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 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 design approaches (skeuomorphic, flat and material) in user’s experience, namely on performance and affective response. We concluded that both age and design have effects in both performance and aesthetic perception in the tasks involved. In terms of age, Older Adults (65+ years) where the ones where performance depended more on design. For aesthetic preference, while younger adults perceived minimalist 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

1 Introduction
The pace of population ageing is largely accelerating. 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) [15]. The significant increase in internet and touchscreen usage among older people in the last years [22], influences how we should look at technology and adapt it to become more inclusive.

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. Inclusive design demands a set of different heuristics, which are often not respected. Despite the importance of age, Human Computer Interaction research is still mainly focused towards the attitudes and characteristics of young, highly-educated people, rarely reflecting the demographic reality [18].

On top of it, it is demonstrated that some of these differences can also affect the aesthetic perception of an interface [20] which was shown to influence aspects such as user satisfaction, perceived usability and performance [7,11].

Regarding aesthetics and design, there was lately the emerge of a design trend called flat design (e.g.: Microsoft 10, iOS 7) which has been topic of controversy. It came in substitution of the more classical design strategy, skeuomorphic design. Although flat design is most commonly used nowadays, comparative studies [4,16,23] between both techniques have questioned the extent of flat design as the better option. This made space for a more hybrid approach that tried to embrace and merge the qualities of both designs.

Although age was proven to affect the aesthetic perception of a user there are almost no studies that focus and compare different design conditions. This dissertation focuses in the three mentioned approaches (skeuomorphism, flat and material) and the effects of them in an ageing population.

With this experiment we want, first, to understand whether there are any factors that affect the performance and aesthetic perception when changing the three design conditions. Second, to identify those factors and report in which way the variables affect those aspects, and eventually report any significant differences found. Third, to understand whether the learning experience of an older user may influence the aspects mentioned above.

To achieve these goals, two empirical studies were conducted. The first (Section 3) aims to respond the first two ones and the second (Section 4) to the third one.

The paper is organized in six sections. Section 2 focuses in the background research made previously to the study. Next, the Sections 3 and 4 provide an analysis of the first and second experiments, respectively. Section 5 uses the major results from the experiments to give a set of design guidelines. Finally, the main conclusions are presented in Section 6.
2 Related Work

This section refers to the background study that was made before the experiments. At first, we focus in understanding which are the main differences that occur with age. We also detail some heuristics of interface design developed to adapt to these changes.

Secondly, we analyze the various elements of user experience that can be affected by the aesthetic appreciation, and why it is so important to include this factor for a good user experience.

Finally, we describe the three designs mentioned in the study (skeuomorphism, flat and material), focusing on their main differences and characteristics.

2.1 Older People and Interface Interaction

Research has consistently documented that increased age is associated with the lowering of the levels of cognitive performance.

In response to such differences, the main difficulties were studied and translated into sets of design guidelines for Older Adults. By comparing a set of different UIs, it was shown that the use of complex and non-straightforward UI structure is 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 [10,12]. Instead, interfaces should be as transparent as possible, with the user being able to understand, at every point, what they can do with the system [1,25].

Also, with 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 [6] and a labelling too illegible for users to be able to recognize [1]. To counterbalance this point, the 14-point fonts was found to the most adequate and preferred for older adults, since it was proven to be more legible, and promote faster reading than a 12-point one [2].

Other important aspect to take into consideration are colors, graphics and symbols. Older adults have more difficulties than younger ones when dealing with bland graphics and poor color contrast [6]. It then is suggested both conservative colors and high contrasts that ensure readability and perceptibility [14].

The conceptual meaning of the symbols used in an interface also influence a lot participant’s performance. Older users transfer knowledge learnt from previous non-digital interfaces (such as typewriters), which can lead to conceptual problems. «Confusion between the concepts of backspace (delete to the left) and back (go to previous screen/back out of interface». The use of affordances (visual cues in the system) should be promoted [1]. Graphical symbols, such as icons should, be drawn according to mental models and previous experiences of Older Adults [19] and its use should be consistent [5].

2.2 Aesthetics in Interface Design

Visual aesthetics 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. It takes part in the affective dimension of Human Computer Interaction, and it was proven to influence multiple aspects related to user experience. In comparison to other factors (such as effectiveness, efficiency and playfulness) aesthetics was demonstrated to be the most important variable responsible for user satisfaction [7].

For a start, the perceived aesthetics of a product showed to influence its perceived usability [17]. When dealing with two interfaces with no difference between any usability objective quality, 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. Perceived aesthetics was also shown to have a large impact forming users’ attitudes towards a first interaction with a website, which will ultimately shape the perceived image of a company [11].

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.

