Tables

List of Figures

Acronyms

A Adults

V Dependent Variables

IV Independent Variables

Fd flat design

OA Older Adults

M Mean Value

Md material design

Sd skeuomorphic design

YA Younger Adults

SD Standard Deviation

Fx, F-statistic

p p-value

1 The Ageing Population and Technology

The world's population is ageing. Countries all over the world are experiencing a growth in life expectancy and in the number and proportion of older people. It is estimated that, over the next 15 years, the percentage of people who are 60 years or older will increase 4 % (from 12.3% in 2015 to 16.5 % in 2030) [36]. The median population age lies currently in 30.1 years (as of July 9, 2017)[1] and more than half of the world population (61%) are Adults between 15 and 59 years of age [29].

Population ageing is becoming «one of the most significant social transformations of the twenty-first century» [36], with impacts in almost every sector (e.g.: financial markets, transportation, technology, demand for services). Working towards a society that is inclusive and adaptable to the differences that come along with age has become one of the main challenges.

Regarding the technology sector, there has been a proliferation of the domestication and access of technological devices with a significant increase in internet and touchscreen usage among older people in the last years. As an example, in the UK only, the proportion of people aged 75+, that have used Internet in the last three months of the conducted study has nearly doubled in five years (from 2011 to 2016) [57]. Technological devices have become an important aspect in older people life, no longer used only for checking emails and messaging but also for other more complicated tasks, such as Internet based functions [35], like medical needs or basic access to knowledge, searching for information, purchasing, banking and comparing products [7].

However, designing interfaces for this age group represents some challenges. The cognitive, emotional and physical differences that come with age affect, in multiple ways, how they interact with the devices. This brought the need to understand the existent implications that these factors might have in terms of design [3,21,32,33] in order to develop proper design guidelines [19,42,60]. Although these problems are known, there are applications in violation of the necessary heuristics [41]. Even Older Adults generally share the opinion that the design is, many times, inappropriate [38]. On top of it, it is demonstrated that some of these differences that come with age can also affect the aesthetic perception of an interface [45] and were shown to affect aspects such as user satisfaction, perceived usability and performance [13,23,52]. The knowledge of the aspects that influence such perception, what works better, together with the correct specification of the characteristics of the existing multiple user groups, can be used to develop inclusive, personalized and adaptive interfaces, that go towards the needs of the population [18].

[1] http://www.indexmundi.com/, last accessed 2018/09/26

1.1 Three Design Approaches and its Relationship with Age

The evolution of technology has brought multiple new design trends. It is of utmost importance to study and test these new approaches regarding the different characteristics of the population, in order to understand if they are being well applied.

Although the necessity of creating inclusive technology is recognized as an important topic in literature, this is not what is most commonly done. Human Computer Interaction research is still mainly focused towards the attitudes and characteristics of young, highly-educated people, rarely reflecting the demographic reality.

Nowadays, there is an emerge of new design techniques. However, the effects that they might have in terms of user satisfaction and ability for the user to properly interact with those interfaces are not well studied in terms of age and familiarization with technology. For instance, regarding design trends, there is a new topic that is provoking controversy among the design community. The adoption of a new approach, called flat design, has emerged, with multiple interfaces following it (e.g.: Microsoft 10, iOS 7). The technique makes use of wide elements, bright colors and clean spaces to bring a sense of cleanliness and minimalism to the design.

Flat came in substitution of the more classical design strategy, skeuomorphic design. Skeuomorphism gives the user a sense of familiarity through the emulation of materials and objects, which is often perceived as unnecessary and too complicated (e.g.: iOS6) [16,47]. Although flat design is most commonly used nowadays, comparative studies [9,16,37,46,53,58] between both techniques have questioned the extent of flat design as the better option. One of the issues pointed out in flat design was the removal of visual cues, such as shadows and highlights, that helped the user distinguish elements. Material design emerged to solve this problem. While continuing with the simplicity of flat, it provides affordances that enable a better usability of the system [9].

Figure 1.1 - Skeuomorphic vs Flat vs Material design [2]

Although the study of design techniques has been presented as a relevant topic in design, and the fact that age has shown to affect users' perception [38,39,52], the effects that age might have in the most common design approaches (skeuomorphism, flat and material) is yet to be investigated (Section 2.4). This dissertation focuses in the three approaches mentioned and the effects of them in an ageing population.

[2] https://onextrapixel.com/flat-design-and-material-design-are-same-oh-are-they-really/, last accessed 2018/09/26

1.2 Goals

The main objective of the dissertation is to understand which are the main differences that occur when participant´s individual characteristics (age and familiarization) interact with the three emergent types of design (skeuomorphic, flat and material).

To do so, we conducted a series of empirical studies to better understand their effect in this topic.

The first study consisted in three tasks, each of them related to an important function regarding interface design: searching for icons/symbols, searching for clickable objects and doing a sequence of instructions in multiple webpages. Each task was conducted in the three different design types. Results show the subjective (aesthetic preference) and objective (efficiency and efficacy) analysis.

A second experiment was executed to the oldest participants, to understand whether the learning aspect might have an influence in their performance and aesthetic preference.

1.3 Contributions

State of the art. Research documents related to the subject in question are gathered and reviewed. First, we identify the main differences that occur with age and identify a set of guidelines of design for Older Adults from previous literature. Second, we discuss the importance of aesthetic perception in design, together with the elements that were identified as interfering with it. Finally, the three design approaches are compared in terms of flaws, strengths and aesthetic preference among users.

Effect of age and other individual characteristics on user performance and aesthetic preference according to the design. We contribute with an empirical study that aims to understand the effects of age regarding different interface designs (skeuomorphic, flat and material). The experiment will be focused on different age groups, where users will be tested in their interaction with the designs.

Effect of the learning aspect in the performance of Older People. The second study focuses in finding out if the repetition of a task might influence the user's performance. We focus in the learning aspect over the oldest group of participants.

Guidelines for design. The conclusions were used to draw a set of design guidelines for website developers and designers. The measures will eventually help in the design process and build interfaces that are more adapted to users of older age.

1.4 Outline

Chapter 2 of the document, «Related Work», describes the state of the art. It is divided in four Sections: «Older People and Web», «Aesthetics in Interface design», «From Skeuomorphism to flat design» and a final «Discussion», which sums up all the conclusions raised from previous literature. Chapter 3, «Effect of Age and design on User Performance and Aesthetic Preference» describes the first experiment, from its planification to its implementation and data collection. The description of its

analysis, major results and answers to the research questions are reported in Chapter 4, «Results». Chapter 5 reports the second experiment «Learning Experience». Finally, we report a set of guidelines of design based in the findings of the two experiments (Chapter 6) and draw the major conclusions and future work (Chapter 7).

2 Related Work

This chapter addresses three domains: «Older People and Interface Interaction», «Aesthetics in Interface Design» and «From Skeuomorphism to Flat design». We start by referring the differences that come along with age and the design guidelines developed to overcome the difficulties felt in their interaction with technology. Then, we address one of the main aspects of user experience: aesthetics. We refer to its importance and the elements that contribute to affect our perception. Finally, we describe the three design approaches (skeuomorphism, flat and material), their differences, characteristics and eventual flaws supported by empirical research.

2.1 Older People and Interface Interaction

To fully understand age and its effects, one must know the main differences that come along with time. Only noticing these aspects, we can fully comprehend the importance to adapt technology to the user's characteristics.

2.1.1 Age Related Differences

To comprehend how the user characteristics might interfere in their interaction with an interface, we will address the cognitive, perceptual and socioemotional changes that come with age. In this dissertation, we refer to young people when people are aged below 39, adults for people aged 40-64, and older adults for the remainder.

Cognitive and Perceptual. Research has consistently documented that increased age is associated with the lowering of the levels of cognitive performance. Although the magnitude of cognitive ageing is largely accelerated in older ages (65 and above), it is believed that it begins relatively early in adulthood [48].

The deterioration affects several cognitive functions. Age is associated with memory declines [10] and retrieval of newly learned information [15]. Activities involving attention demanding tasks also suffer: selective attention (referred to the ability of doing a goal-oriented task while ignoring other irrelevant parts of a stimulus, (color or shape for example)) and divided attention (processing two or more sources of information, performing two or more tasks) [59]. Mental imagery (mental representations of images) declines especially for complicated tasks [24]. Decision making, problem solving and the attitude towards risk [56] are also affected.

Finally, in the perceptual level, the increase of age is associated with the deterioration of the visual capability, and the appearance of eye diseases [25]. It is also associated with a change in color perception [22] and loss of visual acuity [44].

Emotional and social context. Socioemotional aspects (such as well-being and mechanisms of self-regulation) also suffer changes. In terms of motivation, for example, age plays a fundamental role on

what we are driven to achieve and do. Due to a sense that time is limited, Older Adults tend to pursue emotional satisfaction and to enhance old good relationships and patterns. Motivation goes for emotional meaning instead of broadening horizons [49]. On the other hand, Younger people have a much bigger time perception and tend to seek for new information, new relationships and a sense of novelty.

In Older Adults, attention and memory also become in line with emotional goals, showing superior memory for emotional rather than non-emotional stimuli. While younger people tend to favor negative material in information processing, older groups favor positive material [31]. It has also been shown that a positive opinion of an older person's capabilities has a positive effect, whereas a negative one has the opposite effect [3]. The environment (good and bad experiences at work, the self or society's perception that they are too old to learn) can have a deep influence in the learning curve process.

2.1.2 Impacts in Interface Design

The differences that come along with age affect a diversity of aspects in older people's lives. Accordingly, in the field of technology, this age group present different needs than younger ones. Even between young-old adults and old-older adults, differences in performance can be noticed [32].

In response to such differences, the main difficulties were studied and translated into sets of design guidelines for Older Adults. These are generally focused on categories concerning visual issues (e.g., contrast, simplicity of elements, font size and type, button type size and positioning), organization and clarity of the information (e.g., links, screen layout) [61].

Although elements of design are substantial factors in terms of performance, the environment itself and the self-perception of the user also plays a big roll. When learning how to use new devices, older people require self-directed needs to tackle some wrong perceptions that they have about themselves or towards technology. This is an important aspect to present and teach new systems [3].

The elements of design and tasks related to these difficulties are defined below, together with some common approaches and guidelines to face these problems.

General complexity and navigation. Research shows that the use of complex and non-straightforward UI structure is the one of the most violated sub-heuristic in terms of navigation design principles that deal with Older Adults needs. Interfaces are generally too complex, requiring users to concentrate in multiple tasks at once [19,24,55]. In a study regarding the response of navigation tasks on a series done to 40 participants (55 to 73 years old), it was shown that simplification is the key. Simplified menus with less available options are preferred. However, effectiveness and efficiency were the lowest when there was only one menu option. It is then important to provide the multiple tasks at once [63].

Instructions should also be simple. In another experiment made towards retention of computer skills and learning abilities between different age groups (younger and older adults), found that, although younger adults scored higher in performance, simple instructions worked much better for both groups. Length of information had a great impact in the retention of information [32]. Transparency is also another aspect to be highly promoted. The user should be able to understand, at every point, what they can do with the system [3,61].

Text and targets. Due the reduced visual capability that appears along time, older adults tend to present much more difficulties than younger ones when dealing with interactive systems. This fact is generally associated with the small salience of elements, small letter size and thin letters [12], with labelling too illegible for users to be able to recognize [3]. A minimum of 12-point text should be adopted in websites.[3] The 14-point fonts was found to be the most adequate and preferred for the older ones, since it was proven to be more legible, and promote faster reading than a 12-point one [5]. Texts with different fonts and moving text should not be used, to reduce confusion to the user. Headings should be large and clear and space should be given between the lines, in order to improve readability [60,61].

As for targets, they should be large [26,60] and users should not be expected to click more than once in them [60].

Colors and contrast. Heuristics regarding visual design are most often violated due to the inappropriate use of color. Too many different colors should be avoided [61], and the color combination should be done to ensure readability [41].

Older adults have more difficulties than younger ones when dealing with bland graphics and poor color contrast [12]. It then is suggested conservative colors and high contrasts that ensure readability and perceptibility [34]. In an experiment made to visual perception of design elements, it was noticed that simplified graphic should be rendered in warm color. Graphics that include text should be differentiated in colors [43].

Use of Graphics. Graphics and icons should be simple and not used for decoration purposes, since they might increase confusion [60,61]. Too much information in a website is among one of the most common dislikes among older people. The cluttered information is conceived as a non-user friendly design [19].

Explicit instructions and labelling. In interfaces, there is sometimes a lack of explicit instructions or labelling in controls and elements, so users do know what is the intended functionally.

For older users, this fact, together with their inexperience and beiger anxiety problems towards technology increases a lot the difficulty of the perception of instructions [3]. Self- explanatory names (that avoid abbreviations and technical concepts) should be used [41].

Graphical symbol should also be done together with textual explanation is preferred, since it is easier to comprehend [43]. The screen layout and terminology used should be always simple and consistent [61].

Use of familiar concepts. Older users transfer knowledge learnt from previous non-digital interfaces (such as typewriters), which can lead to conceptual problems. As an example: confusion between the concepts of backspace (delete to the left) and back (go to previous screen/back out of interface. The

[3] https://www.marketing-partners.com/conversations2/vision-changes-typography-for-aging-audiences, last accessed 2018/09/26

use of affordances (visual cues in the system) should be promoted [3]. Graphical symbols, such as icons should, be drawn according to mental models and previous experiences of Older Adults [43] and its use should be consistent [11].

Help and training process. Although Older Adults have interest for newer technologies, they tend to continue using technologies that were used to, due to the fear and uncertainty of using something new [38]. There are many theories around learning abilities of older adults. Although different in some aspects, each of them emphasizes that the focus should be towards flexibility, self-direction and the learning process, instead of the content itself [11]. A training process based in collaboration, comprehension and self-reflection has been seen to have a great impact in the learning process. Many of older aged adults suffer from lack of confidence, which make them don´t want to explore the system, with the fear of «trial and error» approach [3]. They tend to blame themselves for the error, rather than the interface, while younger adults tend to react in the opposite way [12].

Therefore, it is important to give an environment of trust and motivation towards technology use, with supportive teachers/researchers [11], promoting the fact that technology is important for communication, entertainment and retrieval of information and giving the help with instruction manuals [3].

Although previous research has explored a multiplicity of important factors and elements to design, it tends to be more focused in tasks, sizes or complexity of information than properly the exploration of different design approaches. Indeed, there is a lack of research in terms of aesthetic preference in interface design for this age group.

The next Section will be focused in what exactly consists this perception and in which way it affects the user, but in a more generic way, ranging other parts of the population in terms of age.

2.2 Aesthetics in Interface Design

Good design is done through the right representation of knowledge and information to the user. The appraisal of a system (the way a user behaves and accepts it) is a balance between both the characteristics and differences of the user and the properties of the interactive system. The multiple components of the user experience (e.g.: subjective feelings and physiological reactions; visual aesthetics; effectiveness, learnability) and their interactions, impact the ultimate judgment of the user towards the system [54]. Visual aesthetics is one of the determinants. It can be defined as the perception of beautiful and it is related to the capacity of attributing different degrees of beauty to forms, colors, movements, landscapes.

Since it is not a matter of logical opinion, the question of what beauty is or not has been debated along centuries, with many the theories developed around it.

A subjectivist approach towards aesthetic, links beauty with the nature of the viewer and its historical and contextual background. It stands for the opinion that aesthetic truth cannot be based by logical principles, yet into personal opinions of what is being perceived (like, dislike). On the other hand, an objectivistic view identifies beauty as the being property of the perceived object. Complexity and symmetry, proportion, contrast and clarity have been studied in ways that can affect such experience

[13,23,45,50].

2.2.1 Effects of Aesthetics in User Experience

This affective dimension of Human Computer Interaction has been shown to have a really important role. For instance, in comparison to other factors, such as effectiveness, efficiency and playfulness, aesthetics was proven to be the most important factor responsible for user satisfaction [13]. A research done by Constantinos et al. enhances the importance of role that aesthetic and playfulness have to create a good website. For creating reliable, easy to use interfaces, design must be accompanied by pleasant and creative experiences, suggesting the influencing factor that aesthetics have over other elements.

The fact that perceived aesthetics can also influence perceived usability of a product was supported by many other researches. For example, when dealing with two interfaces with no difference between any usability objective quality, the user's sense of perceived usability was higher for appealing interfaces than unappealing ones.

The same study found that aesthetic perception may also have an important part in user's performance when completing a task. When dealing with this situation in a serious environment (school, work) motivation would increase with appealing interfaces and the time and number of errors made to completed were less [38].

Aesthetic perception is also believed to be one of the most important factors in the first interaction with a system. Research found that, in addition to affecting perceived utility, perceived aesthetics has shown to have a larger impact than the latter in forming users' attitudes towards a first interaction with a website, which will ultimately shape the perceived image of a company/product [23].

Aesthetics was also shown to have significant impact on the emotions of individuals, affecting subjective feelings, motor expressions and physiological responses [2,6,54,55]. Emotional experience can be categorized in the affective space in terms of both valence (pleasant, neutral and unpleasant affect) and arousal (intensity in the affective valence). Emotional valence is associated with the intrinsic attractiveness of a design. Positive valence corresponds to an attractive perception, a negative valence to a non-appealing one [4]. Affective valence, when related to the perceived aesthetics of the system, was found to be positively related to the perceived pragmatic quality of a mobile application (ability of the app to enable to help the task) [6], implicating once more that perceived aesthetics are a crucial determinant in important factors for a correct user experience.

2.2.2 Aspects of Interface design that influence Aesthetic Perception

Although there is still a lack of generally accepted principles in the field of interface design, research has been made to determine what exactly are the factors that trigger users' aesthetic perception in the relation to different interface elements in the design.

Lavie and Tractinsky [27] found two dimensions of perceived website aesthetics: classical and expressive aesthetics. In their experiment, participants evaluated websites based on different

adjectives. Pleasant, clear and organized were some adjectives from the first dimension. Adjectives such as creative, colorful and original were used for showing the latter. Those same elements have been shown to influence each other. Coursaris and Osch [13] demonstrated that aspects related to classical elements (clarity and order) positively affect expressive elements. It was also shown that classical aesthetics was the most important factor in user's satisfaction. It is only when interfaces are designed with both classical and expressive factors that the evaluations can be more positive. It was shown that the quality perception of an individual towards an interface highly depend on these factors [6].

Different elements were shown to have a clear influence in these subjective facets of design (classical and expressive) [50].

It is then important to understand which are the features of design that implicate with such perception. Based on previous findings, Jiang et al. [23] have identified 5 key determinants to the user aesthetic perception in a first interaction with a website, and studied the user's perceived quality of those different design elements. The determinants were identified as unity (the connection of elements in a meaningful way), complexity (the amount and variety of information and design elements), intensity (color schemes, properties of color), novelty (the adoption of new, unusual displays and elements) and interactivity (the interactive nature of an interface). All the perceived quality of the determinants was demonstrated to positively affect both the perceived website aesthetics and the perceived usability of a website.

The relevance of what is more valuable in terms of aesthetic perception, between all factors, has become a subject of controversy. Some research indicates that structural factors of an interface such as symmetry, balance and complexity have a much larger impact in aesthetic judgment than other factors such as colorfulness [45,50]. Other studies, however, have the opinion that, in order to increase perceived aesthetics, it is more effective to alter intensity and novelty than the rest [23]. The fact is that both colorfulness and visual complexity have been presented continually along empirical research, both individually and in comparison, to other elements, suggesting their evidence as crucial factor in this perception.

Reinecke [45] conducted an experiment of how these elements would influence the aesthetic appeal after viewing a website (after viewing it for a period amount of time 500ms). Visual complexity and colorfulness were demonstrated to explain 48% of the variance in a user´s first impressions. Tuch et al. [55] gathered psychophysiological responses of visual complexity in websites. It was shown that increased complexity affected experienced pleasure and arousal (related to an increased experienced arousal and negative valence appraisal), facial expression (increased facial muscle tension), the task performance, and memory.

Unity of form, related to complexity, and characterized this time by the number of objects and number of different sizes they might present, was also studied regarding its correlation with symmetry. The experiment demonstrated that, in high symmetric webpages, unity has a significant impact in the user´s aesthetic perception. It was shown that interfaces with lower number of objects and sizes were largely preferred by users. These results are more evident in terms of classical aesthetic perception [2].

On the other hand, perceived colorfulness is dependent on the distribution of the images and the composition that they have. It was concluded that this factor has a big influence on the perception of the website functionality. By comparing the same website, with a difference in the color of the presented

elements, the results demonstrated that, to aim for more functional systems, (in terms of efficiency), the colors and their combinations should be cooler. However, if the goal was to achieve a website that was more creative or playful, the colors should change towards warmer pallets [13].

Seckler et al. [50] have also analyzed the effects of both structural factors in website design (vertical symmetry and visual complexity) and color factors (hue, saturation and brightness). All these objective factors were analyzed according to their effect in four aesthetic subjective facets (simplicity, diversity, colorfulness and craftmanship). It was shown that each factor stimulated subjective facets: Symmetry was linked most of all to simplicity, complexity had an effect in all 4 and the color factors in colorfulness. It was also noticed that websites with «high symmetry, low visual complexity, blue hue, medium brightness or medium and high saturation had the highest preferences» achieved higher aesthetic ratings.

Other factors are also object of study. For instance, balance (alignment of interface elements) and originality (in this case, new shapes and unregular shapes in design) were tested. Their impact was studied in terms of both valence and arousal using neurophysiological measures. Originality was shown to be the only one having affects in arousal [6], providing evidence that not every aspect regarding aesthetic preference is related to an emotional response.

Aesthetic preference has also been shown to be dependent on factors such as age and educational level. Even for supposedly well-designed websites, (20 Webby Award for instance), preferences would vary, influenced by the demographic background of the participants [45]. For instance, the study demonstrated that colorfulness is not greatly impacted by age. However, this factor has shown to have a big impact in visual complexity. In an experiment conducted to demonstrate the impacts of a first impression in both website elements, participants older than 45 years showed preference in low visual complexity level more than other age groups [45].

As seen from previous findings, aesthetics is a complex topic that depends on a multiplicity of factors, starting from the user to the characteristics of the system itself. The aesthetic shift from rational to emotional, and its great importance towards the experience of using a system, puts visual design and its different languages in the center of the focus. It then becomes essential to understand the differences in the design approaches and which are the impacts that they might have for the user.

2.3 From Skeuomorphism to Flat design

The mobile revolution has forced designers to reconsider the way interface elements are designed, provoking an ongoing discussion of what are the most appropriate visual paradigms. Skeuomorphism trend and its transition to a flat design approach shows a clear example of such problem. Although being widely criticized by HCI and usability experts, flat user interface design continues to be the predominating visual style of operating systems, websites and mobile apps. Understanding the main differences of these design techniques is the first step in the path for resolving the issue.

2.3.1 Skeuomorphism

Also known as realistic design, skeuomorphism appeared to ease the learning curve that users faced when dealing with new interfaces and features. The trend was set by Apple: bookshelves made of wood to make storage of articles, a note page that resembled paper with leather (Figure 2.1), are just few examples.

In a world of 3D design, passing brusquely to a 2D one, people needed something that intuitively gave cues to deal with such differences and elements began to be designed to resemble something correlated to the user´s daily life. The sense of similarity and familiarity [29], is established with the use of metaphors and affordances: visual cues in the design that serve as guidance of how to interact with the system and uncover the aspects of the element itself [29,47]. The “digital camera” symbol to represent the button for taking a photo, the “trash can” icon used to indicate erase/recycle tasks or the “save” sign resembling a disc, are just a few examples of this approach. For instance, the iPhone’s lock screen was the first touchscreen used by many people. It then needed to be a very physical slide switch that intuitively could represent something the users could interact with.

Besides mimicking aspects of daily life objects, skeuomorphic design is known for creating references in the same elements (e.g.: light and shadow) to give the information for the brain that the shape has volume, and it can be clickable [4].

Skeuomorphism makes use of spatial depth, shadows, textures, high light and gradual changes for designing the elements [58].

In skeuomorphism, colors are also used according to their conceptual meaning in the real world [8]. Examples include the color red when approaching a dangerous action (e.g.: cancel, erase) or green to express the opposite (e.g.: start, give positive feedback).

