Usability Across Generations: Comparing Skeuomorphic, Flat, and Neubrutalist User Interface Design

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This study investigates the effect of three design styles (Skeuomorphism, flat design, and Neubrutalism) on aesthetic pleasure and understandability (app icon identification, and the time spent identifying app icons) among different age brackets. To test this, a quantitative study has been performed through a questionnaire that asked users about aesthetic pleasure and measured understandability. Results indicate a significant interaction effect, with users born after 1980 demonstrating a preference for flat designs over Skeuomorphic styles. Despite this, design style did not significantly affect app icon identification speed or accuracy. However, the study found that user experience significantly influenced the time spent identifying app icons. The outcomes suggest design preferences are age-dependent and highlight the importance of considering user demographics in interface design. Limitations of the study include the subjective nature of design styles, the method of testing through static app icons, and potential language comprehension issues among older participants due to the English questionnaire. Potential future research could further examine Neubrutalism's aesthetic appeal among younger audiences, expand on the design variations evaluated, investigate additional usability aspects, and consider language diversity in the questionnaire.

CCS Concepts: • **Human-centered computing → Graphical user interfaces**.

Additional Key Words and Phrases: Aesthetic Pleasure, Comparative Study, Design, Flat Design, Homescreen Design, Neubrutalism, Skeuomorphism, Understandability, User Interface.

1 INTRODUCTION

User Interface (UI) design plays a crucial role in shaping the user experience of digital products. Over the years, various design styles have emerged, each with its unique characteristics and philosophies. One of these is Skeuomorphism, which mimics real-world objects and materials to make digital interfaces more intuitive. For instance, a trash can icon for deleting items or a floppy disk icon for saving files are examples of Skeuomorphic design [24].

With the evolution of digital technology and user preferences, Skeuomorphism gave way to newer design styles, such as flat design. Flat design emphasizes simplicity, removing real-world metaphors and focusing on minimalistic elements with bold colors [11]. While extensive research has been conducted to compare Skeuomorphism and flat design, findings suggest contrasting preferences among different user groups. For instance, elderly individuals tend to prefer Skeuomorphic design, while younger users often favor flat design [1, 27].

Recently, a new design style known as Neubrutalism has emerged. Characterized by simplicity, a color-rich palette, distinct outline and shadow usage, and a focus on functionality over aesthetics, Neubrutalism offers a fresh perspective on User Interface design [1]. However, despite its growing popularity and its claims about functionality, Neubrutalism remains largely unexplored in academic research, particularly regarding its impact on usability compared to Skeuomorphic or flat design.

Addressing this gap in the literature, this study aims to investigate two aspects of usability, namely aesthetic pleasure and understandability, and compare these between the Skeuomorphic, flat, and Neubrutalist design styles. The study will also compare how these aspects between the younger generation and the older generation, since a difference in preference and usability is proven between Skeuomorphism and flat design in earlier literature [1, 27].

To do comprehensive research on this topic, first, a systematic literature review (SLR) will be discussed, then related work will elaborate on the results of the SLR. It will address the different design styles and how they compare. After, the methodology will be described. Next, the results of the conducted research will follow. Finally, the results will be interpreted and concluded, and limitations and future work will be discussed.

2 SYSTEMATIC REVIEW

The SLR consists of three phases: Identification, Screening, and Inclusion. In the identification phase, a comprehensive search strategy is established. Then, the titles and abstracts have been screened to see if the articles fulfilled the established criteria of the identification section. After, the full-text articles have been screened to exclude the last articles, and during the last phase, the inclusion phase, the studies that meet the inclusion criteria have been set. The results of each phase will be presented in the next sub-sections.

2.1 Identification

To collect sources, four databases have been used: Scopus, ACM, Semanticscholar, and Google Scholar. Scopus and ACM have been used as they are considered reliable libraries for scientific papers. On the other hand, Google Scholar and Semanticscholar were explored to broaden the perspective on design styles, as these databases suggest articles based on 'relevance'; where relevance is dictated by their own recommender systems. Additionally, there are countries and educational institutes that use different platforms to distribute research. These perspectives are included in the systematic review by utilizing Google Scholar and Semanticscholar. This is particularly important in the design domain, as opinions on design can be influenced by cultural background and context [13]. All collected articles have been uploaded into Rayyan, visualized through the PRISMA flow diagram to make use of exclusion criteria and select the relevant articles (see Figure 2).