It is then important to understand which are the features of design that implicate with such perception. Based on previous findings, Jiang et al. [11] 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 (colour schemes, properties of colour), novelty (the adoption of new, unusual displays and elements) and interactivity (the interactive nature of an interface). All of the perceived quality of the determinants has shown to positively affect the perceived website aesthetics and the perceived usability of website.

2.3 From Skeuomorphism to Flat Design

Also known as realistic design, skeuomorphism appeared to combat the learning curve that users faced when dealing with new interfaces and features. The trend was set by Apple: bookshelves made out of wood to make storage of articles, a note page that resembled paper with leather count just as 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 [13], 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 [13,21]. 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. Skeuomorphism makes use of spatial depth, shadows, textures, high light and gradual changes for designing the elements [23].
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 [13] and cleaner. The simplification of the elements allows also websites to load much faster and be easier to resize.1

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 leads it to become adopted for the computer operating system (Windows 8). In this technique, there is 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 [23]. Along with this, elements become plane and wider. Due to the lack of visual resources, the strategy takes advantage of colors (bolder and brighter, highly saturated), typography, grid and iconography to make the impact. Colors become the key-element to represent affordance and build an emotional connection to the user [3].

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 [4]. 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) [9]. This also leads to an unclear distinction between elements, misinterpreting what are their functions, compromising discoverability of functions [8]. To prove this theory, Burmistrov [4] research compared the two approaches and shared the opinion that flat design is much worse for the usability of the system.

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 [23]. Gmail (web + iOS), Google Maps (iOS), and Google+ (iOS) examples of what can be seen as this middle approach.

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). Emotional response between the three different design approaches (traditional, semi traditional and flat) were studied (Lei) [23]. 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.

Figure 2.1 - Skeuomorphic vs Flat vs Material

2.4 Discussion

Conclusions can be drawn from the state of the art to understand the gap presented in the literature. First, 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. However, there is a lack of studies in terms of general design approaches and consequent user satisfaction and emotional preference. When research is done in aesthetic preference, the target group tends to be both Younger Adults and 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.

Regarding the three types of design, despite its importance, the material approach is not always addressed in the studies of comparison between designs. Instead, the focus goes towards flat and skeuomorphic design. Once again, this topic does not address the aspect of age.

3 First Experiment: Effect of Age and Design on User Performance and Aesthetic Preference

Our aim is, first, to understand whether age (or other factors) really affect the performance and/or aesthetic perception when changing the three design conditions. Secondly, to identify those main differences. It can be translated in the following questions:

1. Do other factors beyond age such as participant’s familiarization and use of technology have an effect in task performance and aesthetic preferences?

2. Does age play an effect on task performance?
3. Does age and/or design play an effect in aesthetic preference?

To do so, we made a presentational experiment with a total of 60 volunteering participants with a wide age range (M = 49.05, SD = 19.43). The tasks chosen to conduct the experiment include common elements in computer interaction: icons and a various number of clickable objects. 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 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.

### 3.1 Procedure

The first experiment consisted in doing the three tasks in three different design conditions (flat, material and skeuomorphic).

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 (age and aspects related to familiarization with technology).

The series of proposed tasks began with the following order: the participant began with one type of the three design types and once all the three tasks were concluded, he goes on to the next design until the process is finished and all designs and tasks are covered.

Both the order of the design type (flat, material and skeuomorphic) and the task (multiple webpages, clickable objects and icons) was randomly chosen for each participant. We also made sure that the content of both «clickable objects» and «multiple webpages» tasks was not been repeated (Section 2.2).

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 was always written during on top of the screen during the task, so that the participant could read it when doubtful. When the participant thought to have concluded the task, he clicked the «Next» button. This pattern was repeated until the 15 tasks were completed. At the end of it, the second part of questionnaire was given to collect the participant’s subjective opinion of each design (Section 2.3).

### 3.2 Tasks

All interfaces presented in the experiment were designed from scratch and followed a set of requirements previously found in the related work. These included: letter with14px [2], buttons and other elements were bigger than normal [24], provide clear instructions and make them available (the instructions were simple and were always presented in the top of the interface), avoid unnecessary complexity.

Also, for skeuomorphic design, 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.

All elements were according the designs differences and characteristics (Table 3.1).

<table>
<thead>
<tr>
<th>Feature</th>
<th>Skeuomorphic</th>
<th>Material</th>
<th>Flat</th>
</tr>
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<tr>
<td>Shadow</td>
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<td>High light</td>
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<td>Gradual Change</td>
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<tr>
<td>Texture</td>
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Table 3.1 - Comparisons between the three designs, Lei et al. [23]

**Icons.** Targets measured 16.5 mm and have a spacing of 6.35 mm [53]. The main criteria of 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.