Despite all this sense of easiness, skeuomorphic elements can be difficult to operate and sometimes unnecessary. The aim for familiarity sometimes leads to strange combinations (e.g.: buttons made of leather), and false affordances (e.g.: a page that you can´t turn), that will eventually create confusion, anger and illusion in the user´s mind [16,47]. The rising of technology and the fact we are already used to such features, made this realistic approach rapidly considered to be too cluttered and outdated.

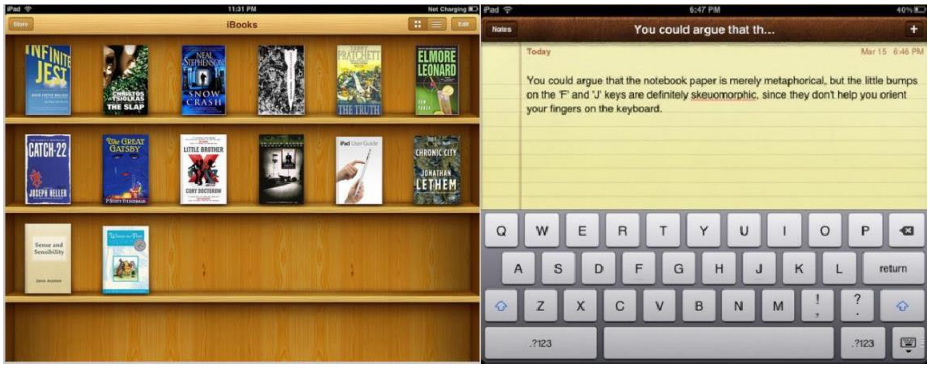

Figure 2.1 - iBooks in iPad and notebook in iOS 6

[4] http://edwardsanchez.me/blog/13568587%20[Accessed%20February%205,%202013, last accessed 2018/09/26

2.3.2 Flat

The tendency now is to move towards simplicity, removing the unnecessary complexity created around the elements. For this reason, designers have opted for a minimalist method. Flat design creates interfaces that seem simpler [29] and cleaner.

One of the reasons that made flat design so popular despite their visual appearance, was the fact that it was a responsive design. The simplification of the elements allows websites to load much faster and easier to resize [5].

Examples of flat platforms include the launching of Metro UI, a design language created by Microsoft, originally developed for the operational system used in mobile (for tablets and Windows Phone 7). The popularity of the design led it to become adopted for the computer operating system (Windows 8) (Figure 2.2). Apple also soon started to abandon the traditional skeuomorphic design approach in favor to the simpler design presented in the iOS 7.

In this technique, graphic forms are simplified, with a clear reduction in visual elements believed to cause visual interference. The attributes used in skeuomorphism (spatial depth, shadow, texture, high light and gradual change) are no longer used in this technique [58]. Along with this, elements become plane and wider.

Figure 2.2 - Windows 8 Start menu

Due to the lack of visual resources, the strategy takes advantage of colors, typography, grid and iconography to make the impact. Colors are bolder and brighter, benefiting from their saturation. They become the key-element to represent affordance and build an emotional connection to the user [8]. Elements are generally plane (one-color only) used over an also colorful background that helps the user to distinguish elements better between the others. The coordination of these “white spaces” and contrasts is used to unify and give a better readability to all design. Text and font are without serif and with a wide use of condensed, light and ultralight variations of typefaces [17].

Flat design has conquered its position among the design community, and the public seems to prefer it too. Designers, have shown, in general, that they tend to have a minimalistic preference towards

[5] https://thenextweb.com/dd/2014/03/19/history-flat-design-efficiency-minimalism-made-digital-world-flat/, last accessed 2018/09/26

design[6], [39]. An online survey, directed to hundreds of web professionals, tried to evaluate the main advantages and disadvantages of flat design, based on their perceptions. Participants considered the design to be perceived as simple, clean, colorful and modern. Among the main disadvantages, it was said to be boring, with lack of «personality», alongside more related to technical aspects such as «unclear what is clickable» and «difficult to execute well» [6]. Another research, concluded that flat icons are associated with "timeliness" and "simplicity" but they were also shown to be too rational and with a lack of emotion [29].

Despite subjective preference, empirical evidence has supported the theory that this may not be the best option. Hou and Ho [20] analyzed different app icons in the market and distributed them, showing that app design follows the two trends: concrete style (skeuomorphic) to abstract one (flat). The study then evaluated the impact that those characteristics had in the emotional reactions of users. Most of the participants (75 %) showed preference towards rich visual design or the use of concrete objects. Users preferred miniaturized designs of real objects.

The problem in flat design is that, as soon we became familiarized with the inherent meanings of technology, designers no longer had to think too much about the mental models once used to implement a certain function [53].

The consequence is the removal of essential visual cues, that are the ones that help the user make the associations with the real world.

Flat design ignores the three-dimensional nature of the human brain, sacrificing usability for the advantage of looking different. The lack of these necessary affordances has a consequent increase in our cognitive load [9]. Without the typical visual hints offered by volume, shadows and light, there is much more difficulty in understanding the correct way to interact with the elements (what needs to be tapped or swiped) [17]. This also leads to an unclear distinction between elements, misinterpreting what are their functions, compromising discoverability of functions[7] [14].

To prove this theory, Burmistrov [9] research compared the two approaches and shared the opinion that flat design is much worse for the usability of the system. Three search tasks were tested in the experiment: the search for a target word in the middle of the text; find a target icon and the to find for clickable objects on a webpage.

For the first task, in flat design, it was concluded that users required a higher cognitive load to perform it (even if the time remained the same). Search in icons was almost twice as slowly as realistic ones. Clickable objects search task was slowlier and much more susceptible to errors in flat. When everything is on the same plane you make it harder to focus on a specific section of the page.

The fact that colors lose their conceptual meaning makes a confusion to the user (with add functions having the same color as delete)[8]. If a symbol is unclear, the users try to find a meaning, even when there is none, feeling less motivation. When the symbol fails to illustrate its functionality, it can confuse the user and provoke the opposite effect. Text can help to clarify the meaning. However, text also brings ambiguity, with some terms not being powerful enough [16].

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[6] https://usabilla.com/blog/flat-web-design-is-here-to-stay/, last accessed 2018/09/26
[7] http://nngroup.com/articles/windows-8-disappointing-usability, last accessed: 2018/09/26

2.3.3 Material

With all the advantages and disadvantages of both designs, a new, hybrid approach, is being adopted. A strategy that tries to merge each design best features, attacking their main flaws. The goal is to achieve the same simplification given by flat but without compromising the good usability of the interface.

Material discards textures and gradual changes but includes shadows and spatial depth as attributes of design [58]. Gmail (web + iOS) (Figure 2.3), Google Maps (iOS), and Google+ (iOS) examples of what can be seen as this middle approach.

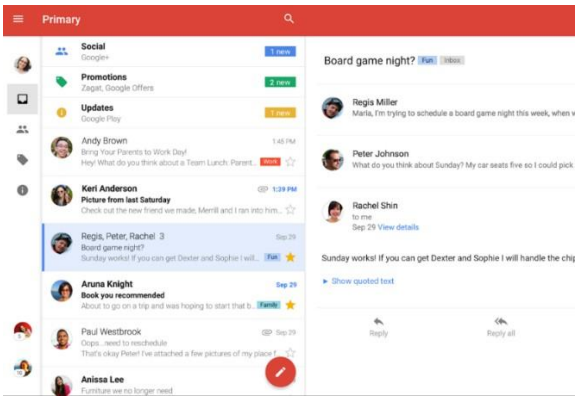


Figure 2.3 - Gmail 5.0

In a study towards designer's subjective preference, it was suggested that skeuomorphism should continue to have a place in UI design, but just not as single design approach but yes as one element of design, suggesting the benefits of a mixed approach [39]. The design strategy stays true to the flat design principles (flat colors, no drop shadows, and use of color to encourage specific user actions) but gradients and shadows are done in a subtle way to inform the user about the functionality of an element (e.g.: inform what is a button)[5]. These shading gradients in the context of almost-flat design, were studied to understand what the implications of the visual search mechanism in this context could be. The results confirmed that convex and concave stimuli (done through luminance and shading) were processed as having a sense of depth and can be processed rapidly in a flat context [14]. Research highlights the importance of using these perceptual and cognitive processes in design for important features.

Empirical research seems to support the theory. Emotional response between the three different design approaches (traditional, semi traditional and flat) were studied (Lei) [58]. The highest user experience rating was attributed to the semi traditional approach, followed by the flat approach and, lastly, the traditional one.

But a problem still rises when material design continues to follow this abstract role of flat design for identifying elements and guiding users. The symbolic logic embedded in our minds continues to be lost. In a comparison regarding icons of Apples IOS6 and iOS 7 (representing respectively, skeuomorphic and flat design styles), and its success among users, it was concluded that unsuccessful apps are the ones where the identity of the icon is lost, making it difficult to perceive their utility. The most successful apps were the ones that became simpler along time, but did not lose meaningful cues [53].

Due t

o the intrinsic connection to the individual's mental models, these design approaches, require, even more, a proper study of the system´s target group. The way a user interprets a symbol and its functionality is highly personal [16,53]. For instance, Younger users showed not to be familiarized with some of the objects. The study suggested the importance of comprehending the user and showed connection between feelings and icons [20]. As a result, some experiments have tried to study the effects of optimal user interface design for specific age demographics.

Robins [46] studied the perception of the icons of the three different design approaches. The results showed that preference in design changes along with age. The «middle age group» (27-45 years old) preferred by far, flat design. Yet, for Younger Adults, the preference was slightly towards skeuomorphism (13-26). Older participants had a slight preference for flat. Zhang et al. [62] studied the impacts of application icons of mobile devices on the user experience of different age ranges (from children to Adults). Participants were involved in a search task, where task efficiency was measured (from identification accuracy level and cognition validity metrics). and emotional reaction towards the different icons were analyzed. Results showed that, Adults and children prefer skeuomorphic icons rather than the youth. The latter believed that skeuomorphism, is better to identify an application. Skeuomorphic icons have also shown to have higher identification accuracy and faster efficiency in comparison to flat ones.

In an experiment towards older people, that compared flat elements with more realistic ones, it was shown that complicated, more detailed symbols, should be as large as 30 mm. The participants have also shown preference for realistic symbol rather than the 2D type of simplified symbols [43].

Another interesting fact is the change in the perception that these design approaches can have when the novelty effect disappears. A study was conducted to understand the subjective perception of both iOS 7 and 6 (corresponding respectively to flat and skeuomorphic design) [37]. Two interviews were made I the space of 8 months between. At the beginning, iOS 7 was attributed to be «fun», whereas the older model was perceived as «grown-up» and «serious». However, in the second questionnaire, opinions shifted, and iOS 6 became increasingly perceived as «fun». Surprisingly, both were tending to be perceived as «natural» indicating that flat design can also be adopted a long time.

2.4 Discussion

Conclusions can be drawn from the state of the art to understand the gap presented in the literature. To do so, a comparison of the characteristics between the most significant case studies mentioned along the document will be made. To present the data, three table are defined below (each one related to each section of the related work).

2.4.1 Older People and Interface Interaction

Table 2.1 evaluates the articles according to the subject of study in question (whether the object of evaluation is a task or a specific element in design). This is important to have a general understanding of what is the major focus of the empirical studies regarding this age group. The articles are also described

according to the metrics used for evaluation. They are effectiveness (task completion rate, number/type of errors, ease of use), efficiency (completion time), cognitive evaluation (work load, verbal working memory, text comprehension), satisfaction (subjective preference of a type of element/learning method/size) and aesthetic preference (subjective preference regarding a design type or design element).

Article	Subject of study	Effec.	Effi.	Cog.	Satis.	Aest.
Morrell, Park et al. [32]	Retention of computer skills: implications in the type and complexity of information and text comprehension	Yes	Yes	Yes	No	No
Chun and Patterson [12]	Navigation tasks: finding, adding, log-in	Yes	Yes	No	Yes	No
Barnard et al.[3]	Exploration of the attitudes towards learning	Yes	Yes	No	Yes	No
Cercone [11]	Summarization of adult learning theories	NA	NA	NA	NA	NA
Pijukkana and Sahachais aeree[43]	Graphic and icon and size; Access menu	--	--	--	--	--
Petrovčič et al.[41]	Evaluation OSs and their basic features; in terms if they are correct to guidelines (violation of heuristics);	NA	NA	NA	NA	NA
Petrovčič et al.[42]	Overview of the existent guidelines and checklists	NA	NA	NA	NA	NA
Ziefle [63]	Navigation performance: Font sizes and number of available functions	Yes	Yes	No	No	No
Page [38]	Navigation mobile for common tasks	Yes	Yes	No	No	No
Bernard et al.[5]	Font-size (legibility, reading speed and perception of font legibility)	Yes	Yes	No	No	No
Hart et al.[19]	Web design Guidelines	Yes	Yes	No	Yes	Yes

Table 2.1 - Older People and Interface Interaction

An analysis to the table show that, when research is made towards older people, the subject of study tends to be more focused on specific aspects of computer interaction such as complexity of information, learning attitudes, usability of the system, specific design elements (e.g.: size of letters, targets) and specific functions (e.g: navigation, text-entry).

The studies generally regard cognitive differences that come along with age and how they can affect the design of an interface and develop the necessary guidelines. As seen from above, there is a lack of studies in terms of general design approaches and consequent user satisfaction and emotional preference. This is supported by the metrics of the evaluation: every experiment (when applicable) makes use of objective evaluation. In the cases where the study uses emotional evaluation, it is in terms of ease of use and satisfaction instead of interface aesthetics.

2.4.2 Aesthetics and Elements of Design

Table 2.2 and Table 2.3 focus on the other part of our research: the study of general design elements and specific approaches to design (skeuomorphic, flat and material). Due to their similarity (design types are a subject of aesthetics), we evaluate the articles using almost the same attributes. The only difference is that the first table refers the interface design elements (e.g.: complexity, intensity) and the second one describes the design type mentioned in the document (skeuomorphic vs flat vs material approaches).

An analysis of the two tables show that the focus group tends to be Younger Adults or Adults, rather than Older Adults. Apart from a few examples that mention the effect of age in this topic, the aesthetic preference of older users is not well discussed.

As for the subject of study, when the focus is in aesthetics per se (Table 2.2), the emphasis goes to aspects such as complexity and colorfulness in interfaces. This is in accordance to what was previously mentioned (see Section 2.2). For Table 2.3, the subject of study demonstrates the focus goes more to both skeuomorphic and flat design. Material design is often not included.

Finally, the method of study indicates that aesthetic preference is mostly tested with the use of scales. Likert, classical and emotional aesthetic scales from Lavie and Tractinsky [21] are widely used. Kansei Engineering and simple questionnaires in terms of preference for design are also used approaches.

Article	User Group	Design attributes	Effects on…	Methods
Tuch et al. [55]	Undergradu ate students	Complexity	Valence and arousal; Facial expression; Task performance; Memory	Psychophysiologica l responses
Seckler [50]	Total mean age: 29.3 years	Complexity; Symmetry; Colourfulness	Objective factors and relation with classical/expressive aesthetics	Subscales (facets) of the VisAWI (Moshagen & Thielsch, 2010)
Reinecke [45]	16 - 70	Complexity and colorfulness	Perceived complexity and colorfulness	9-point Likert scale
Creager and Gillan [14]	Undergrad students	Shape and depth; Luminance	Perceived shape and perceived depth	Visual search paradigm (visual processing speed)
Jiang et al. [23]	Average age: 21.7	Unity; Complexity; Intensity; Novelty; Interactivity	Perceived aesthetic dimensions; Perceived utility	7-point semantic scale
Thüring and Mahlke [54]	20 - 34;	Symmetry; Colourfulness; Shape	Performance measures; Perceived usability, visual aesthetics; Valence, arousal; Physiological reactions	Physiological: EDA and EMG; Visual aesthetics: Cronbach's alpha .76; Emotional response: Self-Assessment Manikin (SAM)
Bhandari [6]	University students	Balance; Originality	Valence and arousal; Perceived quality; Perceived classical and expressive aesthetics	Valence and arousal : Neurological aspects; Quality: Hedonic and pragmatic quality: by (Hassenzahl, 2001). Impact of emotions in quality: Partial Least Squares (PLS) method
Altaboli and Lin [2]	Average age of 40.3	Unity and symmetry	Perceived classical and expressive factors	Classical/Expressiv e questionnaire (Lavie and Tractinsky, 2004).
Sonderegg er and Sauer [52]	13 - 16	Visual appearance	Perceived product attractiveness; Perceived usability	Item scales and Perceived usability on the Post System Study Usability Questionnaire (Lewis, 1995)

Table 2.2 - Aesthetics and Elements of design

Article	User Group	Design types	Effects on…	Methods
Burmistrov et al.[9]	18 - 28	Flat and traditional design (Text; Icons; Clickable Objects)	Measure of cognitive load; Errors; Time;	Oculomotor indicators for cognitive load (fixation time and saccadic measures)
Lei [58]	20-27	Flat, skeuomorphic and middle approach;	Perceived aesthetics	Kansei Engineering
Hou and Ho [20]	Undefined	Flat, skeuomorphic and middle approach; (App design icons)	Perceived aesthetics	Kansei Engineering
Page [39]	University students	Flat vs skeuomorphic	Subjective preference	Survey
Oswald and Kolb [37]	19 - 42; Median age: 27 years	Flat vs skeuomorphic (iOS6 and iOS 7)	Subjective preference	Survey
Li and al. [29]	Undefined	Flat vs skeuomorphic (Icons)	Perceived Identity; Interesting; Timeliness; Familiarity; Simplicity	Grade per scale
Robbins[46]	Three groups: 13-26; 27-45; ≥46	Flat vs skeuomorphic (Icons)	Subjective preference	Survey
Zhang et al. [62]	96% under 30 years old	Flat vs Transitional vs skeuomorphic (Icons)	Identification accuracy; Cognition and emotional validity; degree of emotion arousal	5-point scale (identification, emotional validity and arousal); Multiple choice cognition; Emotional (Ekman's emotions)
Stickel [53]	Not applied	Flat vs skeuomorphic (iOS 6 and iOS7 icons)	Identify successful/ unsuccessful apps; Comparison of characteristics	Semiotic inspection method; Open online questionnaire

Table 2.3 - From skeuomorphic to Flat design

In the end, we derived three important conclusions:

1. **The focus in older people studies tend to be towards cognitive and emotional aspects. When dealing with aesthetics, the focus tends to be towards Younger population.**

2. **Flat and skeuomorphic design have their effects studied but empirical studies regarding age differences are lacking.**

3. **Despite its importance, the material approach is not always addressed.**

3 Effect of Age and Design on User Performance and Aesthetic Preference

As seen in the discussion, there are not many empirical analyzes on the relation between age and design. To tackle this problem, we propose a study on the effect of age on the user's performance and aesthetic perception on the three designs styles (skeuomorphic, flat and material).

Our experiment was inspired by previous research undergone by Burmistrov [7]. In our study, however, the age factor is included. The analysis of the user subjective preference was also considered. Later, we do a statistical analysis to summarize the data and assess significant effects.

3.1 Research Questions

Our main goal is to understand if the different design conditions affect user performance and/or aesthetic preference. If this happens, we want to understand what are the main differences that occur, and which are the individual factors that might be responsible for them.

As factors we included both age and variables related to a participant's familiarization and use of technology (Section 3.9). Along the document we refer to participant´s use of technology as a combination of years of familiarization and the scales regarding the frequency of use of device of each participant. The study was designed to answer three main questions:

1. **Do individual factors (age and participant's familiarization and use of technology) have an effect in task performance and aesthetic preferences?**
2. **Does age and/or design play an effect on task performance?**
3. **Does age and/or design play an effect on aesthetic preference?**

3.2 Participants

Since our goal is to study the effect of age, we interviewed people from youngsters to older people (Section 4.2). To do so, we divided the participants into three groups: Younger Adults (20-39); Adults (40-64) and Older Adults (≥ 65). Since we are studying individual characteristics of each user (age and familiarization with technology), we had the option of dividing them in terms of both cognitive differences or aspects related to their usage and familiarization. Due to our results in Section 4.1.4, we decided to group them according to the first one (Section 4.2). Also finding participants with various familiarization levels, was very time consuming and very difficult due to our time limit. Therefore, age ranges were inspired by previous literature [40], according to the cognitive differences that appear along time.

A total of 60 people were part of the experiment (20 people for each age group). All participants were volunteers. Older participants were recruited from «Universidade Sénior, Lisboa».

Apart from age, we gathered data related to participant's familiarization with technology (number of

years that they have been using it) together with scales that express the frequency they use a set of devices (Section 3.9).

3.3 Material

The stimuli were presented on a portable computer (ASUS VivoBook S14, with a 14-inch NanoEdge Display and a resolution of 1920 x 1080). A computer mouse was used as a pointing device.

3.4 Tasks

The tasks chosen to conduct the experiment include common elements in computer interaction: icons and a various number of clickable objects. The elements were selected both due to their relevance in design and to the fact that they have highly changeable characteristics according to each design type. For testing the previous elements, two search actions (icons and clickable objects) were chosen together with a more complicated task, a set of instructions (multiple webpages). The selected tasks are displayed by their degree of complexity:

Icons. The simplest given task. Search for an icon in a set of icons. Participants must select a specific icon randomly chosen from a set of 16 icons, inserted in a random position of a 4 x 4 matrix.

Clickable objects. Search for clickable elements in a webpage. Participants must select all elements in the screen that look clickable (e.g.: buttons, images, arrows).

Multiple webpages. The most complex one. A task where the user must navigate through webpages and accomplish a goal: search for a specific element in a list of elements, buy a set of requested products and do an interaction with the store (example: call to the store in question).

3.5 Procedure

All participants did all tasks, in all three designs conditions. We started each session with a briefing about the motivation of the experiment. In the beginning of the experiment, the participant was requested to login in the system with the first and last name and fill the first part of a given questionnaire (Appendix A), which included their age data and information about familiarization with technology.

After this, the series of proposed tasks began with the following order: the participant began with one type of the three design types. Once all the three tasks were concluded, he went on to the next one until the process was finished and all designs and tasks were covered. Both the order of the design type (skeuomorphic, flat and material) and the task (icons, clickable objects and multiple webpages) were randomly chosen.

In total, each participant was given 3 interfaces of «multiple webpages» (one for each design) , 9 of «icons» (3 interfaces with icons for each design) and 3 of «clickable objects» (one for each design type).

An instruction page was shown before each task, so the user would have time to reflect on it and

understand the purpose of it.

When comfortable, the participant would click in the «Next» button and proceed with the task that appeared. The instruction remained on top of the screen during the task, so that the participant could read it when in doubt. Once more, the participant clicks on «Next» and another instruction appears. This pattern was repeated until the 15 tasks were completed.

At the end of the experiment, the user filled the second part of questionnaire to collect the subjective preference of each design (Appendix A).

Participants were also debriefed, and general opinions and comments were noted for posterior qualitative analysis. Performance was registered along the experiment in terms of time and errors (Section 3.8).

3.6 Interface design

To develop correct tests, we conducted an exploration phase to understand which elements should be present in the design. Clickable objects, icons and text were adapted to the necessities of Older Adults (Section 2.1). All interfaces presented in the experiment were designed from scratch. To do so, a set of requirements, inspired by previous literature, were respected in all the different designs:

Adapt the size of the elements. Letter has 14pt [5] and buttons and other elements were bigger than normal, of 14mm square [28,60].

Provide clear instructions and make them always available. Apart from the task «multiple webpages», the instructions were short and simple. To avoid confusion for the procedure, they were given before each task and were presented during the task to avoid short memory problems.

Avoid unnecessary complexity. Some particular elements such as: «Shelves» and «Notebooks» were introduced. However, the skeuomorphic attribute of copying reality was more used in the elements itself than in the decoration of the page.

Respect the designs characteristics. The three designs have characteristics that were respected in all elements (Table 4).