Next to the literature, the World Wide Web has been used to collect additional information about the three design styles. Especially concerning Neubrutalism, as no research has been done about this style yet. The search terms used are shown in Table 1, and the results from the queries are shown in Figure 1. As can be seen in Figure 1, the results for studies about Neubrutalism are absent, indicating a

[1]Accessed on 14-06-2023, retrieved from: Neubrutalism - UI Design Trend That Wins The Web.

research gap. The results of the last five years are shown zoomed in, highlighted in green.

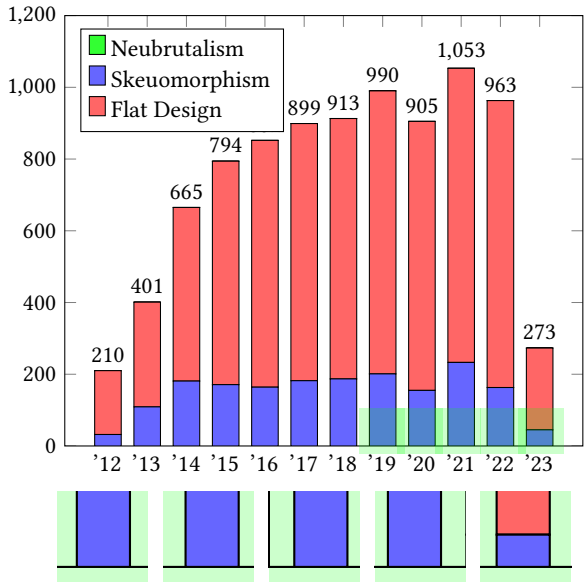


Fig. 1. Quantification of papers containing the queries "flat design", "Skeuomorphism", and "Neubrutalism" per year. Highlighted in green: the lack of articles covering Neubrutalism.

2.2 Screening

After the initial collection of literature and removal of duplicates, each article was scrutinized for reliability. The criteria for trustworthiness for inclusion:

- Publication by a reputable publisher recognized in the field.
- Classification as a scientific article (excluding theses, books, or websites). [2]

Afterward, the titles and abstracts were screened. An article was excluded based on the following criteria:

- The subject field was unrelated to the design.
- The publication date was prior to 2015, as design styles are susceptible to change.
- The content was outside the scope of the review, which focuses on the impact of design styles on perceived usability.
- The study design was inappropriate or insufficient.

In instances of uncertainty, the article was reviewed by multiple researchers to reach a consensus. For example, some articles published before 2015 were deemed valuable enough for the method, thus being included. This rigorous process ensures the reliability and relevance of the literature included in this review.

To be included in the research, the papers were read completely to be fully certain of relevance and the last studies have been discarded.

[2]Even though websites are excluded from the systematic literature review, they are cited extensively in footnotes to describe some design styles as these are missing in scientific literature.

2.3 Inclusion

During the previous phases, all studies that did not meet the established criteria were removed. From these, 24 articles remained. These articles will form the basis of our research. A PRISMA diagram, displayed in Figure 2, illustrates the amount of discarded articles with their corresponding exclusion criteria. The next section addresses the remaining studies.