Icons were disposed in a grid of 4*4 (Figure 3.1) and 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).

The position of every icon (target and non-target) was randomly and the target icon was randomly chosen ones.

![Figure 3.1 - Interfaces of task «icons» in all three design conditions, flat, material and skeuomorphic](image)

**Clickable Objects.** The clickable elements were chosen from a set of the most common elements in webpage ² (Figure 3.2). The task had three versions for its content. The contents chosen were: «Library»; «Pharmacy» and «Toys Shop». A total of twelve clicks were expected during the task.

Multiple Webpages. A set of simple tasks were chosen for the user to execute: find something in a list of elements; buy two objects; select an icon to execute a function.

For this task we also chose three versions. They were: (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. » and (3) «Go to «Peixaria Mar». Buy two Shrimps; Call the owner ».

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, 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.

Data Collection

Participants performance was evaluated in terms of both efficiency and effectiveness. For each task, we gathered both the time to accomplish it (in seconds) and the number that of errors made.

For the task «multiple webpages» we also gathered a third variable called success. It represented whether the participant achieved or not what was proposed in the task. It could 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 success variable marked as one.

Our goal was also to focus in the participant’s aesthetic appreciation for each design. Inspired by previous research from Lei et al. [23], participants were asked to evaluate each one of the three designs based on a set of six scales of Kansei Engineering, chosen from the fifteen attributes used in a previous in the experiment. These scales were responded in the end of the experiment, in the questionnaire.

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 of them varied from «1-Do not agree» at all, to «7- Totally agree».

Higher scores towards the attributes «simple», «fine», «modern», «interesting», «beautiful», «trustworthy», «easy», «fast» were associated with a more positive evaluation of the design. Each participant was also requested to put in order the designs according to their preference (from the most to the least appealing) and to make comments about the designs.

Finally, we collected the user’s age, their previous experience with technology (number of years they have been using it) and frequency of use of technological devices (PC, Tablet, and Mobile Phone). The frequency of use was measured again by Likert scales, from «1- Never use» to «7- Use many times per day» for each device.

3.4 Results

This Section focuses on the results obtained from our first experiment. After gathering all necessary data, we applied statistical tests to answer the research questions raised in Section 2.

First, we conducted a multiple linear regression analysis to determine whether age and familiarization with technology (independent variables) could predict time, errors and aesthetic preference (dependent variables). After being proved that age had an important effect in performance (see answer to question 1), we divided participants into three age groups (each with 20 participants). 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).

A MIXED ANOVA repeated-measures was then used to answer Questions 2 and 3 of the Research Questions. Here, the age group served as the within subjects’ factor and design as the between-subject factor.

To study success, we applied the Kruskal-Wallis test to compare two unmatched groups. Friedman’s test was also applied to determine whether there were any differences between designs for the oldest groups.

Finally, we used Chi-Squared test to verify whether there was a tendency to prefer a specific design for each age group.

Do other factors beyond age such as participant’s familiarity and use of technology have an effect in task
performance and aesthetic preferences? Results showed there is an impact of the factors (age and familiarization with 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 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.

Familiarization with technology and some devices scales (Computer and Mobile Phone) have only been proven to be significant for some specific conditions.

As a result, it made sense to study age as a factor. To do so, as previously mentioned, participants were divided in three groups.

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, flat 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 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 not 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 in aesthetic preference?
Age group impacted all aesthetic scales studied, 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, being it «intuitive» and «user-friendly». Material design was associated with a sense of «newness», a concept that they might not be aware of. Although skeuomorphic design was more rejected, it is important that adjectives such as «detailed» and «careful» were associated with it during the comments phase.

In terms of the scale’s evaluation for this group, skeuomorphic design was regarded as more «complex», «unreliable», less «interesting», less «beautiful», «harder» and «slower» in comparison to the others. Between material and flat: Material had larger mean values than Flat in the positive semantic scales (more interesting, beautiful and trustworthy, easier and faster).

Results from Chi-Squared test confirmed there was a tendency for this group to opt for material design.

Adults showed a much different opinion. Opposite to Younger Adults, this group’s preferable design was skeuomorphic. This was also the design with highest rates in the positive semantic scales. Also, contrarily to the other group, 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.

For this group, flat design was associated with «boring», «confusing», «everything the same» but also appreciated as «simple» and «clean». The first adjectives diverge a lot from the opinion of what the youngest group had. Results did not show, however, a tendency from this group to opt for any design.

Finally, Older Adults were the group with the most differences comparatively with the first. Not one of them chose material design as their favorite and the clear majority pointed for skeuomorphism. It was rated as highest in the positive semantic scales and had larger values than Adults.

According to results, they also find it more «interesting», more «beautiful», more «trustworthy» and «easier» than Younger 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». Results confirmed there was a tendency for this age group in having this design as their favorite.