Feature	Skeuomorphic	Material	Flat
Spatial Depth	✓	✓	--
Shadow	✓	✓	--
High light	✓	--	--
Gradual Change	✓	--	--
Texture	✓	--	--

Table 3.1 - Comparisons of features between the three designs - Lei et al.[58]

Together with the requirements of design, we made other two rules to minimize an existing problem in our study. Since we are dealing with the repetition of tasks (they are repeated for the three designs), the participant might memorize the position of the elements and be faster in the first interaction than in the others. Only in the task «icons» this problem does not exist as both location and requested icon are changed along the experiment. To avoid this problem, we took two approaches for both «clickable objects» and «multiple pages» tasks:

Change the content of the websites. There are three different contents for the task «multiple webpages» and other three for «clickable objects» (Section 3.7). This implied a change of the images and what was written in the texts.

Example: If the participant starts with a task «multiple webpages» with a cooking website environment, then, in the next design, for the same task, the content will change (e.g.: the action is made in a store website).

Slightly alter the position of the given elements. The position of some elements such as text and buttons were slightly changed**,** without altering the complexity or difficulty of the problem itself.

3.7 Tasks

The design of the various tasks was an iterative process. Many different interfaces and types of icons were tested. The result is presented in the next sections.

3.7.1 Icons

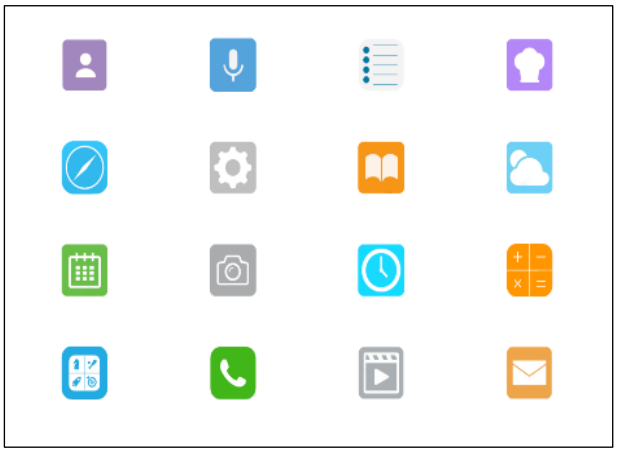
Targets measured 16.5 x 16.5mm and had a spacing of 6.35 mm [53]. The icons were chosen and created to represent well-known features of a common portable device.

Inspired by an icon theoretical analysis done by Li et al. [22], the icons of this experiment were divided in the following categories: communication applications (e.g.: e-mail.), media applications (e.g.: book), life-aided applications (e.g.: cook), entertainment applications (e.g.: videos), tool applications (e.g.: calculator, calendar, microphone). Icons were either created or used/inspired from examples of design already implemented. Icons manipulation was made with Adobe Photoshop, using shadows and layer effects. Colors and contrast were also manipulated so that all icons could be bright and readable[8].

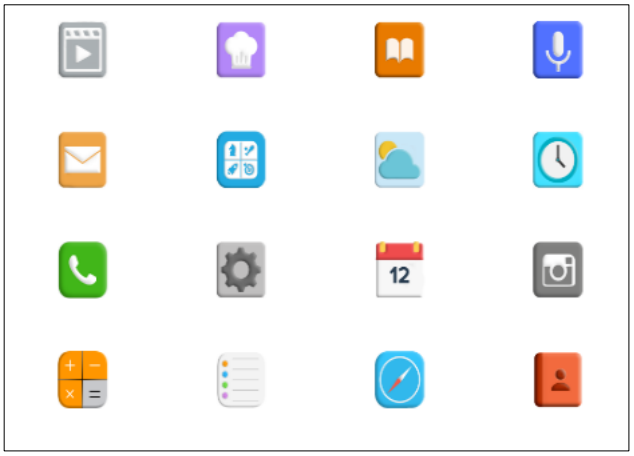
The main criteria for design were: flat icons used only two colors (a bright background and a white symbol), with no 3D effects or shadows; material icons would correspond very similarly to flat ones, although the sense of depth was added and, in some cases, a use of more than two colors. And all skeuomorphic icons had textures and shadows, with elements correspondent more clearly to the reality itself.

[8] https://flatuicolors.com/, last accessed 2018/09/26

Flat



Material



Skeuomorphic

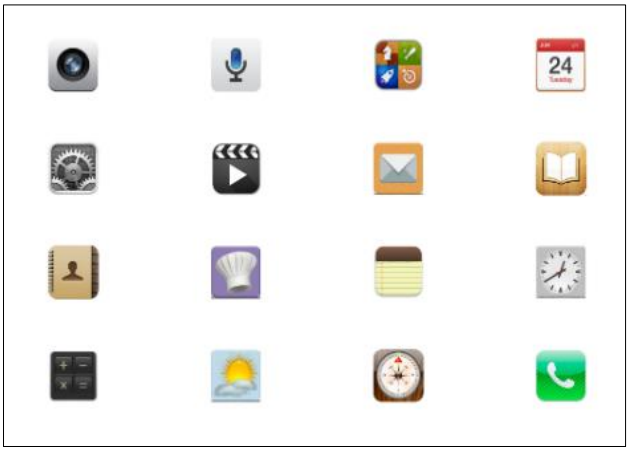


Figure 3.1 - Three interfaces of task «icons» in the different design conditions

Theme	Flat	Material	Skeu
Book			
Calculator			
Calendar			
Camera			
Clock			
Chef/Kitchen			
Compass			
Contacts			
Game Center			
Messages/E-mails			
Microphone			
Movies/Videos			
Notes			
Settings			
Telephone			
Weather			

Table 3.2 - Icons in all three types of design and their respective categories

3.7.2 Clickable Objects

The clickable elements were chosen from a set of the most common elements in webpage [9]. As previously mentioned, this task had three versions for its content. The contents chosen were: «Library»; «Pharmacy» and «Toys Shop».

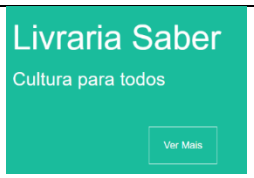
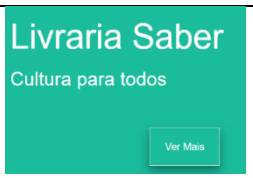
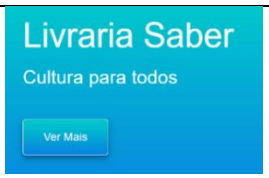
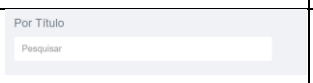
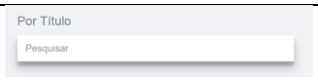
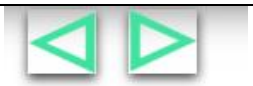
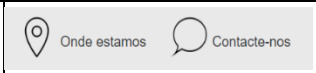
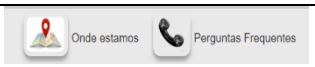
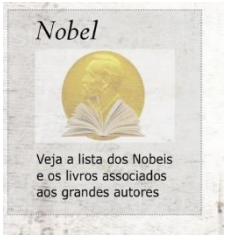
Elements	Flat	Material	Skeuomorphic
Buttons			
Search Bars			
Arrows			
Images			
Icons			
News			

Table 3.3 - Elements in task «Clickable Objects» in all three designs

The elements were disposed as reported in Figure 3.2. A total of twelve clicks were expected during the task.

[9] https://www.usability.gov/how-to-and-tools/methods/user-interface-elements.html, last accessed 2018/09/26

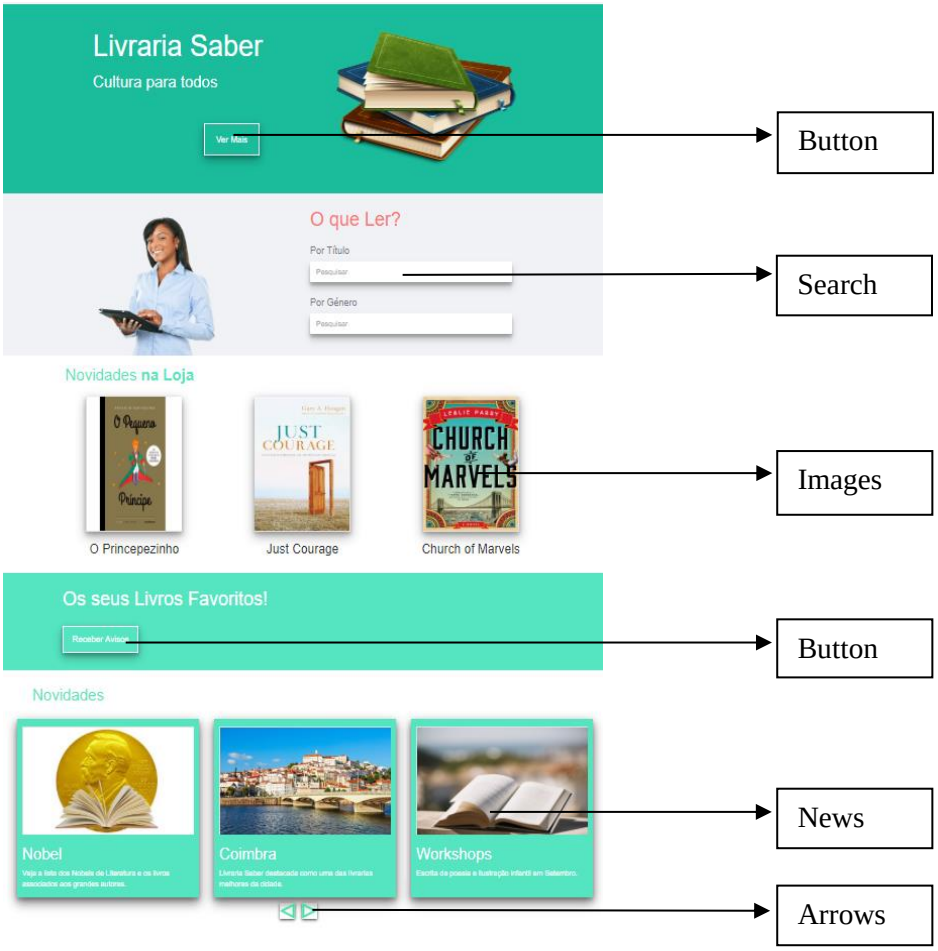


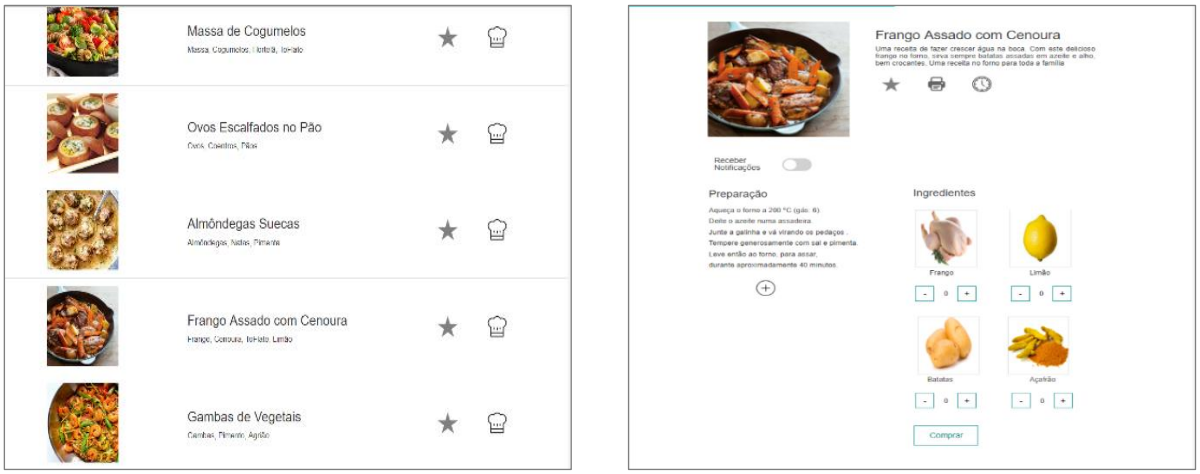
Figure 3.2 - Interface used for «Clickable Object» task, (Library version) and location of its clickable elements.

3.7.3 Multiple Webpages

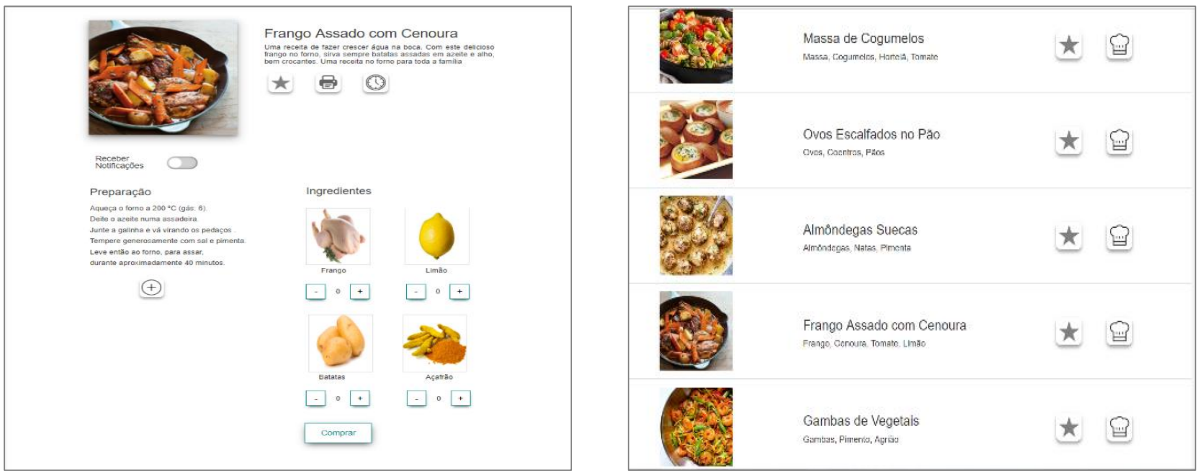
A set of simple steps were chosen for the user to execute. They were «find something in a list of elements», «buy two objects» and «select an icon to execute a function». The three versions of the task are:

1. **«Go Shopping in «BabyShop». Buy two Pacifiers; See the opening hours»**
2. **«Make the Recipe «Frango Assado com Cenoura»; Buy two Lemons; Print the recipe. »**
3. **«Go to «Peixaria Mar». Buy two Shrimps; Call the owner »**

Flat



Material



Skeuomorphic

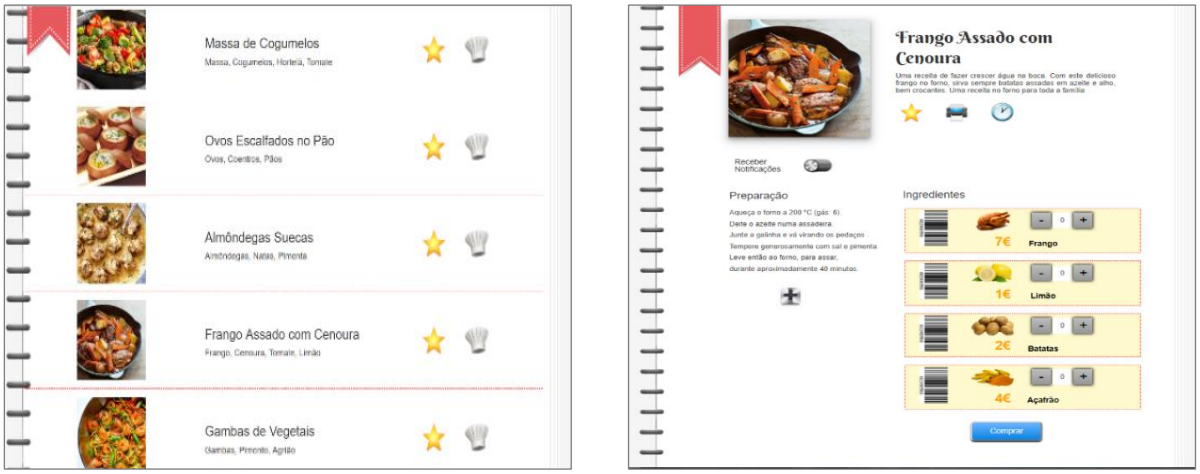


Figure 3.3 - Main and Secondary Pages in the task «multiple webpages» for the three designs, in the «recipe» context

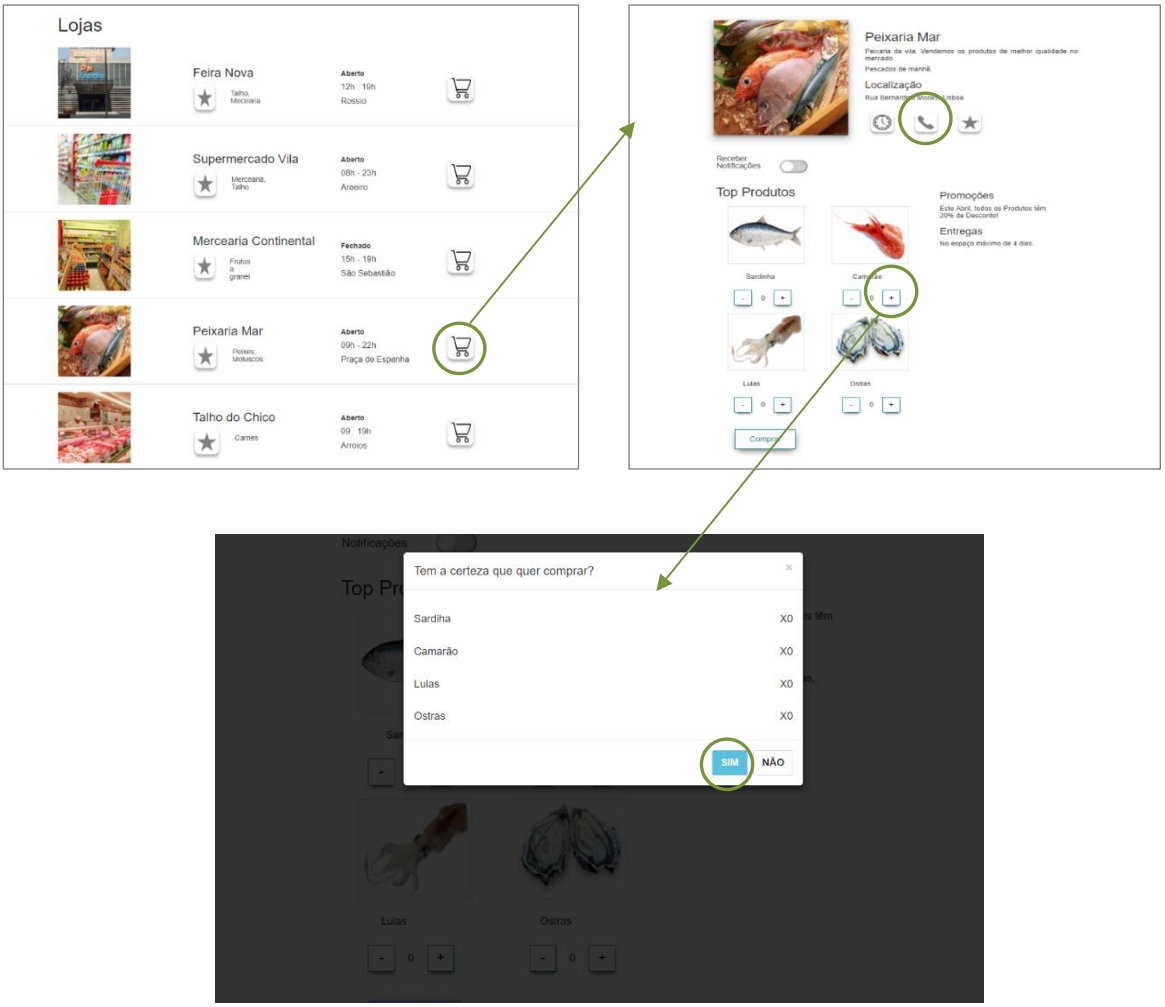


Figure 3.4 - Expected steps in the task «multiple webpages», in the content «store», in material design

A total number of six clicks were expected during the task: one click to enter the correspondent element in the list of elements, plus two clicks in the «plus sign» of purchasing, one click in the «yes» button to purchase, one click in the icon correspondent in the requested context (for this case, «telephone») and one final click to confirm the last action.

Other elements (text, switch button and other normal buttons) were presented on the screen. These were not made to be clicked, but to make a more realistic look of a website.

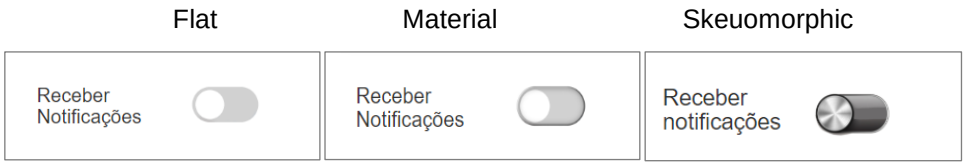


Figure 3.5 - «Switch» element presented in the task «multiple webpages» in its three design versions

3.8 Implementation

An algorithm was developed to make sure that the following conditions were being met:

Have a random order of the design type. Flat, material and skeuomorphic design were the three conditions. The order of the three of them was chosen arbitrarily.

Assure a random position of the icons. The position of every icon (target and non-target) was randomly chosen for each task.

Assure a random choice of the target icon. The target icon was chosen among the 16 available ones.

Have a random order of the task. Instruction, Click and Icon tasks were the conditions. For each design, the order was chosen randomly.

Assure that the content of both click and instruction tasks has not been repeated. E.g.: If a user does a Click task with a specific content (Library webpage), then that content must not appear again in the next design type.

At the end of each task, both time and errors were gathered. Time started to be counted on the instruction page, with the click of the «Next» Button. The counting ended with the click of the «Next» button in the task page (instructions and clicks tasks) or with the click of the correct icon (icon task). Errors were counted every time a user clicked on a place of the screen that was not the actual wanted target. An HTTP server was used to run the pages. At the end of each task, the data was put into a column in a Google Docs spreadsheet.

3.9 Data Collection

As suggested by the SO/IEC 9126-4 approach to usability metrics, we will evaluate the interfaces on their efficiency and effectiveness, to cover objective evaluation. Additionally, the interfaces will be evaluated based on their aesthetics, to cover subjective evaluation.

Objective Evaluation. Higher levels of efficiency and effectiveness have shown to positively impact user satisfaction [11]. Tasks will be evaluated in terms of both aspects. The time to accomplish each task will be used for measuring efficiency and the number and type of errors for effectiveness. This evaluation will span all tasks.

Subjective Evaluation. The methods of subjective evaluation were inspired by previous research analysis (Table 3 of the Section «Discussion»).

The participants were asked to evaluate each one of the three designs based on the a set of six scales of Kansei Engineering attributes, chosen from a set of fifteen attributes used in a previous experiment

by Lei [58]. The attributes corresponded to «Simple-Complex», «Rough-Fine», «Traditional-Modern», «Boring-Interesting» and «Ugly-Beautiful». Scales of the of «Trustworthy-Unreliable». «Hard-Easy» and «Slow-Fast» were also introduced to evaluate the degree to which a participant finds harder or easier to work with an interface that has a specific design. Each scale is represented in the questionnaire by one of its attributes and vary from «1- Do not agree» at all, to «7- Totally agree» (Appendix A). As an example, a participant can say that skeuomorphism is a 6 in the scale of «complex».

Higher scores towards the attributes «simple», «fine», «modern», «interesting», «beautiful», «trustworthy», «easy», «fast» can be associated with a more positive evaluation of the design. This will help to understand if there are any differences in terms of how participants perceive each condition (skeuomorphic, flat and material). Finally, the participant was requested to put in order the designs according to their preference (from the most to the least appealing). Data was divided into independent (IV) and dependent variables (DV), as described below:

Age. The number of years of each participant (IV).

Age group. Which group a participant belongs to: Younger Adults, Adults and Older Adults. (Section 4.2) (IV).

Familiarization with technology. Represents the approximate number of years that the participant has been in contact and using technology (such as computers, tables or mobile phones) (IV).

(Device) usage. Three Likert scales indicating the participant´s usage of a set of devices. The scale runs from 0- «Never Use» to 6-«Use many times per day». (Device) can be Computer, Mobile phone and Tablet (Appendix A) (IV).

Time. Time taken from the moment that a task starts until it finishes. For each design, and for each task (example: time_click_flat) (DV).

Errors. Missing clicks. Measured for each design, and for each task (example: errors_icon_flat) (DV).