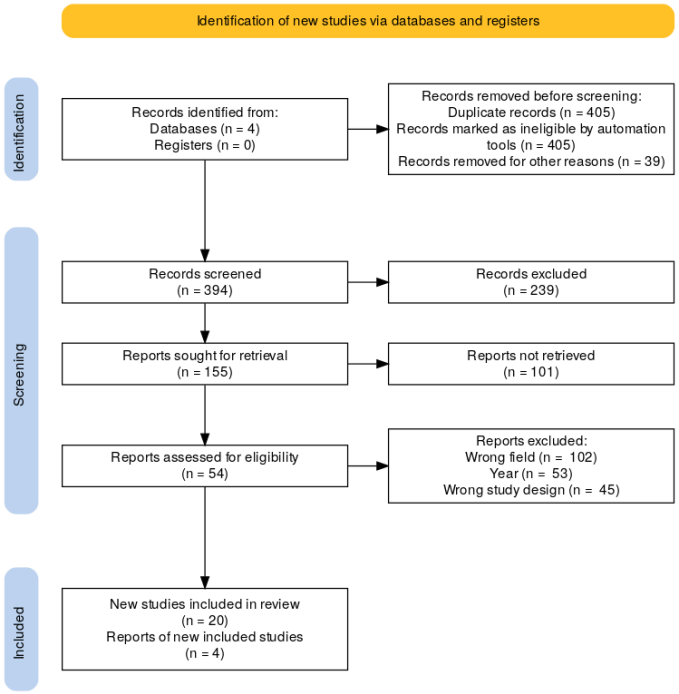


Fig. 2. The PRISMA diagram.

3 RELATED WORK

In the field of User Interface design, the choice of design style plays a crucial role in shaping the user experience. The design style determines how information is presented and how users interact with the interface. In this section, each of the three design styles — Skeuomorphic design, flat design, and Neubrutalism — will be elaborated upon and their implications for User Interface design will be discussed.

3.1 Skeuomorphic design

Skeuomorphism is when an object retains design cues that were necessary for the object it imitates, even when the reasons behind the original design purpose are no longer relevant [24], like electric light bulbs that imitate the shape of candle flames. Skeuomorphism in User Interface design employs this concept by mapping the functionality or aesthetic pleasure to match its real-world counterpart [18]. An example of this, as already stated in the introduction, is using the floppy disk as a ”save” icon, as well as using an actual trash can as an indication of a place where you put files you do not need anymore. The style represents ”perceived affordances”, matching a natural interpretation of objects to their digital world

Table 1. Search queries used.

Style: Skeuomorphism	Style: Flat design	Style: Neubrutalism
"Skeuomorphic design" OR **"Skeuomorphism"**	**"Flat design"**	**"Neubrutalism"** OR **"Neobrutalism"**

counterpart [8]. Through these affordances, users already have a notion of what the software is capable of [23] and could then copy their old behavior to the new design.

As time progressed, the hype of Skeuomorphic design came to an end. People thought the design was often too busy and cluttering the desktop. Moreover, from a designer's perspective, it was viewed as lazy and thought of as usually implemented uncritical.[3] An illustration of Skeuomorphic design can be found in Section 3.4, in Figure 3a.

3.2 Flat Design

The implementation of flat design started with Microsoft 8 [11], which was released in October 2012. It has since grown to be the most-used design style in User Interface.[4] The non-functional features, such as 3D effects and shadows, were removed to create a minimalist look. Flat design brings advantages, like faster loading times and consistency in visual design [1, 19]. Moreover, flat design can improve page scalability and it is helpful in responsive contexts where graphics need to be adjusted to fit different screen sizes [19]. A drawback, when compared to Skeuomorphic design, is that older users may not be familiar with flat design and could miss the metaphors and affordances they are accustomed to [1]. This lack of affordances makes it harder for the human brain to understand the icons and interface [6], and users may mistake interactive elements in an interface without affordances for non-interactive elements [11].

The stark contrast between flat design and Skeuomorphism led many studies to compare the understandability and aesthetic pleasure, which are elaborated upon in Section 3.5.

3.3 Neubrutalism

Neubrutalism, being a relatively new trend in User Interface design, has not been extensively studied in academic research. Most of the current understanding of this design style comes from industry sources and design blogs. Therefore, this section relies heavily on these non-academic sources.

Neubrutalism, also known as Neo-Brutalism, is a contemporary reinterpretation of the Brutalist architectural movement. It amplifies the rawness and simplicity inherent in Brutalism, emphasizing the use of vibrant colors, bold typography, and pronounced graphical elements. Despite its striking visual signature, Neubrutalism does not compromise functionality for aesthetics. It prioritizes an accessible design environment, facilitated by ample whitespace and minimalist layouts. This approach enhances readability, optimizes navigation, and consequently, improves the overall user-friendliness [5] [6] [7]

3.4 Overview of the three design styles

In conclusion, each design paradigm possesses distinct characteristics that influence the user experience. To illustrate this, three interface designs were crafted for a hypothetical calculator application, each embodying one of the three discussed styles. These styles are depicted in Figure 3 and were created comform to the guidelines of each style.