4 Learning Experience
The previous experiment showed there are significant differences between designs and age groups in terms of time, errors and aesthetic appreciation. A second experiment was made to understand whether the learning factor may have any influence in the three aspects mentioned above. Therefore, our fourth and last research question is:

4. Does session and/or design play any effect on Older Adults performance?

The task analyzed to respond to this question was «icons», (together with the task «multiple webpages»). The age group on focus was Older Adults, being this the only one to show significant
differences between designs. Due to our time limit, we opted for the least complex of them.

For this, 9 participants, with age higher than 65 years old (correspondent to our previous Older Adults group), acted as volunteers for the experiment. All volunteers came from «Casa de Repouso Embaixador».

Each participant did a total of 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».

As in the previous experiment, participants completed three pages of «icons» for each design, giving a total of nine pages. Once they completed searching for the three icons, they moved on to the next design until everything is finished. Equally to the last analysis, the order of each design is randomly chosen, and icons will be presented in an arbitrarily position, in a matrix of 4 x 4.

Time and errors were gathered.

### 4.1 Results

**Does session and/or design play any effect on Older Adults performance?** Repeated use influenced both efficiency and effectiveness of Older Adults.

First, in terms of efficiency, there seemed to be 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 session. This means that, for skeuomorphic design, participants improved their efficiency only when the fourth session was completed. Material design had a similar behavior, with the effect also 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 efficacy, the 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 significative diminish 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.

![Figure 4.1 - Average and standard deviation of the time spent for each Session](image1)

![Figure 4.2 - Average and standard deviation of the errors made in each Session](image2)

### 5 Guidelines of Design

Having into account the results of the experiment, a set of guidelines for design were developed.

Since our study is about age and its differences, we divided these recommendations by the age groups mentioned along the document. For each age group we recommend the best design according to what goal the designer is looking for (efficiency, effectiveness or aesthetic appeal). Although our focus was to describe guidelines of design for each age group, there is a conclusion that can be adopted, when the aim is not a specific target, but yet the entire population:

**When working with a broad age span, (ranging also ages up to 65 years old and more) the designer should be careful in the use of flat design, with the risk of compromising participants' overall performance.** Flat design penalized the performance of Older Adults, which results showed to affect the overall performance of the participants.

To work towards a more inclusive system, and to have 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).
5.1 Younger Adults (20-39)

If the focus is efficiency or effectiveness, you can opt for any of the designs. Younger Adults have shown to 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.

If the focus is aesthetics, choose the more minimalistic designs. Both aesthetic scales and preferable designs showed that Younger Adults tend to prefer simplicity in the design. «Unnecessary», «complex», «roughest», «less interesting», «hardest» were attributes associated to skeuomorphic design. It was also the group who found this design less «trustworthy». Younger Adults showed a clear preference towards keeping things as clean and as simple as possible. It has also been shown that these group prefers material design over 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 many times to the attention to detail. Although they did not like the excess that skeuomorphic design brought, they also referred that the attention to colors and details was interesting.

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 that flat brings and create a sense of novelty to the design, which we think is necessary for this group.

5.2 Adults (40-64)

If worried about 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.

If worried about 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.

5.3 Older Adults (65+)

If the focus is efficiency of tasks like «icons» and «multiple webpages» avoid Flat design. Avoid flat if worried about the effectiveness of tasks like «multiple webpages» and, preferably, use skeuomorphic design. Older Adults were the age group that took longer time and made more errors. It is then the group who must be taken into more consideration if we want to maximize performance.

It was also the only age group who showed significative differences in performance when changing design conditions. Whenever there was an interaction between design and age group, flat design was the worse in terms of both efficiency and effectiveness. 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 than the one spent when doing it in skeuomorphic design.

The same happened for the task «multiple webpages». This task had also more errors when performed in flat, than when done 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 be avoided (when the concept is too hard to understand). The designer should always make sure that an element is understandable without having to previous knowledge of other interfaces.

5.4 Including the Repetition Factor

The previous 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 does lead to an improvement. Our results that this 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 are improvements in the time spent in them. 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.

6 Conclusions
Flat, skeuomorphic and material are three design approaches widely discussed in the design community. 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 (Section 2.1). 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. 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.

Once we derived these conclusions and defined our research questions, our second goal was to give an answer to these gaps (Sections 3 and 5). 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.

We found that the number of errors made in flat started to diminish in the fourth session, and that it was the only design to have an effect of repetition, in terms of errors. 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, in the third session.

The evaluation of these 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.

6.1 FUTURE WORK

This study serves as a model for future inclusive studies on different design characteristics. Due to the complexity of this topic, some aspects could not be considered in our experiments. 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