Success. Only used in the task «multiple webpages». It represents whether the participant made everything of the proposed in the task. It can be either 0 (not achieved) or 1(achieved). For example, a participant that does find where the icon for calling is and does not call has a zero in the success variable. Someone who did everything, regardless the number of the errors, has a one.

Aesthetic Scales. Eight Likert Scales that evaluated a set of attributes (Check Data Collection-Subjective evaluation). Scales vary from «1- Totally disagree» to «7- Totally agree» (DV).

Preference. Represents the participant preferable design (DV).

3.10 Data Analysis

We applied statistical tests[10] to the data of the experiment to answer the questions raised in Section 3.1. Preliminary analysis of normality was done to perform the mentioned tests. After, an analysis of homogeneity of variances and sphericity were made, for independent and paired samples, respectively. For all data, normality and homogeneity assumptions were secured. In cases where they were not verified, ANOVA was considered robust to its violations [30]. The values of skewness and kurtosis did not reveal strong problems of asymmetry that justified the use of corrective measures (kurtosis= |<7|, skewness= |3|) and the three age groups in question are proportional in size (N = 20). When sphericity assumption was violated Greenhouse-Geisser Epsilon correction was used. All the analysis was made with the software SPSS Statistics V.22.

Multiple Linear Regression Analysis. Regressive analysis allows to understand whether there are any correlations between variables. It also creates models that predict the value dependent variable based on the value of two or more independent ones. That said, we conducted this test to determine whether age and familiarization with technology (independent variables) can predict time, errors and aesthetic preference (dependent variables). This way we can module a person´s efficiency, effectiveness and subjective perception through a set of independent variables. This method allows to answer to Question 1. Results are reported in Section 4.1.4.

MIXED ANOVA repeated measures. Since all participants performed the same conditions (all three tasks in all three designs), and since age is also a factor to be taken into consideration – there is an independent and multiple dependent variable to be studied - we used a MIXED ANOVA repeated-measures to answer Questions 2 and 3 of the research questions. Age group was the between subjects' factor and design the within-subject factor.

This method allows to understand if there exist any differences between the three groups and the executed tasks and if there is an effect of the independent variable (age group) in the dependent variables of study (time, errors and aesthetic scales). Results are reported in Section 4.2.5.

Kruskal-Wallis and Friedman tests. To study success (Section 3.9) we applied the Kruskal-Wallis test to compare two unmatched groups. This way, we assessed significant differences between the groups of participants. Kruskal-Wallis is used as a non-parametric version of the ANOVA. We also applied Friedman's test to study if there are any differences between designs.

Chi-Square independence test. This non-parametric test is used to verify the association between two qualitative variables. We used it to verify whether there was a tendency to prefer a specific design for each age group. Results are reported in Section 4.2.4 and help to respond to Question 3 of the research questions.

[10] http://yatani.jp/teaching/doku.php?id=hcistats:start#what_statistical_test_should_i_use, last accessed 2018/09/26

4 Results

In this Chapter, we report the data from the experiment. We also analyze the results from the statistical tests mentioned above.

Independent variables are analyzed in Section 4.1.1, and dependent variables are described further, in Section 4.2. Results from the multiple linear regressive analysis are presented in Section 4.1. The analysis of the MIXED ANOVA repeated measures, Kruskal-Wallis and Friedman's test are in Section 4.2.3.

Each Section of the statistic results will be divided in efficiency (time), effectiveness (errors) and aesthetic preference to respond to the questions in Section 3.1. All calculations were rounded to the second decimal place.

4.1 Modelling Task Performance

This Section analyzes the results obtained using the Multiple Linear Regressions method. It is focused on answering to question 1 of the research questions (Section 3.1).

We begin by making a descriptive analysis of the independent variables in the study.

Secondly, a summarization of the dependent variables related to efficiency, effectiveness and aesthetic preference are described as functions of those IV (Table 4.1 and Table 4.2).

In the tables, β represents the regression beta coefficient. In a multiple linear regression model, the β of an explanatory variable expresses the relationship between the dependent variable and an IV, when the other independent variables in the regression are kept constant. This coefficient, however, does not indicate the relative importance of each IV in the explanation of the DV. Instead, this is measured by Beta. $R^2\ adjusted$ is an alternative variable to R^2 (a descriptive measure of quality of the adjusted model of regression). Contrarily to the latter, it is adjusted to the number of predictors and the sample dimension. The variable is used to make a comparison of the different models. It does so by giving a percentage of variation of the independent variables that affect the dependent variable in question.

The F value is used in combination with *p* value (significance) to decide whether the results are significant. If the *p* value is small (less than 0.05), the result is statistically significant, allowing the rejection of the null hypothesis (the hypothesis that something must be nullified).

4.1.1 Descriptive Statistics (Independent Variables)

Here we describe the independent values regarding the participant´s individual characteristics (age and variables related to the user´s technology use: years of familiarization and scales regarding the use of a set of devices.

The age of participants ranged from 20 to 77 years (M=49.05, SD=19.43), as reported in Figure 4.1. It was non-normally distributed (with skewness of 1.87 and kurtosis of 3.93).

Although we had less participants between ages from 30 and 50, we guaranteed that we had 20 people in each age group [40].

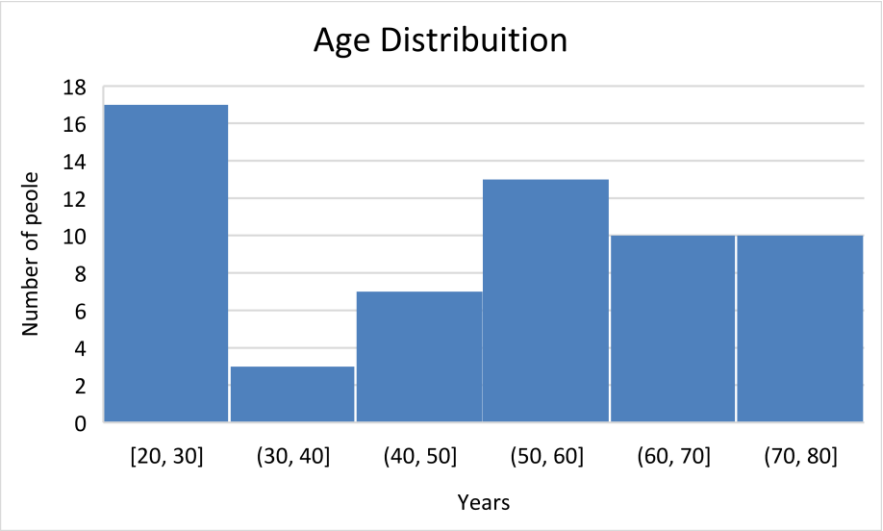


Figure 4.1 - Participant's age distributed by intervals of 10 years

Familiarization with technology ranged from to 0 to 39 years of experience (M=17.0 and SD=8.48). The graph (Appendix B) shows a symmetry to the left, with a higher frequency of individuals that have used it for less than 20 years. Contrarily to the last one, the distribution of both computer (M=5.07, SD=1.62) and mobile phone (M=5.15, SD=1.79) are more to the right (Appendix B) showing that multiple participants use often these two devices. As we can also see, most of the participants tend to use both Computers (with 39 people) and Mobile Phone (41 participants) multiple times per day (level 6 in Likert Scale).

As for Tablet (M=1.22, SD=1.15), most of the sample population do not use this device, with a total of 43 participants that never used it.

4.1.2 Modelling Efficiency

Age was a significant predictor in all models, with an explanatory factor (Beta) always larger than .40 (meaning this variable was responsible for more than 40% of the variance of the concluded effects).

As expected, the efficiency of each task decreased with the increase in participant´s age [51], for all cases, meaning the older the participant is, the longer is the time to make a task.

However, factors related to familiarization with technology and device scales did not seem to interfere with the efficiency of any task, with the exception of «multiple webpages» in skeuomorphic ($F_{(5,54)}$=12.7 e p<.001) and flat design ($F_{(5, 54)}$=6.77 e p<.001).

As an example, for «multiple webpages» in skeuomorphic design (Table 4.1), age (B=1.85, p<0.001), years of familiarization with technology (B=- 1.85, p<.01) and mobile phone (B=6.39, p<.05) were the three explanatory factors, explaining approximately 50% of the DV's variation. From all, age was the factor that contributed the most to the variation of the results (β =.83). Results mean that the increase of one year of the participant explains an increase of about 1.85 seconds to do the task, and one year more of familiarization represents a decrease of 1.85 seconds. Whereas the increase in the mobile

phone scale (Section 3.9) represents an increase in 6.39 seconds.

Analyzing Table 4.1 we can also conclude that age was specially an important factor for tasks «clickable objects» and «multiple webpages», where its Beta was larger. These were also the tasks with a larger R^2 adjusted.

Design	Tasks (DV)	Explanatory variable	β	Beta	R^2 $adjusted$	F	p
Flat	Icon	(Constant)	.89	--	.19	3.6	.007**
		Age	.23 *	.40			
	Clickable Objects	(Constant)	-41.44	--	.46	11.05	.000***
		Age	2.21 ***	.75			
	Webpages	(Constant)	-43.76	--	.34	6.77	.000***
		Age	2.62 ***	.731			
		Familiarization	-3.06 **	-.376	.45		
Material	Icon	(Constant)	9.73	--	.31	6.04	.000 ***
		Age	.15 *	.421			
	Clickable Objects	(Constant)	14.29	--	.46	11.21	.000***
		Age	2.48 ***	.770			
	Webpages	(Constant)	9.49	--	.39	8.45	.000***
		Age	1.48 ***	.621			
Skeuomorphic	Icon	(Constant)	.084	--	.16	3.24	0.013 *
		Age	.152 **	.59			
	Clickable Objects	(Constant)	4.35	--	.42	9.12	.000 ***
		Age	1.56 ***	.633			
	Webpages	(Constant)	-40.41	--	.50	12.7	.000 ***
		Age	1.85 ***	.83			
		Familiarization	-1.85 **	-.36			
		Mobile Phone	6.39 *	.27			

Table 4.1 - Linear regression predicting Time for all participants, in all designs and tasks, from demographic and familiarization with technology variables. Significance codes: *** < .001, ** < .01, * <.05

4.1.3 Modelling Effectiveness

Age was the independent factor common to most models. The only exception was for the task «clickable objects» in material design. Also, the factor explained more than 37.5% of all model's variance. The increase of the IV is responsible for a decrease of effectiveness in all tasks, meaning that participants with more age made more errors.

There were two models that included factors related to technology (task «clickable objects» in material and task «icons» in skeuomorphic design). For the first, both familiarization with mobile phone (B=-.39, *p*<.001) and computer (B=.4, *p*<.05) were significant predictors. For the second, familiarization appeared

(B= -0.16, p<.05) together with age (B=.01, *p*<.01).

As expected, the increase in age contributed to a larger amount of errors [51]. While the increase in familiarization with technology and a larger number in the scales of device use contributed to a lower amount of them.

Differently from efficiency, there seems to be no explanatory models for both «clickable objects» and «multiple webpages» tasks in terms of given number of errors made in skeuomorphic design.

Design	Tasks (DV)	Explanatory variable	β	Beta	R^2 *adjusted*	F	p
Flat	Icon	(Constant)	-1.19	--	.14	2.95	.020 *
		Age	.03 **	.52			
	Clickable Objects	(Constant)	-.89	--	.16	3.26	.012 *
		Age	.04 *	.37			
	Webpages	(Constant)	-6.44	--	.26	5.08	.001 **
		Age	.076 **	.51			
Material	Icon	(Constant)	-.58	--	.12	2.67	.032 *
		Age	.016 **	.53			
	Clickable Objects	(Constant)	5.58 ***	--	.29	5.62	.000 ***
		Mobile Phone	-.39 ***	-.41			
		Computer	-.40 *	-.37			
	Webpages	(Constant)	.83	--	.18	3.50	.008 **
		Age	.033 *	.38			
Skeuomorphic	Icon	(Constant)	-.60	--	.17	2.25	.044 *
		Age	.010 **	.54			
		Familiarization	-0.16 *	-3.92			

Table 4.2 - Linear regression predicting Error for all participants, in all designs and tasks, from demographic and familiarization with technology variables. Significance codes: *** < .001, ** < .01, * < .05

4.1.4 Major Results

An analysis of the previous results provides an understanding to what degree the independent variables have a significant effect in efficiency and effectiveness.

Aesthetic scales were also analyzed but their results were not significant. Therefore, we did not include it in the multiple linear regressive analysis. From efficiency and effectiveness, some conclusions can be drawn according to our experiment, namely the significance and importance of each independent variable:

Age. As expected to see from the study, age was always presented as a significant variable for all the dependent variables that presented explanatory models (apart from the task «clickable objects» in effectiveness of skeuomorphic design). When significant, the increase of this factor was responsible for the increase in both time and errors. Age was also the variable with larger explanatory power (with β between .37 and .83).

Finally, the more complicated tasks («clickable objects» and «multiple webpages») were the ones where time increased most with the increase of age (an increase from 1.56 to 2.62 s with the increase

of one year). While in the task «icons» age had a lower influence (0.15 to 0.23 s).

Familiarization with technology and usage scales. Dependent factors related to familiarization with technology just had an impact in some of the models (for both efficiency and effectiveness of the tasks).

Familiarization with technology had an impact in the efficiency of the «multiple webpages» for flat and skeuomorphic designs and effectiveness of the «icons» task of skeuomorphic design. The increase of familiarization decreased the time needed/ the errors made in the mentioned tasks. The factor appeared twice for efficiency of the most complex task in our experiment. This shows that familiarization with technology might have an important effect when dealing with more complicated exercises.

Usage of Mobile Phones was also a predictor for time in the task «multiple webpages» for skeuomorphic design.

It was also a factor related to the prediction of errors in the task «clickable objects» for material design, together with the use of Computer.

The usage of tablet did not show any significance when modelling the independent variables.

However, these results are not in accordance to previous literature, that has shown that such factors related to familiarization are a big contribution to both efficiency and effectiveness [1]. A posterior analysis of possible explanations for these results are described in detail in section 4.4.

Our main goal in conducting a multiple linear regression analysis was to understand which components (age or factors related to technology and its familiarization) were the best variables to explain and preview the variations of time, errors and aesthetics. The major conclusion was that age was by far the best variable to model DVs.

Having this into consideration, age acted as the criteria to divide the groups and perform the posterior analysis. Our goal is to see the effects that the three different designs might have within and between age groups and whether there are significant differences between them. Linear regression is not a repeated measures analysis, so it does not allow us to answer our question. A MIXED ANOVA repeated measures is then necessary.

4.2 Comparing Age Groups and Different Designs

This Section reports the results of MIXED ANOVA repeated measures. It answers the question whether age has any significant influence between the results of the groups. It also reports the Kruskal-Wallis and Friedman's tests for success in «multiple webpages».

First, since age was proven to be the IV that most significantly affected the results (Section 4.1.4) we divided participants into three age groups (20 participants per group) to see if there were any differences between them. Younger Adults ranged from 20 to 39 years old (M=24.6, SD=5.24), Adults ranged from 42 to 64 (M=52.55, SD=4.35) and Older Adults from 65 to 77 (M=70.0, SD=4.23).

In the next Sections, we start by analyzing the three tasks (icons, clicks and multiple webpages) and then continue by evaluating the aesthetic results. Results from performance are reported by task (with both efficiency and effectiveness). Results from aesthetic appreciation are divided by each aesthetic

scale. All of them are accompanied by graphs.

Before performing the tests, some assumptions had to be met. First, we realized a sphericity test. Once this was made, and the effects verified (p <0.05), we continued by making a decomposition of the effect via post-hoc tests (with Bonferroni correlations) per design and age group.

Data is shown in more detail in tables (Appendix C) organized by two factors: age (with Younger Adults as «YA», Adults by «A» and Older Adults by «OA») and design (skeuomorphism, flat and material).

After grouped, the DV's of time and errors are represented with their respective mean value (M) and standard deviation (SD). We also calculate the relative dispersion of results, a coefficient of variation (CV), which helps understanding the homogeneity of the results. This is calculated dividing SD by M and then multiply it by 100. The higher the coefficient, the more heterogeneous it is. From the data presented in the Appendix we can see there is a larger homogeneity from 20 to 39 years old (YA) than in the group of 40 to 65 (A).

As age increases, the averages of results increase and there is a bigger dispersion of results (bigger values of SD and CV). These disparities of results are in accordance with our previous research (Section 2.1). Older adults need more care and have many differences in both cognitive and emotional aspects, being a diverse group, in comparison to the younger ones.

For the task «multiple webpages», we also included the success (Section 3.9).

4.2.1 Icons

Efficiency. There was a main effect of both age group ($F_{(2,57)}$=35.25, p < .001) and design ($F_{(2,114)}$=6.47, p<.01) in the time taken to complete the task «icons».

In terms of age groups, Younger Adults took a significant lower amount time performing the task in the three designs (M=5.05 s, SD=1.70 s) in comparison to Adults (M=9.13 s, SD=5.63 s, p<.05) and Older Adults (M=16.23 s, SD=9.28 s, p<.001) (Figure 4.2). Older adults took three times longer than YA, and Adults almost twice as long.

In flat design, Older Adults (M=22.3 s, SD=15.62 s) took a significant longer time than Adults (M=9.81 s, SD=6.74 s, p< .01) and Younger Adults (M=5.69 s, SD=2.56 s, p<.001). The same happened for material ($M_{YA} = 4.89\ s, M_{A} = 9.10\ s,\ M_{OA}$=15.16 s) and skeuomorphic design (M_{YA} = 4.60 s, $M_{A} = 8.47\ s, M_{OA}$ = 11.24 s).

In terms of design, there was a significant difference between flat and skeuomorphic (p< 0.01). Tasks in flat design took, on average, longer (M=12.6 s, SD=8.31 s) than the ones performed in skeuomorphic design (M=8.06 s, SD=3.59 s).

Results also showed a significant interaction between the two factors ($F_{(4,114)}$=3.46, p< .05).

For Older Adults, the time spent when in flat design (M=22.3 s, SD=15.62 s) was significant larger than in material (M=15.16 s, SD=7.42 s, p<.05). Also, the time spent when performing in flat was almost twice as the one spent in skeuomorphic conditions (M=11.24 s, SD=4.81 s, p<.001).

For the other age groups there are no significant differences between designs.

Effectiveness. Same as before, we found significant a main effect of both design ($F_{(2,114)}$=6.16, p<.01), and age group ($F_{(2, 57)}$= 8.94, p<.001). Here though, there was no significant interaction between the two

factors ($F_{(4,114)}$=1.11, p>.05).

For design, results showed significant differences between flat and skeuomorphic (p<.01). For age group, between Older Adults and Younger Adults (p<.01) and between Older Adults and Adults (p<.001).

In average, the number of errors made in flat design (M=0.52, SD=0.76) was larger than in skeuomorphic (M=0.16, SD=0.33). Also, Older Adults made more errors (M=0.63, SD=0.90) than Adults (M=0.21, SD=0.38) and Younger Adults (M=0.11, SD=0.24).

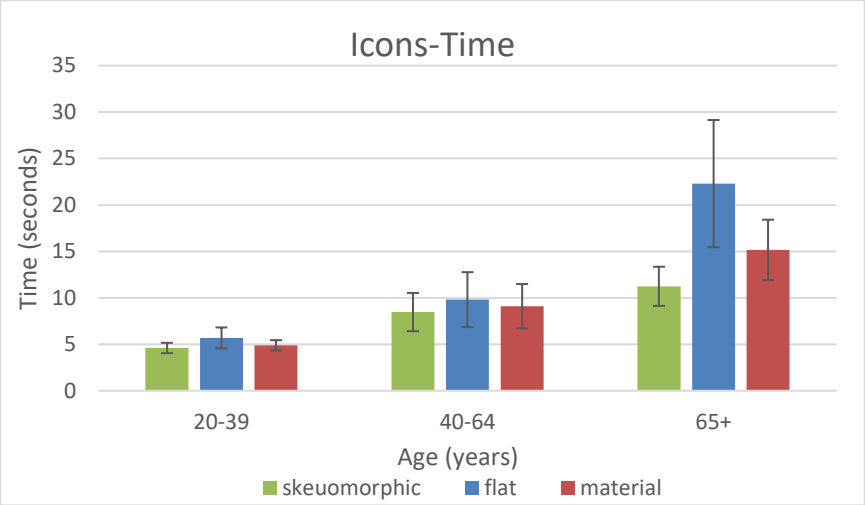


Figure 4.2 - Average and standard deviation of the time taken in task «icons» per group of participants

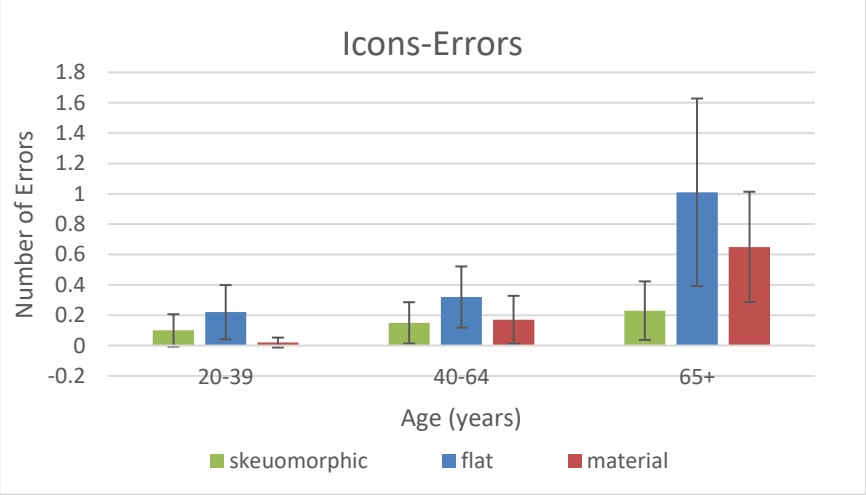


Figure 4.3 - Average and standard deviation of the errors made in task «icons» per group of participants

4.2.2 Clickable Objects

Efficiency. Results only showed a significant main effect of age group ($F_{(2,57)}$=36.21, p>.05). There was no significant main effect of design ($F_{(2,114)}$=.27, p>.05) nor of the interaction between the two factors ($F_{(4,114)}$=1.49, p>.05).

For this case, Older Adults took longer time (M=124.15 s, SD=62.34 s) than Adults (M=62.19 s,

SD=29.22 s, p<.001) and Younger Adults (M=29.69 s, SD=8.02 s, p<.001). Also, Adults took longer time than Younger Adults (p<.05). As we can see from the results, OA took, in average, almost twice as long as A and more than four times the amount of time needed for the YA group.

Effectiveness. There was a significant effect of design ($F_{(2,112)}$=12.99, p<.001) for errors made during the task. We found significant interactions between flat and skeuomorphic (p<.05), between flat and material (p<.001) and between skeuomorphic and material (p<.05).

Flat design is the one where participants gave more errors (M=2.22, SD=1.66) comparing to material (M=1.51, SD=1.44, p<.05) and skeuomorphic (M=0.98, SD=0.88, p <.001). Also, errors made in material design are significant more than in skeuomorphic (p < .05). This means that skeuomorphic design is the design where participants give, on average, less errors.

We also found a significant effect of age group ($F_{(2,57)}$=6.96, p<.01), which reported that Older Adults make significant more errors (M=2.11, SD=1.58) than Younger ones (M=0.98, SD=0.88, p<.001). Statistical results show no significant effect of the interaction between age group and design ($F_{(4,114)}$=1.11, p>.05).