3.4.1 Characteristics of Skeuomorphic design. Skeuomorphism in User Interface can employ real-life analogies, creating shadows, complex features, textures, and gradients to match its real-world counterpart [18]. It tries to replicate the look and feel of real-world objects and materials, often using visual metaphors to make digital interfaces more familiar and intuitive [20]. Skeuomorphism and metaphors are closely related as it can be argued that Skeuomorphism is a visual subset of metaphors.[8] Based on this, Skeuomorphic design should (try) to be a metaphor for the object or purpose it represents.

Figure 3a showcases the Skeuomorphic design. This approach emulates tangible materials and objects, creating an interface that closely resembles a physical calculator. It features realistic 3D buttons, beveled edges, and shadows, along with the application of lifelike textures such as plastic and metal.

3.4.2 Characteristics of flat design. In contrast, flat design is different from Skeuomorphism. It avoids the use of 3D elements, such as shadows, gradients, or textures, and instead focuses on simplicity [20, 25]. Flat design focuses on simplicity with a minimalistic approach and uses simple shapes like circles and squares for buttons and icons. Bold colors are often used to make interactive elements stand out [11]. However, there are no definite rules for what colors are used in flat design. Typography plays a significant role in guiding users, and color palettes are bright and vibrant with retro colors being popular [25]. Sans-serif fonts are preferred [6]. A popular example is the hamburger menu which represents an expandable menu in web design. Another common example of flat design can be seen in Figure 3b where a calculator application is shown with round color blocks and no shadows.

[3] Hobbs. "Can We Please Move Past Apple's Silly, Faux-Real UIs?", accessed on 14-06-2023, retrieved from: https://www.fastcompany.com/1669879/can-we-please-move-past-apples-silly-faux-real-uis (30-05-12), accessed on 12-06-2023.

[4] Retrieved from Mobile App Design Trends 2023, accessed on 19-06-2023.

[5] Łabądź, Justyna Weronika. "Neubrutalism: Web Design Trend," Dodonut (2023), accessed on 14-06-2023, retrieved from: https://dodonut.com/blog/Neubrutalism-web-design-trend/.

[6] Malewicz, Michał. "Neubrutalism is taking over the web," Hype4 Academy (2023), accessed on 14-06-2023, retrieved from: https://hype4.academy/articles/design/Neubrutalism-is-taking-over-web.

[7] Yazdi, Sepideh. "How can I design in the Neo Brutalism style?," UX Design Bootcamp (2023), accessed on 14-06-2023, retrieved from: https://bootcamp.uxdesign.cc/how-can-i-design-in-the-neo-brutalism-style-d85c458042de.

[8] Retrieved from The Apple Watch, Skeuomorphism, and metaphors., accessed on 14-06-2023

Figure 3b presents an example of flat design. This style emphasizes simplicity, employing basic shapes and elements devoid of depth. The absence of shadows or gradients results in a clean, uncluttered aesthetic.

3.4.3 Characteristics of Neubrutalism. Neobrutalism employs a broad spectrum of colors throughout its design, extending to backgrounds that are often left grayscale or muted in other styles.[6] The color combinations in Neobrutalism often defy conventional design norms, pairing colors typically perceived as clashing.[5] [4]. Neobrutalism does not employ any gradients in its design.[6] Blacks in Neobrutalism are generally pure black (#000000), providing a stark contrast to the vibrant colors.[5] [6] Other styles, in comparison, often blend blacks with a hint of the accent color.[5]

Most interface elements are visually separated from their colorful environments through the use of black-colored outlines (strokes), drop shadows, or both.[4] [5] [6] Drop shadows in Neubrutalism, unlike in other styles, have no blur on them (giving them a distinct edge) and are not transparent (meaning they have 100 % opacity), further enhancing the visual contrast of User Interface elements.[4] [5] [6] Moreover, the shadows help provide a sense of depth to the interface.