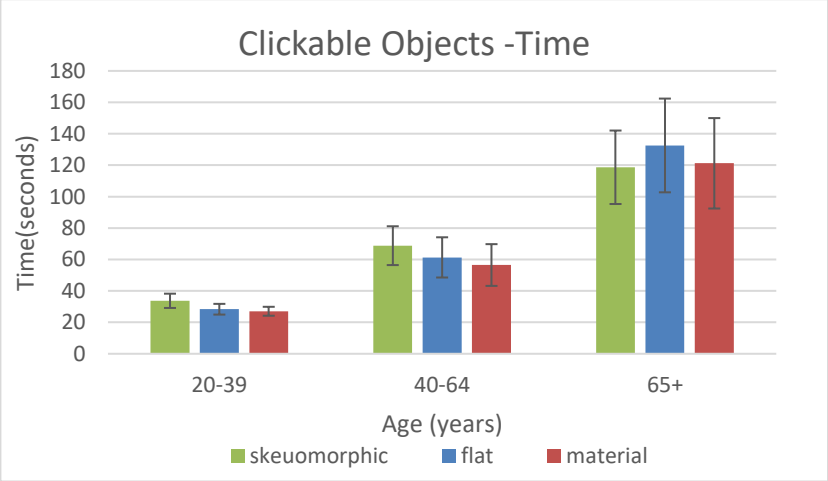


Figure 4.4 - Average and standard deviation of the time taken in task «clickable objects» per group of participants

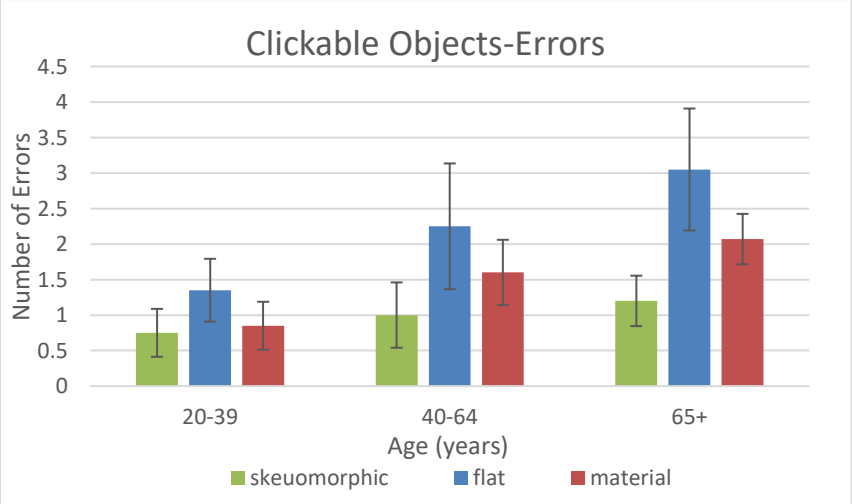


Figure 4.5 - Average and standard deviation of the errors made in task «clickable objects» per group of participants

4.2.3 Multiple Webpages

Efficiency. First, we found a main effect of age group ($F_{(2,57)}$=31.18, p<.000). Equally to what happened to the other tasks, there were significant differences between Older Adults, Younger Adults (p<.001) and Adults (p<.001). The oldest group took longer (M=108.58 s, SD=29.17 s) than the other two. Older Adults needed, in average, almost more than twice the time needed for Adults (M=53.07 s, SD=12.36 s, p<.001) and more than the triple of the time than Younger Adults (M=30.85 s, SD=11.5 s, p<.001). Results show no main effect of design ($F_{(2,114)}$=1.86, p>.05).

There was, however, there were significant differences between design and age group ($F_{(4,114)}$=2.78, p < .05).

Older Adults were the only group to show differences between the different design conditions. For them, when it was performed in flat design, the task took a considerably longer time to execute (M=124.65 s, SD=40.65 s), than when done in skeuomorphic (M=100.3 s, SD=22.89 s, p<.01), and material (M=100.80 s, SD=23.96 s, p<.05). For each design condition, Older Adults took a significant larger amount of time than Adults and Younger Adults (see Appendix C.3 and C.5).

Effectiveness. For errors done in the task «multiple webpages» we found a main effect of design ($F_{(2,114)}$=7.88, p<0.01) and age group ($F_{(2,57)}$=15.29, p< 0.001). There were more errors performed in flat (M=1.65, SD=1.5) than in skeuomorphic design (M=0.72, SD=0.90, p<0.01). There were also significant interactions between Older Adults and the rest of the groups. Older Adults made more errors (M=2.12, SD=2.09) than Adults (M=0.83, SD=1.16, p< 0.001) and Younger Adults (M=0.4, SD=0.60, p<0.001).

There were also significant interactions between design and age group ($F_{(4,114)}$=6.014, p < .001).

In flat design, OA gave a significant larger amount of errors (M=3.5, SD=2.69), in comparison to A (M=1.05, SD=1.16, p<.001) and YA (M=0.4, SD=0.66, p<.001). In material design there was also a significant difference between OA (M=1.9, SD=2.43) and YA (M=0.2, SD=0.4, p<.01). Only for skeuomorphic design, there were no significant differences.

The only group to show significant differences between designs was the Older Adults. For this group, in flat (M=3.6, SD=2.69) participants gave a significant larger amount of errors(almost twice) than in material (M=1.9, SD=2.43, p<.01) and skeuomorphic (M=0.95, SD=1.16, p<.001), making more than the triple of the mistakes made in this condition. The errors made in material were also bigger than skeuomorphic (p<.05).

Success. As seen from above, Younger Adults have all completed the task with success in all designs. The same did not happen for Adults or Older Adults, though. Some of the participants of these age groups could not complete the task when performed in flat or material design. Some participants of these groups either could not buy the requested elements (did not see the «buy now» button/ did not understand the meaning of the «+» button) or could not find the icon which they were supposed to click

(«print»/ «phone»/«receipt»), failing to do the proposed task. Interestingly, for all age groups, skeuomorphic design was the only one where the task was always finished with success.

During the study, it was noted that, most participants who started and failed the exercise with the most simplified designs, figured the solution when it changed to the skeuomorphic one. This means that the use of more simplistic solutions can compromise the understanding of the task itself for older groups of people. Results from statistical tests show the significant differences. Applying Kruskal-Wallis we compared the three age groups. This reported that flat design was the only one to have, in average, an effect over success in all three groups ($X^2(2)=17.23$, $p<.001$). There was no effect of material ($X^2(2)=2.07$, $p>.05$) or skeuomorphic ($X^2(2)=0.00$, $p>.05$) designs.

After, we applied Friedman's test to see whether there were differences between designs for each age group. Results showed no significant differences for both Younger Adults (success is always 1) and Adults ($X^2(2)=1.0$, $p>.05$). For Older Adults however, there were significant differences ($X^2(2)=13.4$, $p<.01$) between flat and skeuomorphic ($X^2(1) = 9.0$, $p<.01$) and material ($X^2(1)=5.44$, $p<.05$) designs. Success in flat was lower, (55% of success) than in material (90% of success) or skeuomorphic (100% of success) designs.

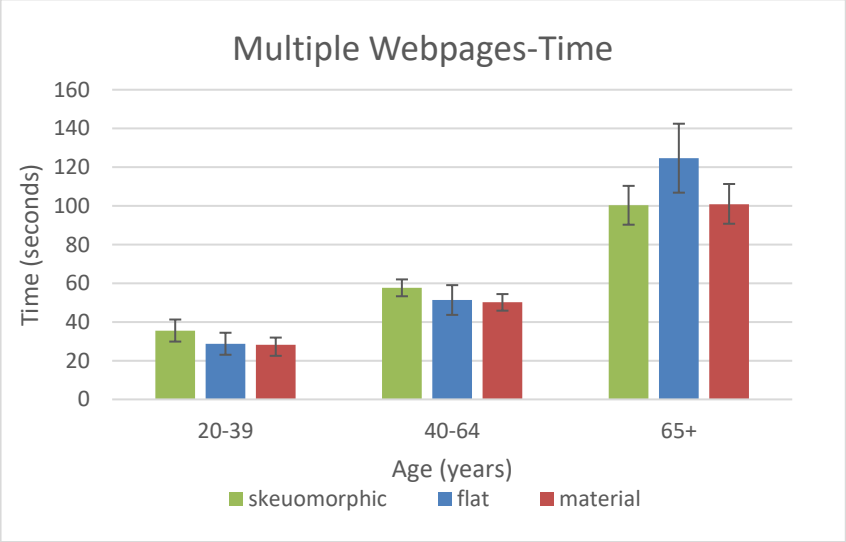


Figure 4.6 - Average and standard deviation of the time taken in task «multiple webpages» per group of participants

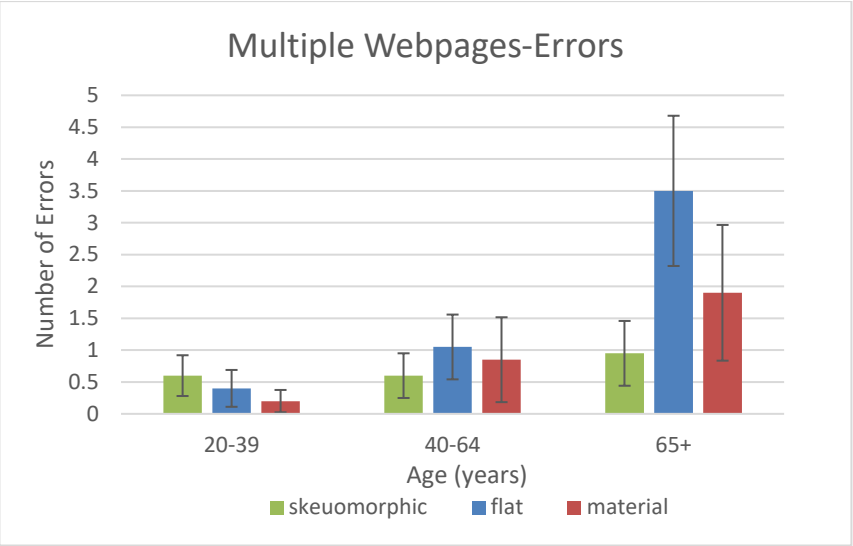


Figure 4.7 - Average and standard deviation of the errors made in task «multiple webpages» per group of participants

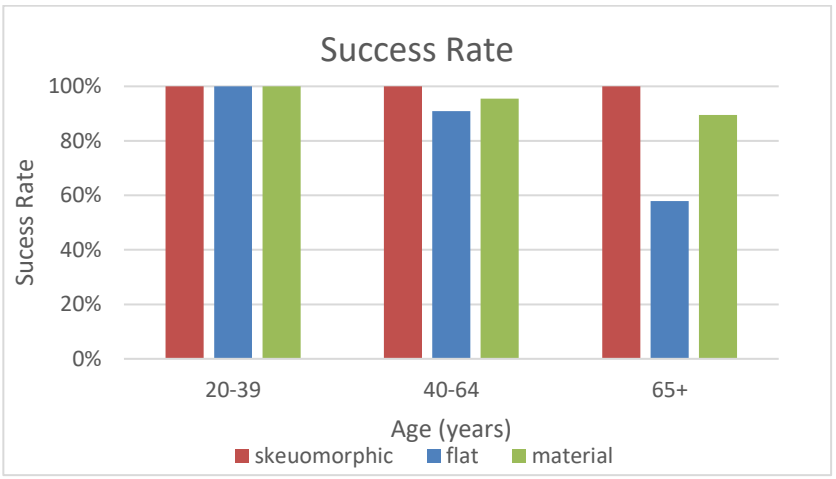


Figure 4.8 - Success of the task «multiple webpages» represented in percentage

4.2.4 Aesthetic Scales

Simple-Complex. Design had a main effect in the scale «Simple-Complex» ($F_{(2,114)}$=66.78, p<.001). Skeuomorphic design was considered the most complex design (M=4.45, SD=1.31), in comparison to flat (M=2.33, SD=1.32, p<.001) and material (M=3.1, SD=1.28, p<.001). Being also considered simpler than material design (p <.001) flat was, from all, perceived as the simplest design.

Results did not show a main effect of age group ($F_{(2,57)}$=1.64, p >.05), but there was a significant interaction between the two factors (F(4, 114)=2.88, p <.001). Older Adults considered skeuomorphic design simpler (M=4, SD=1.3) when compared to Younger Adults (M=5.2, SD=1.17, p<.05).

When comparing the different designs for each age group, Younger Adults regarded skeuomorphic significantly more complex (M=5.2, SD=1.17) than flat (M=2.35, SD=1.35, p <.001) and material (M=3.35, SD=1.05, p <.001) designs. The same happened for Adults who found skeuomorphic design

as more complex (M=4.15, SD=1.46) than both flat (M=2, SD=1.05, *p*<.001) and material (M=2.95, SD=0.97, *p*<.001). Older Adults were the only group to not show a significant difference between the three conditions in terms of complexity of design.

Rough-Fine. Results showed a main effect of design ($F_{(2,114)}$=112.21, *p*<.001). Skeuomorphic was considered the roughest design (M=3.63, SD=1.18) in comparison to both flat (M=5.98, SD=1.27, *p*<.001) and material (M=5.92, SD=1.27, *p*<.001). There are no differences between flat and material design.

Same as before, there was a significant interaction between design and age group ($F_{(4,114)}$=3.97, *p*<.01) and no main effect of age group itself ($F_{(2,57)}$=.02, *p*>.05). Adults perceived skeuomorphic as finer (M=4.1, SD=1.09) than Younger Adults (M=3.15, SD=1.15, *p*<.05).

Also, Younger Adults were the only ones to show a different opinion between designs. For this age group, skeuomorphic was considerably roughest (M=3.15, SD=1.15) than flat (M=6.2, SD=1.25, *p*<.001) and material (M=6.2, SD=1.25, *p*<.001) design.

Traditional-Modern. This scale showed no effects of design ($F_{(2,114)}$=1.70, *p*>.05), age group ($F_{(2,57)}$=.89, *p*>.05), nor the interaction between both factors ($F_{(4,114)}$=1.33, *p*>.05).

Boring-Interesting. Again, we found a main effect of design for the scale «Boring- Interesting» ($F_{(2,114)}$=4.19, *p*<.05). For this case, there was just one significant interaction between material and flat, where the first was considered more interesting (M=5.72, SD=1.09) than the second one (M=5.07, SD=1.63, *p*<.01).

There was also a significant interaction between design and age group ($F_{(4, 114)}$=7.15, *p* <.001) but no main effect of age group ($F_{(2, 57)}$=.78, *p*>.05).

Older Adults considered skeuomorphic design more interesting (M=6.45, SD=1.12) than Younger Adults (M=4.55, SD=1.47, *p* <.001).

All groups showed significant differences regarding the interestingness of the three designs. Younger Adults found skeuomorphic less interesting (M=4.55, SD=1.47) than material design (M=5.95, SD=1.12, *p*<.001), Adults found material more interesting (M=5.55, SD=0.92) than flat design (M=4.7, SD=1.73, *p*<.01) and Older Adults found skeuomorphic more interesting (M=6.45, SD=1.12) than flat (M=4.95, SD=1.8, *p*<.01).

Ugly-Beautiful. There was a main effect of design ($F_{(2,114)}$=3.86, *p*<.05) in the scale of beauty. Material design had a significant higher score (M=5.77, SD=0.93) in comparison to flat (M=5.1, SD=1.52, *p*<.01).

There was also a significant interaction between design and age group ($F_{(4, 114)}$=6.52, p<.001).

Both Adults (M=5.85, SD=1.62, *p*<.01) and Older Adults (M=6.4, SD=0.97, *p*<.001) considered skeuomorphic design more beautiful than Younger Adults (M=4.2, SD=1.67, *p*<.001). Once more, the youngest group opinion shows a big contrast to the other groups. Skeuomorphic design is associated with lower qualities (less beautiful) by this group of participants.

Also, both Younger Adults and Adults perceived the designs has different in terms of beauty. Younger Adults found skeuomorphic less beautiful (M=4.2, SD=1.67) than material design (M=5.9, SD=0.83, *p*<.001). Adults found material as more beautiful (M=5.7, SD=0.9) than flat design (M=4.75, SD=1.44, *p*<.05). As always, there was no main effect of age group over the scale ($F_{(2, 57)}$=2.72, *p*>.05).

Unreliable-Trustworthy. The only scale where age group had any main effect ($F_{(2,57)}$=7.85, *p*<.01) and where design had none ($F_{(2, 57)}$=2.25, *p*>.05).

Older Adults gave significant higher values of trustworthiness (M=6.57, SD=0.67) for designs in comparison to the remaining groups (M_A=5.65, SD=1.16, *p* < .01, M_{YA}=5.77, SD=1.24, *p*<.01).

Results also showed a significant interaction between design and age group ($F_{(4, 114)}$=9.23, *p* <.001).

Both Older Adults (M=6.2, SD=1.21, *p* <.05) and Younger Adults (M=6.15, SD=1.35, *p*<.05) regarded flat as more trustworthy than Adults (M=5.05, SD=1.53).

Both Adults (M=6.15, SD=1.06, *p*<.01) and Older Adults (M=6.95, SD=0.22, *p*<.001) considered skeuomorphic as more trustworthy than Younger Adults (M=4.9, SD=1.55).

Younger Adults regarded both flat (M=6.15, SD=1.35, *p*<.01) and material (M=6.25, SD=0.83, *p*<.001) as significantly more reliable than skeuomorphic (M=4.9, SD=1.55), showing once again the preference of minimalistic designs over the skeuomorphic one.

Adults found flat (M=5.05, SD=1.53) as less reliable than both material (M=5.75, SD=0.89, *p*<.05) and skeuomorphic (M=6.15, SD=1.06, *p*<.05) designs.

Hard-Easy. Results showed a main effect of design in the scales of «Hard-Easy» ($F_{(2,114)}$=7.21, *p* <.01). Here, material was considered easier (M=6.1, SD=0.88) than flat (M=5.4, SD=1.34, p<.001).

There was also significant interaction between design and age group (F(2, 114)=11.98, p<.001) and no effect of age group (F(2, 57)=1.18, p>.05). Both Adults (M=6.25, SD=0.99, p<.001) and Older Adults (M=6.85, SD=0.48, p<.001) considered skeuomorphic design easier to operate with than Younger Adults (M=4.75, SD=1.61). Also, for this case, every group regarded at least two designs differently in terms of easiness. Younger Adults regarded skeuomorphic (M=4.75, SD=1.61) as the hardest, compared to material (M=6.05, SD=1.61, p<.01) and flat design (M=6, SD=1.12, p <.05). Adults found material as easier (M=6.15, SD=0.91) than flat design (M=5.25, SD=1.61, p < .001). Finally, Older Adults thought that flat was harder (M=4.95, SD=1.36) than material (M=6.1, SD=0.62, p<.001) and that the latter was harder than skeuomorphic (M=6.85, SD=0.48, p<.001).

Slow-Fast. We found a main effect of design in the scale of «Slow-Fast» ($F_{(2, 114)}$=11.38, *p*<.001).

Here both material (M=6.12, SD=0.77, *p*<.001) and skeuomorphic (M=5.95, SD=0.93, *p*<.01) were considered faster than flat design (M=5.18, SD=1.50).

There was a significant interaction between design and age group ($F_{(4,114)}$=9.33, *p*<.001). Both Older Adults (M=6.85, SD=0.48, *p*<.001) and Adults (M=6.3, SD=0.95, p <.001) gave higher scores to skeuomorphic design than the youngest group (M=4.7, SD=1.35).

In terms of differences between designs for each group, Younger Adults found skeuomorphic slower than material design (M=6.05, SD=0.92, *p*<.01), while Adults found flat as slower (M=5.3, SD=1.65) than

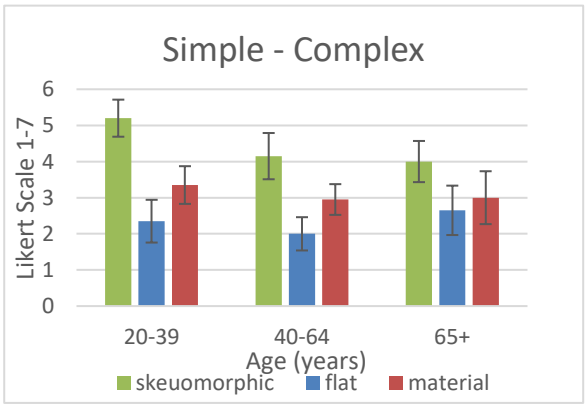
material (M=6.1, SD=0.89, p<.001). As for Older Adults, flat was perceived the slowest (M=4.7, SD=1.62) in comparison to skeuomorphic (M=6.85, SD=0.48, p<.001) and material (M=6.2, SD=0.51, p<.001). Once more, there was no main effect of age group ($F_{(2, 57)}$=3.02, p>.05).

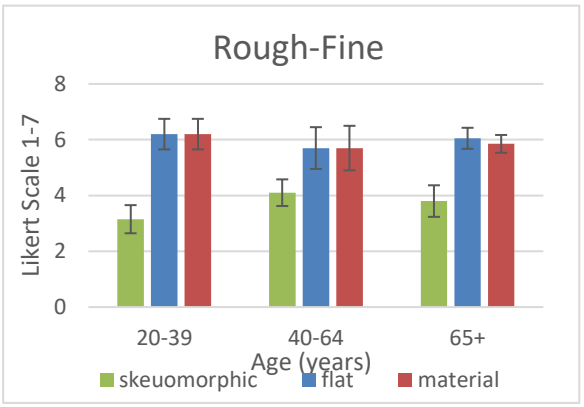
Preferable design. Together with aesthetic scales, we also analyzed the preferable design for each age group. As we can see in Figure 4.2, while Younger Adults prefer the minimalistic designs, Adults and Older Adults happen to find more appealing the more realistic one.

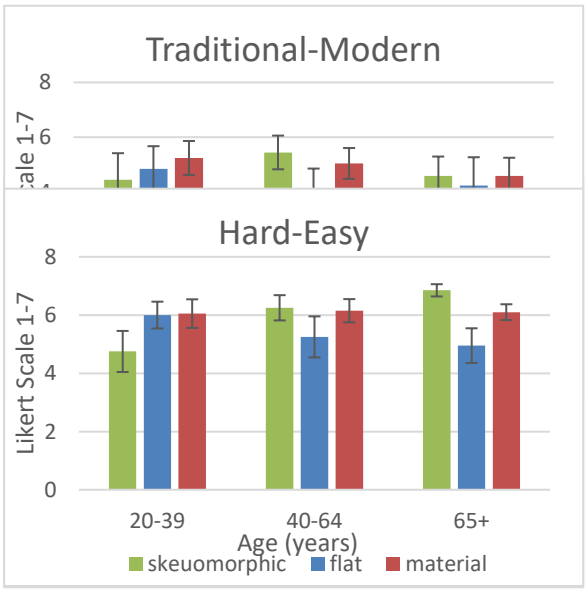
For the youngest group, there was no participant who chose skeuomorphic design as their favorite. What is more, 80% of the YA voted in material design as their favorite one.

As soon as age increases, skeuomorphic design becomes the leader. Half of the users from the age group Adults reported skeuomorphic as their favorite design, 30% chose material and the remaining 20% flat design. This trend towards the most complicated design is even more obvious for OA, with 75% of this group choosing skeuomorphic as their favorite. No participant of this age group voted for material design.

According to the Chi-Square test, there was an association between the age group and the preferable design (X^2(4)=28.89, p<.001). Younger Adults showed a tendency to prefer material design (Adj-res = 3.9) and Older Adults to prefer skeuomorphic design (Adj-res = 3.5). Adults did not manifest a preference for any of the designs.







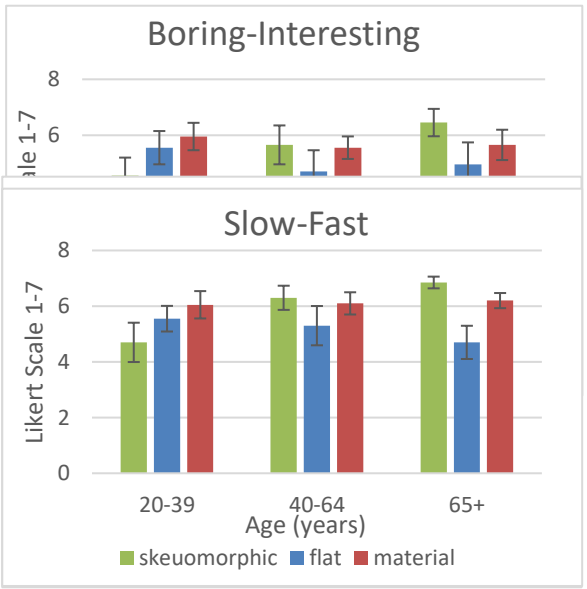


Figure 4.9 - Average and standard deviation of the evaluation of designs in the eight Aesthetic Scales per group of participants

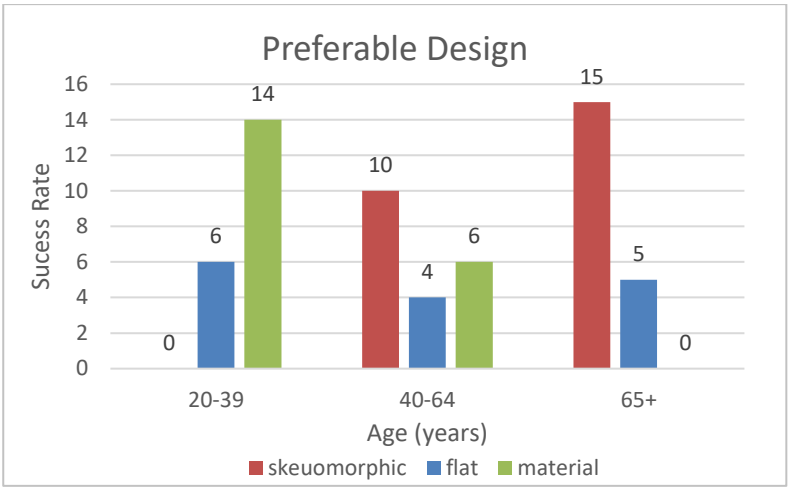


Figure 4.10 - Participants preferable design by each age group

4.2.5 Major Results

In this Section, we compare the results from the statistical analysis of three aspects (efficiency, effectiveness and aesthetic perception). To draw the conclusions, we focused in the patterns that occurred in the significant differences we found.

Older Adults was the group of participants that took more time to complete all tasks. They were also the ones who made more errors. Age group was the only factor that was constantly present in the results of the MIXED ANOVA repeated variables for all dependent variables related to performance. Also, this variable's significance value was always smaller than .001.

Results showed that Older Adults took a significant larger amount time to conclude each of the purposed tasks. As an example of these differences, this group took three (for «multiple webpages» and «icons») and four times longer («clickable objects») than Younger Adults.

They were also the ones who make a biggest number of mistakes, making five times more mistakes than Younger Adults in «multiple webpages», and almost the double of mistakes in «clickable objects».

All these supports, once more, the importance of age in participant's performance.

Participants made, on average, more errors in flat than in skeuomorphic design. It was also, on average, the slowest design to perform the task «icons». Design had a main effect in all variables related to effectiveness. This means that the condition in which participants operated the tasks influenced the number of errors made. For all tasks, flat design was the one more susceptible to mistakes, in comparison to skeuomorphic. In the task «clickable objects» there were more interactions, apart from the latter. Here, the number of errors made in both flat and material was bigger than when performed in skeuomorphic design.

In terms of efficiency, the design influenced the performance of the task «icons», where participants took, on average, longer time in flat than in skeuomorphic design. There were no significant differences

of efficiency for the remaining tasks.

In terms of performance, Older Adults were the only group to show significant differences between designs for the tasks «icons» and «multiple webpages». Flat was the design that more negatively impacted it and skeuomorphic was the one with the best results. In average, flat showed to be worse for participants performance (for efficiency of the task «icons» and effectiveness of all three tasks). When looking at each group, however, Older Adults were the only one where these design differences really affected their performance.

First, in the task «icons», Older Adults took a larger amount of time in flat than in the other designs. Here, the average of the time spent in flat was almost twice as much as than the one spent when doing it in skeuomorphic design.

Efficiency was also compromised for the task «multiple webpages», where flat took, once again, longer time than the other two designs. The errors made when performing this task in flat were also bigger in comparison to the other two conditions. In flat design, participants made more than the triple of the errors than when making in skeuomorphic and almost twice when performing it in material design. Also, in material design, participants gave twice the amount of errors than in skeuomorphic. For this task, in terms of effectiveness, skeuomorphic design was the best option.

Finally, flat design had also an influence in the success of the task «multiple webpages» for Older Adults. The success among Adults and Older Adults was not always 1 (the case where all tasks are completed). However, when doing the same task in skeuomorphic design, all of them were able to make it through the end. Results showed that flat design had a negative effect in the success of the task «multiple webpages» for Older Adults (55% of the participants from this group could not complete the task until the end). Although some Adults could not do the task until the end in flat, results did not show that these differences were significant enough.

The three designs were perceived differently in almost across all scales. Age group just affected the scale of trustworthiness. The way participants overall perceived the different designs had some common characteristics. First, flat was perceived as the simplest design and skeuomorphic as the roughest. This are expected results. Flat has simple features and skeuomorphic has much more detail.

What is interesting is that the remaining significant differences only involve material and flat designs. Material was considered more beautiful, easier, more interesting and faster than the latter.

As for the age group, it just had an effect in the scale «Unreliable-Trustworthy», where Older Adults gave higher scores than both Younger groups.

Younger Adults associated material and flat designs to a more positive evaluation. Younger Adults tended to find the simplest designs (material and flat, in order of preference) better than the most complicated one, skeuomorphic design. Comparatively to the others, skeuomorphic design was regarded as more «complex», «unreliable», «boring», «uglier», «harder» and «slower».

Between material and flat: material had larger mean values than flat in the positive semantic scales (more «interesting», «beautiful» and «trustworthy», «easier» and «faster»). However, these differences

were not significant enough. The opinion for the preferable design also supports these conclusions. Not even one participant of YA group reported skeuomorphic as its favorite design. Material stood out, by far, in the first place (with 80% of the participants voting for this design), with results from Chi-Square test supporting there was a tendency towards preferring this design.

Adults showed larger differences between flat and material. However, the age group did not manifest a clear preference towards a specific design type. Contrarily to the latter, this group of participants seemed to have a much more positive opinion regarding skeuomorphic design. Not only it was, for the majority, the preferable design, but it also had the highest mean values in the positive semantic attributes of the scales. Results showed, however, there was not a clear tendency to prefer any of the three designs. This age group seems to be the one where opinions diverge the most.

Also, it was the group where the two simplistic designs (flat and material) had more differences. They found material as «easier», «faster», more «beautiful» and more «interesting» than flat design. This also indicates that flat design has a more negative connotation, which was not present in YA.

For OA, flat design is always present in the interactions. Positive evaluation goes more to skeuomorphic. Older Adults showed a strong preference regarding skeuomorphic design (with 80% of the participants choosing this condition) and results showing a tendency to prefer this design. This age group also found the design more «interesting», more «beautiful», more «trustworthy» and «easier» than Younger Adults. These captures the differences that seem to appear between the two age groups.

What is more, flat design was always present in the significant interactions that involved Older Adults. It was perceived as slower and harder than material design and less interesting than skeuomorphic.

4.3 Qualitative Results

Inspired by an online study to 100 web professionals, regarding their opinions towards flat design [11], we chose to add a qualitative study to our analysis. In the last part of the questionnaire we asked the participants to express their opinion towards each design and give comments about what were the adjectives that best described them. After, we counted them (Appendix C.8) and used the results to do findings described in this section. Each participant could give as many attributes as they wanted. Adjectives with the same meaning were grouped together in just one.

Flat design. The five things that Younger Adults associate more with flat design are: «intuitive» (25%), «simple» (30%), «familiar/used to them/user friendly» (25%) and «clean» (15%). These results show how used to this design Younger people are. This was very different from the participants of the older groups, which thought of flat design mostly as: «monotonous/boring» (40% of Adults and 45% of Older Adults), and «not careful enough» (15% for Adults and 20% for Older Adults). Finally, Adults also used the adjective: «clean» and «simple» for flat design, which were not once used for Older Adults.

[11] https://usabilla.com/blog/flat-web-design-is-here-to-stay/, last accessed 2018/09/26

Material design. This simplistic design had almost the same results as the previous one. Interestingly, when questioning participants from the youngest group, the adjective «familiar/common» was not once used. Instead, they considered it to be «curious/different» (15%). Some participants of this group associated material design with «simple» (15%) and «appealing» (15%).

For older groups of people, they continued to view this simplistic design as «boring/dead» (20% of Adults and 15% of Older Adults) but with a less percentage than flat design.

Skeuomorphic design. When we asked the participants about their thoughts on skeuomorphic design, participants from all groups referred it as «a design that looks is trying to be familiar». The other observation made by all different groups was that «it had too much information».

However, in some aspects, skeuomorphic design was viewed differently in all age groups. Younger Adults viewed it as a «detailed/careful design» (15%). Older participants used adjectives that were not used for Younger ones, mainly «colorful» (20% of Adults and 25% of Older Adults), «perceptible/with an easy reading and comprehension» (15% of Adults and 30% of Older Adults).

An important characteristic in skeuomorphic design was the use of elements such as «shelves» and «coupons» to decorate and help to perform the task.

Other comments were made, and some Younger Adults pointed out that, although minimalistic design was their preferable option, it still lacks a lot of detail. Attention to make something appealing a was big request for this group.

Older Adults focused much more in the functionality of the system. They referred to the help and instructions that should be clear and that the buttons should be visible and understandable. Most of the time, what happened was that they preferred skeuomorphic because of its colors and its easiness to see. When confronted with the differences between flat design and material many older adults did not point the use of shadows around the elements.

4.4 Discussion

In this Section, we use the major results of the experiment to answer the research questions raised before (Section 3.1) and focus in the limitations of the study.

4.4.1 Answering Research Questions

Do other factors beyond age such as participant's familiarization and use of technology have an effect in task performance and aesthetic preferences? Results showed there is an impact of the factors (age, familiarization with technology and use of technology) in both efficiency and effectiveness. Only aesthetic preference did not seem to be affected by them.

Between all factors, age was proven to be, by far, the most important one. Not only did it explain from 36.9% to 83% of the results obtained, but it was also present in most of the resulting modules (only failing in the effectiveness of «clickable objects» for material design). The increase of this IV was

responsible for the increase of the errors made and the time spent during a task. The increase of age had a larger influence in the efficiency of both «clickable objects» and «multiple webpages» than in the task «icons». This goes in accordance with the results of related work (Section 2.1) that state the difficulty of doing more tasks that are complicated for Older Adults.

Familiarization with technology and some devices scales (Computer and Mobile Phone) were only proven to be significant for some specific conditions (Section 4.1.4), which might have to do with some limitations of the study (Section 4.4).

As a result, it made sense to study age as a factor. We then divided participants in three groups, studied along the document (Section 4.2).

Does age and/or design play an effect on task performance? Age group had always a main effect in both efficiency and effectiveness of every task. Older Adults group were the ones who took longer time and made more errors. This shows us, again, how age is important to the performance of a participant.

When looking at all participants, there were differences between designs. In average, the task «icons» took longer in flat than skeuomorphic design. In terms of effectiveness, it was also worse than skeuomorphic for both «icons» and «multiple webpages». For the task «clickable objects», skeuomorphic was, in average, the condition where participants made less mistakes.

Though, when seeing each group individually, Older Adults were the only one whose performance depended in the design which they were operating. Whenever there was an interaction between age group and design (time of «icons» and time and errors of «multiple webpages»), flat was the worst option in comparison to the other designs. Skeuomorphic was the best option for the effectiveness of the task «multiple webpages».

The success of «multiple webpages» was also dependent on age. While all members of the Younger Adults group finished the task with success, some participants of the older groups could complete it, when it was performed in minimalistic designs. Results showed that flat design was responsible for the main differences that occurred in Older Adults, being this condition the one where they failed the most.

Does age and/or design play an effect on aesthetic preference? Age group impacted all aesthetic scales studied (Section 3.9), except for the one of «Traditional-Modern». The main differences were between the Younger Adults group and the older groups (particularly the Older Adults).

First, Younger Adults preferred the simplest designs over skeuomorphic. The latter was associated as more (higher values in the semantic scales) «complex», «unreliable», «boring», «ugly», «harder» and «slower» than flat design. Most of the participants of this group pointed material as their favorite design and none of them chose skeuomorphic as their preference. Qualitative results pointed some important reasons why this could be. Younger Adults reported that « they are used to» flat, perceiving it as «intuitive» and «user-friendly». Material design was associated with a sense of «newness». Although skeuomorphic design was more rejected, it is important that adjectives such as «detailed» and «careful» were associated with it during the comments phase.

Adults showed a much different opinion. Opposite to Younger Adults, the group's preferable design

was skeuomorphic. It was also the design with highest rates in the positive semantic scales. Contrarily to Younger Adults, there was a much bigger difference between material and flat design. The first was rated as «easier», «faster», more «beautiful» and more «interesting» than last design. Also, for this group, according to the qualitative results, flat design was associated with «boring», «and not careful enough», but also appreciated as «simple/clean». Material was also associated with being «boring», but with a less percentage of participants sharing this opinion. The adjectives diverge a lot from the opinion of what the youngest group had.

Older Adults were the group with the most differences comparatively to the first. Not one of them chose material design as their favorite and the clear majority pointed for skeuomorphism. The latter was rated as highest in the positive semantic scales and had larger values than Adults. Factors that may be responsible for the choice of this design in both older groups is a better comprehension of the information. Skeuomorphic was «colorful», «perceptible» and «with an easy reading». All groups said though, that it had «too much information».

Concluding, as age increases there seems to be a tendency to find more attractiveness in the more detailed designs over the more simplistic ones.

The fact that flat and material design become worse options with the increase might be since Young Adults are constantly adapting to change and have been using this design a while ago. We will make an experiment to understand whether the learning process is the factor behind a worse performance in flat design than in skeuomorphic for Older Adults.

4.4.2 Limitations

From the conclusions outlined in the main results of the previous sections, the experiment has faced some limitations. Here we state some solutions to face the problems that we encountered with the experiment.

Have a larger user sample with a bigger range of familiarization with technology. As reported in Section 4.1.4, contrarily to age, familiarization with technology was not a substantial factor for predicting the dependent variables in the study. This does not match with its recognized importance [1]. These results might have to do with the fact that there was not enough evidence to support this theory. The sample did not range an enough diversity of familiarization with technology.

When confronted with the question of participating in the experiment, people who were not used to deal almost in a daily basis with technology, did not feel comfortable enough to take the test. Therefore, we might attribute this output to the fact that there were not enough people to model these differences.

Reduce the effect of memory. Both task and click did not show significant differences in time. We believe that the factor that played a role in these results was the effect of memory.

Participants remembered the previous task and were faster in the first interactions. As mentioned in section 3.6, we believe all possible measures were made to diminish this effect.

5 Learning experiment

The previous experiment showed there is a significant difference between designs in terms of time, errors and aesthetic appreciation. Results were especially considerable for the Older Adults group.

A second experiment was made to understand whether the learning factor may influence the three aspects mentioned above. Therefore, our fourth and last research question is:

4. Does session (repeated use) and/or design play an effect on Older Adults performance?

The task used for this analysis was the «icons» task. We chose it because, according to our previous results, it was among the ones who showed the most significant differences (together with the task «multiple webpages»). Due to our time limit, we opted for the least complex of them.

This experiment was done with 9 participants, ranged from 69 to 93 years old (M=76.3, SD=8.15) (correspondent to our previous Older Adults group), from «Casa de Repouso Embaixador». The design of all icons is the same as the first experiment.

5.1 Procedure

Each participant was evaluated over four sessions, with one day apart from each other. In each session, the user performed the task «icon» in the three different design conditions. However, this time, only three of the sixteen types of icons were searched: «book», «clock» and «weather» (Table 3.2).

Like the previous experiment, participants completed three pages of «icons» for each design, totaling of nine pages. Once they completed the search for the three icons, they moved on to the next design until everything was finished. Equally to the last analysis, the order of each design was randomly chosen, and the icons were presented in an arbitrarily position, in a 4 x 4 matrix.

5.2 Data Analysis

For this experiment, we gathered time and errors. To study efficiency and effectiveness, we used two-way repeated measures ANOVA. This test was used because every participant does the same tasks in the three design conditions over four sessions.

Results can be seen in more detail in Appendix D. We use the word “design” to refer to the design condition in the test (skeuomorphic, flat or material) and “session” to refer to the session number.

Efficiency. Results from the statistical test show a significant interaction between design and session ($F_{(2.37,18.9)}$=3.42, p<.01). Concerning contrasts between session, there was a significant difference between the first session (M=17 s, SD=9.85 s) and the third one (M=9.45 s, SD=3.33 s, p<.05) for flat design. Material design showed the most significant differences between sessions. The time spent in session one (M=14.86 s, SD=7.19 s) was significantly higher than session four (M=5.62 s, SD=1.53 s, p<.05). From the third to the fourth session there was also a significant difference (p<.05). Skeuomorphic design saw a similar behavior. The time spent in the last session (M=5.87 s, SD=1.64 s) was lower than

the second (M=7.34 s, SD=2.82 s, p<.05) and third one (M=7.27 s, SD=2.6 s, p<.05).

Concerning contrasts between designs in the same session, skeuomorphic design (M=8.84 s, SD=4.01 s) took less time than flat (M=17s, SD=9.85 s, p<.05) and material (M=14.86 s, SD=7.19 s) in the first session. The same happened for the second and third sessions (see Appendix D). In the fourth session, however, the significant differences were only between material (M=5.62 s, SD=1.53 s, p<.01) and flat designs (M=7.97s, SD=1.52 s, p<.01).

Finally, there was a main effect of design ($F_{(1.16,9.3)}$=14.22, p<.01). It stated that the skeuomorphic design took less time (M=7.33 s, SD=2.77 s) than both flat (M=12.02s, SD=5.49 s, p<.05) and material designs (M=9.98 s, SD=4.73 s, p<.05). Material also took less time than flat.

There was a main effect of session ($F_{(3,24)}$=6.95, p<.01), where times in session one (M=13.44 s, SD=7.02 s) and three (M=8.43 s, SD=3.05 s, p<.05) were significantly bigger than in the last one (M=6.48 s, SD=1.89 s, p<.05).

Effectiveness. Although there is an indication of a main effect of design ($F_{(1.15,9.2)}$=5.56, p<.05) the multiple comparisons showed no differences between designs.

Results showed, however, there was a main effect of session ($F_{(1.8,14.5)}$=6.67, p<.05). In average, the number of errors made in the first session (M=1.77, SD=1.72) were significative higher than in the second one (M=0.78, SD=0.76, p<.05). Apart from the latter, there were no more significant differences between sessions. There was also a significant interaction between design and session ($F_{(1.6,13)}$=7.68, p<.01). In the second session, the number of errors made in flat were higher (M=1.11, SD=1.09) than in skeuomorphic (M=0.33, SD=0.47, p<.05) and material designs (M=0.89, SD=0.74, p<.05).

Also, in the fourth session, skeuomorphic (M=0.11, SD=0.31) had a lower number of errors in comparison to flat design (M=0.33, SD=0.47, p<.05). This time, there were no significant differences between skeuomorphic and material.

Concerning design, the differences in the number of errors changed between sessions solely in flat. In the first session, the number of mistakes given in this condition were three times more, in average, (M=3, SD=2.64) in comparison to the third one (M=1, SD=0.82, p<.05). Also, the number of errors given in this design in the third session (M=1, SD=0.82, p<.05) were higher than the last one (M=0.55, SD=0.68, p<.05). There were no effects between the first and second sessions. This indicates an effect of repetition in the third session and again in the fourth one.

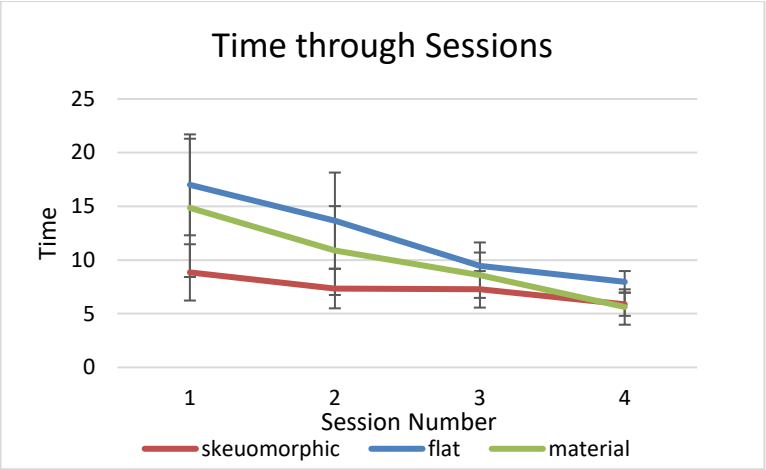


Figure 5.1 - Average and standard deviation of the time spent for each Session

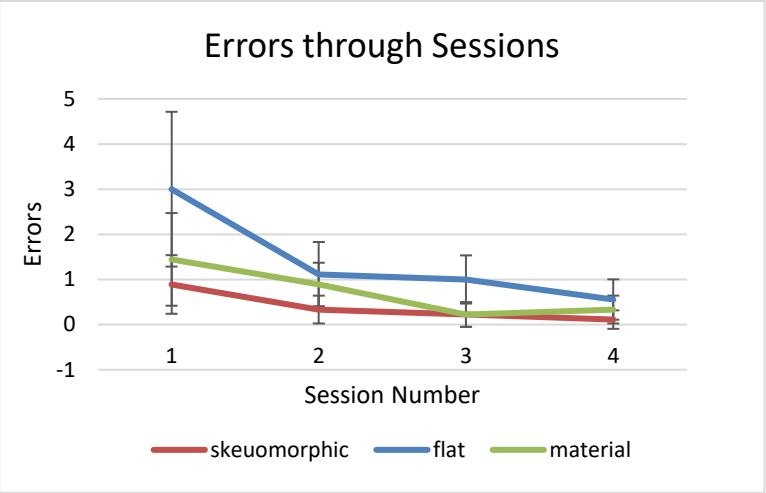


Figure 5.2 - Average and standard deviation of the errors made in each Session

5.3 Discussion

This Section answers the fourth research question, raised in the beginning of this experiment.

Once again, we state the limitations of the study and propose a solution to the problem.

5.3.1 Answering Research Questions

Does session (repeated use) and/or design play an effect on Older Adults performance? Repeated use influenced both efficiency and effectiveness of Older Adults.

In terms of efficiency, there is an effect of the repetition for all the design conditions. The time spent in skeuomorphic design, in session four was significantly lower than in the second and third sessions. This means that, for skeuomorphic design, participants improved their efficiency only after three sessions. Material design had a similar behavior, with the effect felt between the third and fourth session. For flat design, the impact was felt earlier, in the third session, in which the time spent doing the task lowered.

Although there was a convergence of results, flat still takes longer time than material design, at the end of the experiment.

In terms of effectiveness, the biggest differences between designs were felt in the second session.

Here, participants gave a higher number of errors in flat design than in material. And a higher number of errors in material than in skeuomorphic. In the fourth session it is just observed a difference between flat design and skeuomorphic, which showed to have more errors than skeuomorphic.

The only design where we can observe an effect of repetition in terms of efficacy, was flat design, with a significant reduction of the errors between the second and third sessions and the third and fourth.

For this situation, there is a convergence of results in the first sessions, that tends to stabilize. Although it improved, in the last session, flat design is still worse than skeuomorphic in terms of effectiveness.

5.3.2 Limitations

Explore participants' individual differences. The sample was small due to the time limit. The participants of the study showed a high diversity of individual cognitive characteristics. We noticed that the time taken to conclude the task varied significantly in the participants. We believe this was due to a variety of factors concerning the participants' health. Deteriorated memory made some participants seem they were doing the experiment for the first time while others knew the exercise by heart. Reduced visual capabilities increased the time the participants took to adapt to the monitor due to its brightness. Finally, hand tremors affected the ability and time it took point at a target.

We believe the solution is to previously study these individual factors (cognitive, visual and physical capability) and divide the participants according to the results.

6 Guidelines for design

Considering the results of the experiments, we developed a set of guidelines for design of future interfaces.

Though the focus was describing guidelines for design for each age group, we drew a conclusion for designing for the entire population:

When implementing an interface for all ages, the designer should be careful in the use of flat design, with the risk of compromising participants' overall performance. According to previous results, the time taken to search for icons was, on average, larger in flat than in skeuomorphic design. If we take into consideration all participants, the time taken in flat was approximately one and a half times higher than in the more realistic design. Additionally, on average, users made more mistakes in flat than in skeuomorphic design for tasks «icons» and «multiple webpages».

Flat design penalized the performance of Older Adults, which results affected the overall performance of the participants.

Focusing on a more inclusive system, and in having a design able to provide the best performance, we recommend the use of the other two design conditions (material and skeuomorphic).

Designers should then opt for features of these two designs: visible and comprehensible elements, with images that are in accordance to mental models common to all users (from a younger to older age). In addition, the designer should ensure the elements of the interface (e.g.: buttons, arrows) are legible and have with enough contrast. Elements such as icons and buttons should have a certain degree of shadow to hint that they can be clicked.

The remaining guidelines of this Section are divided according the results of the first (Section 6.1) and second experiment (Section 6.2).

6.1 Guidelines per Age Group

As our study is about age and its effect, we divided these recommendations by the different age groups. For each group, we recommend the best design according to the goal the designer is looking for (efficiency, effectiveness or aesthetic appeal).

6.1.1 Younger Adults (20-39)

To focus on efficiency or effectiveness, opt for any design. Younger Adults take relatively the same amount of time and errors in all three designs. This means that, in terms of performance, it is not needed to adapt the design to this age group.

To focus on aesthetics, choose the more minimalistic designs. Results from aesthetic scales and preferable design showed that Younger Adults tend to prefer simplicity. «Unnecessary», «complex»,

«roughest», «less interesting», «hardest» were attributes associated to skeuomorphic design. The group found this design less «trustworthy». Thus. Younger Adults showed a clear preference towards keeping things as clean and as simple as possible.

It was shown that this group prefers material design to flat design. According to the qualitative results, this might have to do with the fact that material gives «a sense of difference».

Younger Adults referred that the attention to colors and details was interesting. However, considered skeuomorphic design to bring this attention to an excess.

For this group, designers could and should opt for minimalistic designs but should be aware that there should be characteristics of skeuomorphic design that should be incorporated (shadows, gradients, more colors, etc.). This would avoid the amount of errors from flat design and create a sense of novelty to the interface, which we think is necessary for this group.

Overall, the page should keep its simplicity and, if opting for one of the two designs, we recommend material as a better option (it was shown to have a better performance and higher scores in aesthetic scales).

6.1.2 Adults (40-64)

To focus on performance, adopt the same behavior mentioned for Younger Adults. Since Adults had the same behavior as Younger Adults, the measures adopted should be the same.

To focus on aesthetics, avoid flat design. When compared to the Younger Adults, this group of participants have a much more positive opinion towards skeuomorphic design («more beautiful») and a more negative towards flat. Material was considered more «interesting», more «beautiful», «faster», and «easier» to operate than flat. Flat was perceived as the least «reliable» of the three conditions.

Both material and skeuomorphic can be used when trying to appeal this group. Characteristics common to both designs, such as shadows in turn of the elements, should be incorporated when designing a page/icon.

6.1.3 Older Adults (65 +)

To focus on the efficiency of tasks like «icons» and «multiple webpages», avoid flat design.
To focus on the effectiveness of tasks like «multiple webpages», avoid flat and use skeuomorphic design. Older Adults were the age group that took longer time and made more errors. We should take this group into the most consideration when maximizing performance.

This age group also showed significant differences in performance when changing design conditions. Flat design was the worse in terms of both efficiency and effectiveness, when significant differences between designs were found. Older Adults took a larger amount of time in flat than in the other designs in the task «icons», taking almost twice as much as in skeuomorphic.

The same happened for the task «multiple webpages». This task reported more errors when performed in flat, than in the other designs: in flat, participants made more than the triple of the errors than when making in skeuomorphic and almost twice when performing in material design. Flat design was also

responsible for the lack of success in the task «multiple webpages» for some participants.

Choose to draw skeuomorphic elements when worried about aesthetics. The overall page should be kept simple. Among all designs, Older Adults preferred skeuomorphic design (with 75% opting for this condition). While flat and material were associated to a possible larger difficulty of use (perceived as «harder» and «slower» in the semantic scales), skeuomorphic was associated as more «interesting» (larger values for the scale «Boring-Interesting»).

One of the most criticized components of both flat and material design was that they tended to be «boring/blend», contrary to the skeuomorphic one. Participants from this group emphasized the use of color and the fact that was more comprehensible. Although this happened, we must understand that the webpages that were drawn in this experiment were relatively simple in comparison to what used to be done in skeuomorphic design webpages.

When confronted to the fact whether decorative elements such as shelves and coupons helped in the performed task, most participants (60%) from this age group did not defend its use. Those elements often made «noise» in the webpage, without adding any effect or help.

In conclusion, we support a design where symbols clearly represent their function and where stylized elements should are avoided (when the concept is too hard to understand). The designer should always make sure that an element is understandable without having to have previous knowledge of other interfaces.

6.2 Including the Repetition Factor

The mentioned guidelines are especially appropriate for the first interactions. From the second experiment we noticed that repetition does have an effect in both efficiency and effectiveness. This means that some of the difficulties encountered can be resolved through time. Designing for a system that is not so worried about the first interaction, but yet will be used many times, should consider the following:

For flat design, the effect of repetition has an earlier impact. For the other two designs, the impact is shown later. In terms of effectiveness, the effect of repetition just worked for flat design. In this task, (proven to be the most susceptible to mistakes) the repetition factor did lead to an improvement. Our results showed that this effect comes, on average, in the fourth interaction with the system. In the other designs, where there were a smaller number of errors made, there was no impact of such repetition.

In terms of efficiency, for all designs there were significant improvements throughout the sessions. In both skeuomorphic and material designs these improvements come in the fourth session. In flat design, however, these improvements seem to start earlier, in the third interaction with the system.

Although there are improvements in flat for both efficiency and effectiveness, the design continues, in the last session, to be a worse choice in comparison to others.

In conclusion, the impact of the learning experiment is much larger in the design where in the beginning there are more difficulties.

7 Conclusions

This chapter focuses in the main conclusions that were derived from our studies, together with the goals that were achieved. We also present a set of future research avenues this project can be extended to understand better the connection between age and the interface design.

7.1 Goals Achieved

Flat, skeuomorphic and material are three design approaches widely discussed in the design community. However, empirical studies are lacking in comprehending their effects on users and which one is the best solution. Although there are some studies regarding this topic, the effects that some user's characteristics might have, such as age, were still not studied. Our purpose was to understand if this factor had any impact in the way that users perceived and use these three design conditions.

Our first goal achieved was a research of the present state of the art. We started by gathering the main differences that occur with Older Adults (65+) in both cognitive and emotional ways and how they might impact the way users interact with an interface. For instance, Older Adults are often less secure when dealing with new tasks, which might bring a need of more help and guidance in the beginning. Also, cognitive functions such as memory, visual capacity, attention and decision-making processes are, many times, compromised. We then focused in the measures most used to try to adapt to these changes (e.g.: bigger elements and lettering, bigger contrasts, smaller length of information given, use of more visual cues). We finally addressed the three types of design mentioned above in the light of the Aesthetics field. We discussed their main issues and characteristics and in which way this aesthetic appreciation can affect user satisfaction and performance.

Our analysis confirmed that, although it has a great importance, Aesthetics was not very present in the studies regarding Older Adults' participants (Section 2.4). Experiments tend to focus mainly on cognitive functions and differences in performance. Also, studies that involve the three designs approaches scarcely include the oldest groups.

Our second goal was to answer the research questions (Section 3.1 and 5.3.1) that would fill those gaps found in previous literature (Section 2.4). To do so, our first study evaluated the aesthetic response and overall performance of participants, considering the age factor. Based on our data, we presented models of efficiency and effectiveness, which inform opportunities for a better understanding towards how different people react towards each design. We found that, in comparison with familiarization and use of technology, age was the most important factor in modelling performance. This was the first indicator that age is indeed necessary to be considered when we change designs. The fact that the other factors did not show the expected impact might have to do with the limitations reported in the study (Section 4.4).

Having proven that age was the factor to be considered, we divided our participants into three age groups (Younger Adults, Adults and Older Adults) and compared them. Our results showed once more that age was a major factor in efficiency and effectiveness. Older Adults was the group of participants that took more time to complete the tasks and the ones who make more errors. Flat design made them

compromise their performance specially in comparison to skeuomorphic design. The time this age group spent in the simplest task, «icons» was bigger in flat, and the overall performance of the most complicated task, «multiple webpages» was also compromised by this design.

What is more, in simplistic designs (flat and material), some participants of this age group could not finish the proposed task. The same did not happen when performed in skeuomorphism. Our results pointed flat as the condition that compromised the success in this task (45% of the participants of this age group could not complete it entirely when doing it in this design).

For all participants, on average, flat design was the one responsible for users giving more mistakes. This means that for effectiveness, when looking at the entire population, flat was shown to be not a good option. In terms of efficiency, flat was also worse, on average, in the task «icons».

Aesthetic preference depended also in the age group. While Youngsters showed preference for the more simplistic designs (flat and material), Adults and Older Adults showed preference for the characteristics of skeuomorphic. Qualitative results showed this might have to do with the fact that symbols in this last design are more comprehensible and buttons and other elements are more visible due to their shadows and gradients.

Our fourth research question was related to the repetition of the tasks and whether the behavior we saw through the results would continue or not. To do so, a second experiment was made. We repeated the task «icons» through 4 sessions and studied the changes in efficiency and effectiveness.

For effectiveness there was the effect of repetition for flat design in the fourth session. Here, the number of errors made started to diminish. In terms of efficiency, for all designs there were significant improvements throughout the sessions. In both skeuomorphic and material designs these improvements came in the fourth session. In flat design these improvements seem to start earlier.

The evaluation of the results helped creating new possible design guidelines (third goal), aligned with our main goal of creating interfaces that are more adaptable each user group. In accordance to results from the second experiment, we also gave indications for how many times a user should use a system so that such difficulties can start to be surpassed.

Though, designers should be aware that skeuomorphism can be a very complicated design, adding complexity where many times is not needed. Therefore, it is important to keep things simple, but always assure the understandability, highlight the clickable elements in the design, and make use of images that are in accordance to conceptual models common to all population, especially when the goal is to have an inclusive design.

7.2 Future Work

This study serves as a model for future inclusive studies on different design characteristics. Although some conclusions could be drawn from the study, the process of creating interfaces according to a specific design is dependent on several factors. Many of them were not considered in this experiment. This is partly due to the time frame of the experiment and our target population (Older Adults, who take longer and need more assistance) and especially because this is an extremely complex topic, involving many aspects, hard to put all together.

As an example, in this case, both tasks and design were relatively simple, which might not represent

what is out in the real world. Testing both the amount and complexity of information presented, in all three design types could allow to understand into what extent we can use a specific design. It could be useful to put real life examples of different webpages.

Another aspect not tested was the first impression. It would be interesting to make tests of visualizing a webpage for a specific limit amount of time, in all three designs. Participants could report what is the website about and which were the elements that were more retained.

An interesting factor that was also not analyzed in this experiment was movement. Icons, buttons and other elements did not provide visual feedback when passing through them. A combination of movement in future studies would be interesting, since it is something very present in interfaces.

Most of all, the most important improvement would be a bigger population sample and a more complete study in the individual characteristics of the participants. This study took a great amount of time for each user and required the interviewer to be personally with each of them. Therefore, with a smaller study and simpler tasks, a larger sample of the population could be gathered (online for example). A new experiment could include their motor and visual capabilities and correlate it with their performance.

References

1. S. M.Zabed Ahmed, Cliff McKnight, and Charles Oppenheim. 2004. A study of users' performance and satisfaction with the Web of Science IR interface. *Journal of Information Science* 30, 5: 459–468. https://doi.org/10.1177/0165551504047018
2. Ahamed Altaboli and Yingzi Lin. 2012. Effects of unity of form and symmetry on visual aesthetics of website interface design. *Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting*: 728–732. https://doi.org/10.1177/1071181312561152
3. Yvonne Barnard, Mike D. Bradley, Frances Hodgson, and Ashley D. Lloyd. 2013. Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior* 29, 4: 1715–1724. https://doi.org/10.1016/j.chb.2013.02.006
4. Lisa Feldman Barrett and James A. Russell. 1999. The Structure of Current Affect. *Current Directions in Psychological Science* 8, 1: 10–14. https://doi.org/10.1111/1467-8721.00003
5. Michael Bernard, Chia Hui Liao, and Melissa Mills. 2001. The effects of font type and size on the legibility and reading time of online text by older adults. *CHI '01 extended abstracts on Human factors in computer systems - CHI '01*: 175. https://doi.org/10.1145/634164.634173
6. Upasna Bhandari, Tillmann Neben, Klarissa Chang, and Wen Yong Chua. 2017. Effects of interface design factors on affective responses and quality evaluations in mobile applications. *Computers in Human Behavior* 72: 525–534. https://doi.org/10.1016/j.chb.2017.02.044
7. Leonieke C. van Boekel, Sebastiaan Tm Peek, and Katrien G. Luijkx. 2017. Diversity in Older Adults' Use of the Internet: Identifying Subgroups Through Latent Class Analysis. *Journal of medical Internet research* 19, 5: e180. https://doi.org/10.2196/jmir.6853
8. Letizia Bollini. 2016. From Skeuomorphism to Material Design and back. The language of colours in the 2nd generation of mobile interface design. October.
9. Ivan Burmistrov. 2015. Human-Computer Interaction – INTERACT 2015. 9299, September. https://doi.org/10.1007/978-3-319-22723-8
10. Selene Cansino, Evelia Hernández-Ramos, Cinthya Estrada-Manilla, Frine Torres-Trejo, Joyce Graciela Martínez-Galindo, Mariana Ayala-Hernández, Tania Gómez-Fernández, David Osorio, Melisa Cedillo-Tinoco, Lissete Garcés-Flores, Karla Beltrán-Palacios, Haydée Guadalupe García-Lázaro, Fabiola García-Gutiérrez, Yadira Cadena-Arenas, Luisa Fernández-Apan, Andrea Bärtschi, and María Dolores Rodríguez-Ortiz. 2013. The decline of verbal and visuospatial working memory across the adult life span. *Age* 35, 6: 2283–2302. https://doi.org/10.1007/s11357-013-9531-1
11. Kathleen Cercone. 2008. Characteristics of Adult Learners with Implications for Online Learning Design. *Association for the Advancement of Computing In Education Journal* 16: 137–159. https://doi.org/Article
12. Young J. Chun and Patrick E. Patterson. 2012. A usability gap between older adults and younger adults on interface design of an Internet-based telemedicine system. *Work* 41, SUPPL.1: 349–352. https://doi.org/10.3233/WOR-2012-0180-349

13. Constantinos K. Coursaris and Wietske Van Osch. 2016. A Cognitive-Affective Model of Perceived User Satisfaction (CAMPUS): The complementary effects and interdependence of usability and aesthetics in IS design. *Information and Management* 53, 2: 252–264. https://doi.org/10.1016/j.im.2015.10.003
14. James H Creager and Douglas J Gillan. 2016. Toward Understanding the Findability and Discoverability of Shading Gradients in Almost-Flat Design. 339–343.
15. Ian J. Deary, Janie Corley, Alan J. Gow, Sarah E. Harris, Lorna M. Houlihan, Riccardo E. Marioni, Lars Penke, Snorri B. Rafnsson, and John M. Starr. 2009. Age-associated cognitive decline. *British Medical Bulletin* 92, 1: 135–152. https://doi.org/10.1093/bmb/ldp033
16. Jacob Dittmer and Johan Hägerhult. Metaphorical Connections to Interfaces.
17. T Esteves, J; Mullig. 2016. Flat design aplicado ao design de interfaces: uma análise acerca da estética visual e da usabilidade da tendênia Flat. *Blucher Design Proceedings* 9, 2: 1–2. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf%5Cnwww.un.org/.../population/.../WPA2009/WPA2009
18. Peter Gregor, Alan F. Newell, and Mary Zajicek. 2002. Designing for dynamic diversity. *Proceedings of the fifth international ACM conference on Assistive technologies - Assets '02*: 151. https://doi.org/10.1145/638249.638277
19. T. A. Hart, B. S. Chaparro, and C. G. Halcomb. 2008. Evaluating websites for older adults: Adherence to "senior-friendly" guidelines and end-user performance. *Behaviour and Information Technology* 27, 3: 191–199. https://doi.org/10.1080/01449290600802031
20. Kai-Chun Hou and Chun-Heng Ho. 2013. A Preliminary Study on Aesthetic of Apps Icon Design. *IASDR 2013 5th International Congress of International Association of Societies of Design Research*: 1–12.
21. Hwan Hwangbo, Sol Hee Yoon, Beom Suk Jin, Young Suk Han, and Yong Gu Ji. 2013. A Study of Pointing Performance of Elderly Users on Smartphones. *International Journal of Human-Computer Interaction* 29, 9: 604–618. https://doi.org/10.1080/10447318.2012.729996
22. Keiko Ishiharaa, Higekazu Ishiharaa, Mitsuo Nagamachia, Sugaru Hiramatsub, and Hirokazu Osakic. 2001. Age-related decline in color perception and difficulties with daily activities-measurement, questionnaire, optical and computer-graphics simulation studies. *International Journal of Industrial Ergonomics* 28, 3–4: 153–163.
23. Zhenhui (Jack) Jiang, Weiquan Wang, Bernard C.Y. Tan, and Jie Yu. 2016. The Determinants and Impacts of Aesthetics in Users' First Interaction with Websites. *Journal of Management Information Systems* 33, 1: 229–259. https://doi.org/10.1080/07421222.2016.1172443
24. Michael Kalicinski, Matthias Kempe, and Otmar Bock. 2015. Motor imagery: Effects of age, task complexity, and task setting. *Experimental Aging Research* 41, 1: 25–38. https://doi.org/10.1080/0361073X.2015.978202
25. Ronald Klein and Barbara E.K. Klein. 2013. The prevalence of age-related eye diseases and visual impairment in aging: Current estimates. *Investigative Ophthalmology and Visual Science* 54, 14: 15–18. https://doi.org/10.1167/iovs.13-12789

26. Sri Kurniawan and Panayiotis Zaphiris. 2005. Research-Derived Web Design Guidelines for Older People. *Proceedings of the 7th International ACM SIGACCESS Conference on Computers and Accessibility*: 129–135. https://doi.org/10.1145/1090785.1090810
27. Talia Lavie and Noam Tractinsky. 2004. Assessing dimensions of perceived visual aesthetics of web sites. *International Journal of Human Computer Studies* 60, 3: 269–298. https://doi.org/10.1016/j.ijhcs.2003.09.002
28. R Leitão and Pa Silva. 2012. Target and spacing sizes for smartphone user interfaces for older adults: design patterns based on an evaluation with users. *Conference on Pattern Languages of Programs* 202915: 19–21. Retrieved from http://hillside.net/plop/2012/papers/Group 1 - Elk/Target and Spacing Sizes for Smartphone User interfaces for Older Adults - Design patterns Based on an Evaluation with Users.pdf
29. Chun Fu Li, Hui Ting Shi, Jing Jing Huang, and Lu Ying Chen. 2014. Two typical symbols in human-machine interactive interface. *Applied Mechanics and Materials* 635: 1659–1665. https://doi.org/10.4028/www.scientific.net/AMM.635-637.1659
30. João Maroco. 2007. Violação dos Prossupostos de Normalidade e Homogeneidade de Variâncias. In *Análise Estatística com Utilização com SPSS*.
31. Mara Mather and Laura L. Carstensen. 2005. Aging and motivated cognition: The positivity effect in attention and memory. *Trends in Cognitive Sciences* 9, 10: 496–502. https://doi.org/10.1016/j.tics.2005.08.005
32. Roger W. Morrell, Denise C. Park, Christopher B. Mayhorn, and Catherine L. Kelley. 2000. Effects of age and instructions on teaching older adults to use eldercomm, an electronic bulletin board system. *Educational Gerontology* 26, 3: 221–235. https://doi.org/10.1080/036012700267213
33. L G Motti, N Vigouroux, and P Gorce. 2014. Drag-and-drop for older adults using touchscreen devices: Effects of screen sizes and interaction techniques on accuracy. *26th French-Speaking Conference on Human-Machine Interaction, HMI 2014*: 139–146. https://doi.org/10.1145/2670444.2670460
34. Noel E. O'Connor and Cathal Gurrin Niamh Caprani. 2017. World ' s largest Science , Technology & Medicine Open Access book publisher : https://doi.org/http://dx.doi.org/10.5772/intechopen.68547
35. Galit Nimrod. 2016. The hierarchy of mobile phone incorporation among older users. *Mobile Media & Communication* 4, 2: 149–168. https://doi.org/10.1177/2050157915617336
36. ONU. 2015. World population, ageing. *Suggested citation: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Ageing* United Nat, (ST/ESA/SER.A/390: 164. https://doi.org/ST/ESA/SER.A/390
37. David Oswald and Steffen Kolb. 2014. FLAT DESIGN VS . SKEUOMORPHISM – EFFECTS ON LEARNABILITY AND IMAGE ATTRIBUTIONS IN DIGITAL PRODUCT INTERFACES. September: 1–6.
38. Tom Page. 2014. Touchscreen mobile devices and older adults: a usability study. *International Journal of Human Factors and Ergonomics* 3, 1: 65.

https://doi.org/10.1504/IJHFE.2014.062550

39. Tom Page. 2014. Skeuomorphism or flat design: future directions in mobile device User Interface (UI) design education. *International Journal of Mobile Learning and Organisation* 8, 2: 130. https://doi.org/10.1504/IJMLO.2014.062350
40. Diane E Papalia and Ruth Duskin. 2013. *Desenvolvimento Humano*. https://doi.org/10.1007/s13398-014-0173-7.2
41. Andraž Petrovčič, Ajda Rogelj, and Vesna Dolničar. 2017. Smart but not adapted enough: Heuristic evaluation of smartphone launchers with an adapted interface and assistive technologies for older adults. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2017.10.021
42. Andraž Petrovčič, Sakari Taipale, Ajda Rogelj, and Vesna Dolničar. 2017. Design of Mobile Phones for Older Adults: An Empirical Analysis of Design Guidelines and Checklists for Feature Phones and Smartphones. *International Journal of Human-Computer Interaction* 7318, August: 1–14. https://doi.org/10.1080/10447318.2017.1345142
43. Kingkarn Pijukkana and Nopadon Sahachaisaeree. 2012. Graphical Design and Functional Perception on Technology-Driven Products: Case Study on Mobile Usage of the Elderly. *Procedia - Social and Behavioral Sciences* 42, July 2010: 264–270. https://doi.org/10.1016/j.sbspro.2012.04.190
44. Regional Primate. 1993. Neural Bases of Visual Deficits During Aging. 33: 2589–2609.
45. Katharina Reinecke, Tom Yeh, Luke Miratrix, Rahmatri Mardiko, Yuechen Zhao, Jenny Liu, and Krzysztof Z. Gajos. 2013. Predicting users' first impressions of website aesthetics with a quantification of perceived visual complexity and colorfulness. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*: 2049. https://doi.org/10.1145/2470654.2481281
46. William Robbins. 2014. Design Practices In Mobile User Interface Design. 1–18. Retrieved from http://digitalcommons.calpoly.edu/grcsp/130
47. Da Saffer. 2005. The Role of Metaphor in Interaction Design. *Citeseer*: 29. https://doi.org/10.1207/s15327868ms2003_1
48. Timothy A. Salthouse. 2009. When does age-related cognitive decline begin? *Neurobiology of Aging* 30, 4: 507–514. https://doi.org/10.1016/j.neurobiolaging.2008.09.023
49. Susanne Scheibe and Laura L Carstensen. 2010. Emotional Aging: Recent Findings and Future Trends. *Journal of Gerontology: Psychological Sciences* 65B, 2: 135–144. https://doi.org/10.1093/geronb/gbp132.
50. Mirjam Seckler, Klaus Opwis, and Alexandre N. Tuch. 2015. Linking objective design factors with subjective aesthetics: An experimental study on how structure and color of websites affect the facets of users' visual aesthetic perception. *Computers in Human Behavior* 49: 375–389. https://doi.org/10.1016/j.chb.2015.02.056
51. Michael W. Smith, Joseph Sharit, and Sara J. Czaja. 1999. Aging, Motor Control, and the Performance of Computer Mouse Tasks. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 41, 3: 389–396. https://doi.org/10.1518/001872099779611102

52. Andreas Sonderegger and Juergen Sauer. 2010. The influence of design aesthetics in usability testing: Effects on user performance and perceived usability. *Applied Ergonomics* 41, 3: 403–410. https://doi.org/10.1016/j.apergo.2009.09.002
53. Christian Stickel, Hans Martin Pohl, and Jan Thorsten Milde. 2014. Cutting edge design or a beginner's mistake? - A semiotic inspection of ios7 icon design changes. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 8518 LNCS, PART 2: 358–369. https://doi.org/10.1007/978-3-319-07626-3_33
54. Manfred Thüring and Sascha Mahlke. 2007. Usability, aesthetics and emotions in human-technology interaction. *International Journal of Psychology* 42, 4: 253–264. https://doi.org/10.1080/00207590701396674
55. Alexandre N. Tuch, Javier A. Bargas-Avila, Klaus Opwis, and Frank H. Wilhelm. 2009. Visual complexity of websites: Effects on users' experience, physiology, performance, and memory. *International Journal of Human Computer Studies* 67, 9: 703–715. https://doi.org/10.1016/j.ijhcs.2009.04.002
56. A. Tymula, L. A. Rosenberg Belmaker, L. Ruderman, P. W. Glimcher, and I. Levy. 2013. Like cognitive function, decision making across the life span shows profound age-related changes. *Proceedings of the National Academy of Sciences* 110, 42: 17143–17148. https://doi.org/10.1073/pnas.1309909110
57. Age UK. 2016. The Internet and Older People in the UK – Key Statistics. July: 1–5.
58. Lei W. 2015. Skeuomorphism and Flat Design: Evaluating Users' Emotion Experience in Car Navigation Interface Design Conference. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 9186, July 2015. https://doi.org/10.1007/978-3-319-20886-2
59. Theodore P Zanto and Adam Gazzaley. 2014. Attention and ageing. *The Oxford handbook of attention.*: 927–971. https://doi.org/10.1017/CBO9781107415324.004
60. Panayiotis Zaphiris, Mariya Ghiawadwala, Shabana Mughal, Sanjay J Koyani, Robert W Bailey, Carol Barnum, John Bosley, Barbara Chaparro, Joseph Dumas, Melody Y Ivory, Bonnie John, Hal Miller-Jacobs, James R Lewis, Stanley Page, Judith Ramey, Janice (Ginny) Redish, Jean Scholtz, Steve Wigginton, Cari A Wolfson, Larry E Wood, and Don Zimmerman. 2005. Age-Centered Research-Based Web Design Guidelines. *CHI '05 extended abstracts on Human factors in computing systems - CHI '05*: 1897. https://doi.org/10.1145/1056808.1057050
61. Panayiotis Zaphiris, Sri Kurniawan, and Mariya Ghiawadwala. 2007. A systematic approach to the development of research-based web design guidelines for older people. *Universal Access in the Information Society* 6, 1: 59–75. https://doi.org/10.1007/s10209-006-0054-8
62. Xiaoming Zhang, Qiang Wang, and Yan Shi. 2017. Contrastive Analysis on Emotional Cognition of Skeuomorphic and Flat Icon. 417: 225–232. https://doi.org/10.1007/978-981-10-3530-2
63. Martina Ziefle. 2010. Information presentation in small screen devices: The trade-off between

visual density and menu foresight. *Applied Ergonomics* 41, 6: 719–730. https://doi.org/10.1016/j.apergo.2010.03.001

Appendix A

A.1 Questionnaire

This questionnaire is destined to support an investigation made by Professor Hugo Nicolau and his student Inês Urbano, from Instituto Superior Técnico.
All provided data is confidential.

Demographic Data
Name: _____
Date of Birth: _____/_____/_____
Since when, in years, do you use electronic devices (Computer, Tablet, Mobile, etc.)? _____

How often do you use technological devices?	Never	Once per month	Many times, per month	Once per week	Many times, per week	Once per day	Many times, per day
Mobile Phone							
Computer							
Tablet							

Design
Classify each design according to the correspondent scales (1- flat design, 2 – material design, 3- skeuomorphic design).

	Totally Disagree						Totally Agree
Complex	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Fine	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Modern	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Interesting	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Beautiful	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Trustworthy	1	2	3	4	5	6	7
1							
2							
3							

	Totally Disagree						Totally Agree
Easy	1	2	3	4	5	6	7
1							
2							
3							

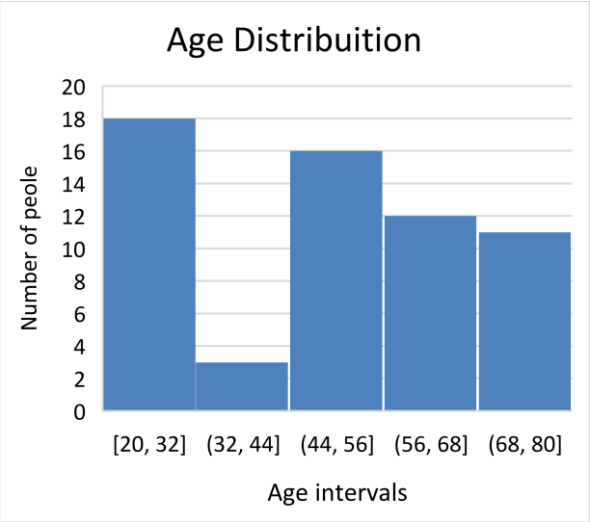
	Totally Disagree						Totally Agree
Fast	1	2	3	4	5	6	7
1							
2							
3							

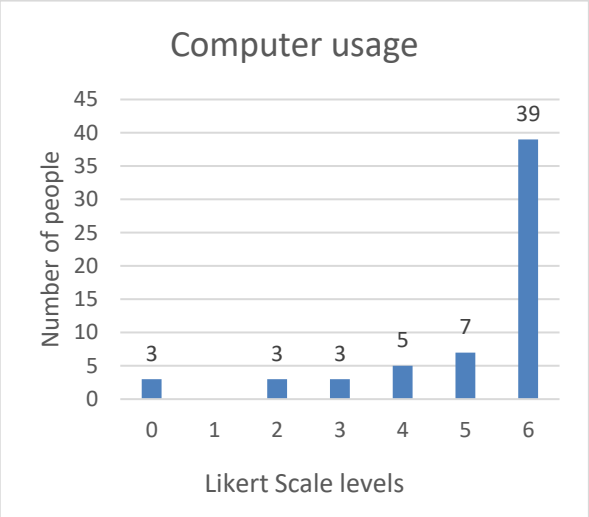
Which of the three designs was your favourite? _____

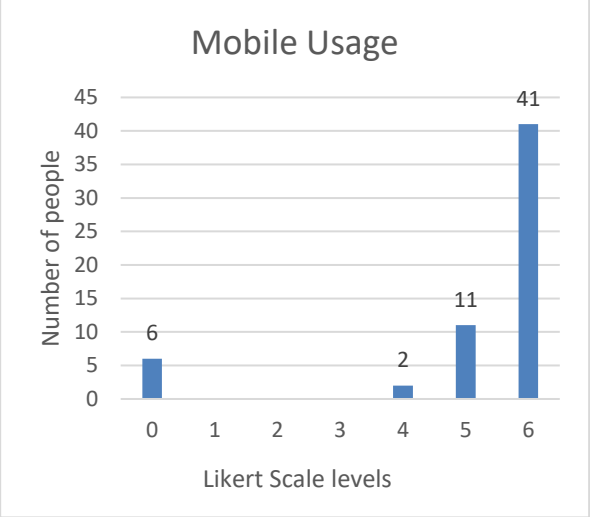
Thank you for your collaboration.

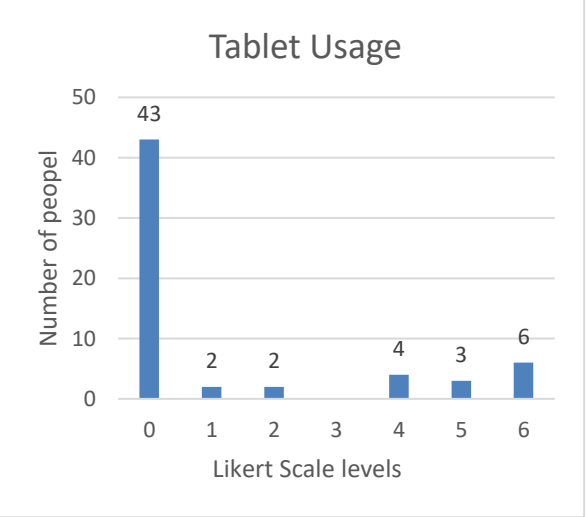
Appendix B

B.1 Results from the Demographic Part









Appendix C

C.1 Data from «Icons» Task

Age Group	Design	Measure	M	SD	CV (%)
YA	Flat	Time	5.69	2.56	45.80
		Errors	0.22	0.40	181.82
	Material	Time	4.89	1.26	25.77
		Errors	0.02	0.07	350
	Skeuomorphic	Time	4.60	1.27	27.6
		Errors	0.1	0.24	240
A	Flat	Time	9.81	6.74	68.71
		Errors	0.32	0.48	150
	Material	Time	9.10	5.44	59.78
		Errors	0.17	0.36	211.76
	Skeuomorphic	Time	8.47	4.70	55.49
		Errors	0.15	0.31	206.67
OA	Flat	Time	22.3	15.62	70.04
		Errors	1.01	1.41	139.60
	Material	Time	15.16	7.42	48.94
		Errors	0.65	0.83	127.69
	Skeuomorphic	Time	11.24	4.81	42.79
		Errors	0.23	0.44	191.30

C.2 Data from «Clickable Objects» Task

Age Group	Design	Measure	M	SD	CV (%)
YA	Flat	Time	28.34	7.78	27.45
		Errors	1.35	1.01	74.81
	Material	Time	27.04	6.48	23.96
		Errors	0.85	0.85	100.00
	Skeuomorphic	Time	33.69	10.36	30.75
		Errors	0.75	0.77	102.67
A	Flat	Time	61.32	29.19	47.60
		Errors	2.25	2.02	89.78
	Material	Time	56.47	30.31	53.67
		Errors	1.6	1.50	93.75
	Skeuomorphic	Time	68.78	28.17	40.96
		Errors	1	1.05	105.00
OA	Flat	Time	132.56	68.05	54.15
		Errors	3.05	1.96	64.26
	Material	Time	121.21	65.64	51.34
		Errors	2.07	1.97	95.17
	Skeuomorphic	Time	118.67	53.33	44.94
		Errors	1.2	0.81	67.50

C.3 Data from «Multiple Webpages» Task

Age Group	Design	Measure	M	SD	CV (%)
YA	Flat	Time	28.76	12.97	45.10
		Errors	0.4	0.66	165.00
	Material	Time	28.21	8.54	30.27
		Errors	0.2	0.4	200.00
	Skeuomorphic	Time	35.58	12.99	36.51
		Errors	0.6	0.73	121.67
A	Flat	Time	51.36	17.52	34.11
		Errors	1.05	1.16	110.48
	Material	Time	50.21	9.63	19.18
		Errors	0.85	1.52	178.82
	Skeuomorphic	Time	57.65	9.93	17.22
		Errors	0.6	0.8	133.33
OA	Flat	Time	124.63	40.65	23.77
		Errors	3.5	2.69	76.86
	Material	Time	100.80	23.96	32.62
		Errors	1.9	2.43	127.89
	Skeuomorphic	Time	100.3	22.89	22.82
		Errors	0.95	1.16	122.11

Age Group	Design	Percentage (%)
YA	Flat	100
	Material	100
	Skeuomorphic	100
A	Flat	95
	Material	95
	Skeuomorphic	100
OA	Flat	55
	Material	90
	Skeuomorphic	100

C.4 Results for Aesthetic Scales

DV	Age Group	Design	M	SD	CV (%)
1.Simple-Complex	YA	Flat	2.35	1.35	57.45
		Material	3.35	1.19	35.52
		Skeuomorphic	5.2	1.17	22.50
	A	Flat	2	1.05	52.50
		Material	2.95	0.97	32.88
		Skeuomorphic	4.15	1.46	35.18
	OA	Flat	2.65	1.56	58.87
		Material	3	1.67	55.67
		Skeuomorphic	4	1.30	32.50
2.Rough-Fine	YA	Flat	6.2	1.25	20.16
		Material	6.2	1.25	20.16
		Skeuomorphic	3.15	1.15	36.51
	A	Flat	5.7	1.71	30.00
		Material	5.7	1.82	31.93
		Skeuomorphic	4.1	1.09	26.59
	OA	Flat	6.05	0.86	14.21
		Material	5.85	0.73	12.48
		Skeuomorphic	3.8	1.29	33.95
3.Traditional-Modern	YA	Flat	4.85	1.89	38.97
		Material	5.25	1.41	26.86
		Skeuomorphic	4.45	2.22	49.89
	A	Flat	4	1.97	49.25
		Material	5.05	1.28	25.35
		Skeuomorphic	5.45	1.40	25.69
	OA	Flat	4.25	2.34	55.06
		Material	4.6	1.50	32.61
		Skeuomorphic	4.6	1.60	34.78
4.Boring-Interesting	YA	Flat	5.55	1.36	24.50
		Material	5.95	1.12	18.82
		Skeuomorphic	4.55	1.47	32.31
	A	Flat	4.7	1.73	36.81
		Material	5.55	0.92	16.58
		Skeuomorphic	5.65	1.59	28.14
	OA	Flat	4.95	1.80	36.36
		Material	5.65	1.24	21.95
		Skeuomorphic	6.45	1.12	17.36
5.Ugly-Beautiful	YA	Flat	5.35	1.56	29.16
		Material	5.9	0.83	14.07

		Skeuomorphic	4.2	1.67	39.76
	A	Flat	4.75	1.44	30.32
		Material	5.7	0.9	15.79
		Skeuomorphic	5.85	1.62	27.69
	OA	Flat	5.2	1.57	30.19
		Material	5.7	1.05	18.42
		Skeuomorphic	6.4	0.97	15.16
6. Unreliable - Trustworthy	YA	Flat	6.15	1.35	21.95
		Material	6.25	0.83	13.28
		Skeuomorphic	4.9	1.55	31.63
	A	Flat	5.05	1.53	30.30
		Material	5.75	0.89	15.48
		Skeuomorphic	6.15	1.06	17.24
	OA	Flat	6.2	1.21	19.52
		Material	6.55	0.59	9.01
		Skeuomorphic	6.95	0.22	3.17
7.Hard-Easy	YA	Flat	6	1.05	17.50
		Material	6.05	1.12	18.51
		Skeuomorphic	4.75	1.61	33.89
	A	Flat	5.25	1.61	30.67
		Material	6.15	0.91	14.80
		Skeuomorphic	6.25	0.99	15.84
	OA	Flat	4.95	1.36	27.47
		Material	6.1	0.62	10.16
		Skeuomorphic	6.85	0.48	7.01
8.Slow-Fast	YA	Flat	5.55	1.24	22.34
		Material	6.05	0.92	15.21
		Skeuomorphic	4.7	1.35	28.72
	A	Flat	5.3	1.65	31.13
		Material	6.1	0.89	14.59
		Skeuomorphic	6.3	0.95	15.08
	OA	Flat	4.7	1.62	34.47
		Material	6.2	0.51	8.23
		Skeuomorphic	6.85	0.48	7.01

C.5 Decomposition of Effects for Efficiency

DV	Effects	F	p	Decomposition of the effects	p
Time_icons	Design	F(2,114) =6.47	.002**	Fd > Sd	.004
	Age group	F(2,57)=35.25	.000 ***	OA > YA OA > A A > YA	.000*** .000*** .011 **
	(Design* Age group)	F(4,114) =3.46	.011 *	Fd: OA > YA Fd: OA > A Md: OA > YA Md: OA > A Sd: YA < A Sd: YA < OA OA: Fd > Md OA: Fd > Sd;	.000 *** .001 ** .000 *** .003 ** .012 * .000 *** .021 * .000 ***
Time_click	Design	F(2,114)=.27	.761	--	--
	Age group	F(2,57)=36.21	.000***	OA > A OA > YA A > YA	.000 *** .000 *** .017 *
	(Design*Age group)	F(4,114)=1.49	0.21	--	--
Time_webpages	Design	F(2,114)=1.86	.161	--	--
	Age group	F(2,57)=31.18	.000***	OA > A OA > YA	.000*** .000***
	(Design*Age group)	F(4,114)=2.78	.030 *	Fd: OA > YA; Fd: OA > A Md: OA > YA; Md: OA > A; Sd: OA > YA; Sd: OA > A OA: Fd > Md; OA: Fd > Sd;	.000 *** .000 *** .000 *** .000 *** .000 *** .001 ** .031 * .002 **

C.6 Decomposition of Effects for Effectiveness

DV	Effects	F	p	Decomposition of the effects	*p*
Errors_icons	Design	F(2,114)= 6.16	.003 **	Fd > Sd	.005 **
	Age group	F(2,57)=8.94	.000***	OA > YA; OA > A;	.001 ** .006 **
	(Design * Age group)	F(4,114) =2.24	.069	--	--
Errors_click	Design	F(2,112)=12.99	.000 ***	Fd > Md; Fd > Sd; Md > Sd;	.044 * .000 *** .038 *
	Age group	F(2, 57)=6.96	.002 **	OA > YA;	.000 ***
	(Design * Age group)	F(4,114)=1.11	.356	--	--
Errors_webpages	Design	F(2,114)=7.88	.001**	Fd > Sd	.001**
	Age group	F(2,57)=15.29	.000***	OA > YA; OA > A;	.000*** .001**
	(Design * Age group)	F(4, 114)=6.01	.000 ***	Fd: OA > YA; Fd: OA > A; Md: OA > YA; OA: Fd > Md; OA: Fd > Sd; OA: Md > Sd;	.000 *** .000 *** .004 ** .004 ** .000 *** .026 *

C.7 Decomposition of Effects for Aesthetic Scales

DV (Scales)	Effects	F	p	Decomposition of the effects	p
1. Simple - Complex	Design	F(2,114)=66.78	.000 ***	Sd > Fd Sd > Md Md > Fd	.000*** .000*** .000***
	Age group	F(2,57)=1.64	.202	--	--
	(Design*Age group)	F(4,144)=2.88	.026 *	Sd: OA < YA; YA: Fd < Sd; YA: Md < Sd; A: Fd < Sd; A: Md < Sd;	.02 * .000 *** .000 *** .000 *** .000 ***
2. Rough- Fine	Design	F(2,114)=112.21	.000 ***	Sd < Fd Sd < Md	.000 *** .000 ***
	Age group	F(2,57)=.02	.978	--	--
	(Design*Age group)	F(4,114)=3.97	.005 **	Sd: YA < A; YA: Sd < Fd; YA: Sd < Md	.048 * .000 *** .000 ***
3.Traditional-Modern	Design	F(2,114)=1.70	.187	--	--
	Age group	F(2,57) =.89	.418	--	--
	(Design * Age group	F(4,114) =1.33	.265	--	--
4.Boring-Interesting	Design	F(2,114) = 4.19	.010 *	Md > Fd .	.001 **
	Age group	F(2,57)=.78	.465	--	--
	(Design*Age group)	F(4,114)=7.15	.000 ***	Sd: YA < OA YA: Md > Sd; A: Fd < Md; OA: Sd > Fd;	.000 *** .000 *** .014 * .007 **
5.Ugly-Beautiful	Design	F(2,114)=3.86	.024*	Md > Fd	.002 **
	Age group	F(2,57)=2.72	.074	--	--

	(Design*Age group)	F(4,114)=6.52	.000 ***	Sd: YA < A Sd: YA < OA YA: Md > Sd A: Fd < Md	.003 ** .000 *** .000 *** .015 *
6. Unreliable - Trustworthy	Design	F(2,114)=2.25	.111	--	--
	Age group	F(2,57) =7.85	.001**	OA > A OA > YA	.002 ** .007 **
	(Design*Age group)	F(4,114) =9.23	.000 ***	Fd: YA > A Fd: A < OA Md: OA > A Sd: YA < A; Sd: YA < OA; YA: Fd > Sd YA: Md > Sd A: Fd < Md; A: Fd < Sd;	.049 * .037 * .007 ** .002 ** .000 *** .009 ** .000 *** .020 * .025 *
7.Hard-Easy	Design	F(2,114)=7.21	.001**	Fd < Md	.000 ***
	Age group	F(2, 57)=1.18	.315	--	--
	(Design* Age group)	F(4, 114)=11.98	.000 ***	Sd: YA < A; Sd: YA < OA; YA: Fd > Sd YA: Md >Sd A; Fd < Md; OA: Fd < Md; OA: Md < Sd;	.000 *** .000 *** .013 * .001 ** .001 ** .000 *** .000 ***
8.Slow-Fast	Design	F(2, 114)=11.38	.000 ***	Fd < Md Fd < Sd	.000 *** .014 **
	Age group	F(2, 57) = 3.02	.57	--	--
	(Design*Age group)	F(4, 114) =9.33	.000 ***	Sd: YA < A Sd: YA < OA YA: Md > Sd A: Fd < Md OA: Fd < Md; OA: Fd < Sd	.000 *** .000 *** .001 ** .013 * .000 *** .000 ***

C.8 Qualitative Results

Adjective	Younger Adults			Adults			Older Adults		
	Fd	Md	Sd	Fd	Md	Sd	Fd	Md	Sd
Outdated	1						1		
Intuitive	5	2		1			1		
Alive									2
Colorful				1	1	4			6
Perceptible						3			6
Clean	3	1		1			1		
Monotonous/ Boring	1	1		9	4	1	8	3	
Not careful	1			3	1		4	1	
Too much information			2			3	1		2
Slow to understand							1		
Curious/New		3							
Stylized							1		
Interesting							1		2
Fast		1							1
Beautiful			2			2			
Simple	6	3		2	3	1	2		
Practical	3	1							2
Objective	1	1		2					
Modern	1								
Familiar	4								
Attention to detail		1	3			1			
Minimalist	3								
Sense of familiarity			4			2			3
Appealing	1	3	1	1	1				
Sophisticated			1						
Trustable			1						
Cold	1								
Different			1						
Confusing			2						
User Friendly	3			1	1				
Hard							2		
Complex						1			

Appendix D

D.1 Data from the Learning Experiment

Session	Design	Measure	M	SD
First: 1	Flat	Time	17	9.86
		Errors	3	2.64
	Material	Time	14.86	7.19
		Errors	1.44	1.57
	Skeuomorphic	Time	8.85	4.01
		Errors	0.88	0.99
2	Flat	Time	13.66	6.33
		Errors	1.11	1.09
	Material	Time	10.88	6.86
		Errors	0.89	0.74
	Skeuomorphic	Time	7.34	2.82
		Errors	0.33	0.47
3	Flat	Time	9.45	3.23
		Errors	1	0.82
	Material	Time	8.58	3.33
		Errors	0.22	0.4
	Skeuomorphic	Time	7.27	2.6
		Errors	0.22	0.4
Last: 4	Flat	Time	7.97	2.52
		Errors	0.55	0.68
	Material	Time	5.62	1.53
		Errors	0.33	0.47
	Skeuomorphic	Time	5.87	1.64
		Errors	0.11	0.31

D.2 Decomposition of Effects

DV	Effects	F	p	Decomposition of the effects	p
Time	Design	F(1.16,9.3)=14.22	.003**	Sd < Fd Sd < Md Md < Fd	.05* .013* .017*
	Session	F(3,24)=6.95	.002 **	S1 > S4 S3 > S4	.028* .032*.
	(Design* Session)	F(2.37,18.9)=3.42	.003 **	S1: Sd < Fd S1: Sd < Md S2: Sd < Md S3: Sd < Md S3: Sd < Fd S4: Md < Fd Sd: S2 > S4 Sd: S3 > S4 Fd: S1 > S3 Md: S1 > S4 Md: S3 > S4	.039* .039* .030* .012* .025* .001** .049* .023* .18* .036* .004**
Errors	Design	F(1.15,9.2)=5.56	.038*	--	--
	Session	F(1.8,14.5)=6.67	.010*	S1 > S2	.030*
	(Design* Session)	F(1.6,13)=7.86	.008**	S2: Sd < Md S2: Md < Fd S4: Sd < Fd Fd: S1 > S3 Fd: S3 > S4	.048* .024* .012 * .049* .048*