A unique aspect of Neubrutalist design is the use of floating window-like cards, similar to windows as typically seen on operating systems such as Windows or Mac. Sometimes these windows even feature distinct title bars, icons, or minimize/maximize/-close buttons.[5] Besides those cards, it is also common to see the usage of simple shapes, such as triangles, circles, (rounded) squares, (rounded) rectangles, stars, etc.[6]

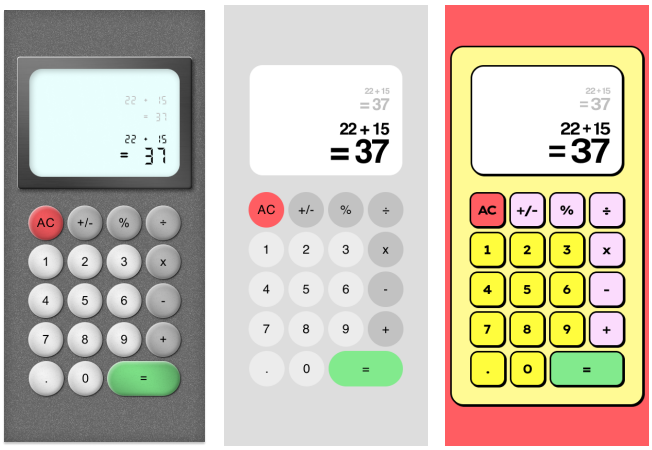
Typography in Neubrutalism is often sans-serif, using large font sizes for headings. Experimentation with line height and letter spacing is common. Some commonly used fonts include Lexend Mega, Public Sans, Mabry Pro, Archivo Black, and Bebas Kai.[6] While the chosen fonts often exhibit unique or playful characteristics, their presentation remains committed to clear legibility.[5]

Neubrutalism is yet to be thoroughly explored in academic research. This lack of comprehensive studies presents a unique opportunity for further investigation, particularly given the unique characteristics of Neubrutalism that set it apart from other design styles.

Figure 3c exemplifies a Neubrutalist design. The calculator application designed in this style has a floating 'window' like card, features a wide range of vibrant colors, and uses pure blacks and sharp drop shadows to visually separate elements. The font used is typical of Neubrutalist User Interface (Lexend Mega for the button text and Public Sans for the display text).

3.5 Comparing design styles for user interfaces

As previously briefly mentioned, there have been multiple studies conducted comparing flat and Skeuomorphic User Interface designs or icons on some form of usability. Usability can be clustered into three aspects based on ISO-9241-11 [5]; namely effectiveness, efficiency, and satisfaction. In User Interface research that focuses solely on design, a form of understandability is often tested as a part of effectiveness. Moreover, user satisfaction is in this same scope usually tested by measuring aesthetic pleasure. Efficiency, on the contrary, can not be measured solely in the User Interface design context, as it measures how quickly a system can be operated. Therefore, this research aims to investigate understandability and aesthetic pleasure as components of the greater usability concept.



(a) Skeuomorphism. (b) Flat. (c) Neubrutalism.

Fig. 3. Calculator in accordance to the conventional guidelines of Skeuomorphism (a), Flat design (b) and Neubrutalism (c). These figures are purely meant as examples of the design styles and are not used in the survey.

3.6 Influence of design style on understandability

Most studies comparing flat and Skeuomorphic design have shown that Skeuomorphism has a higher score of understandability compared to flat design.

For starters, it has been demonstrated that users are generally faster and more accurate in a visual searching task when the design is in a Skeuomorphic style compared to a flat style [9, 12, 17, 31]. These studies have demonstrated this effect in both icon design contexts as well as fully functional user interface contexts. Moreover, this difference in understandability between the two design styles is even more present in people who are over 65 years old [14, 27–29]. People, regardless of age, can get confused when they have to search for clickable objects in a flat design since they are uncertain whether the object could be interacted with or not [27].

On the other hand, research investigating the difference between Skeuomorphic and flat icon design on cognition load showed that flat design has a higher cognitive performance compared to Skeuomorphic design, for both younger and older people. Nonetheless, the cognitive load was lower for older people in Skeuomorphic design. This made the authors believe that the simplicity of the flat design helped with quick processing and would therefore have a higher cognitive performance. However, people who are unfamiliar with flat design icons and the corresponding functionality would therefore experience an increase in their cognitive load [21].

3.7 Influence of design style on aesthetic pleasure

Comparing flat and Skeuomorphic design in the icon design context, the clear difference between older and younger generations can be seen. The older generations prefer a Skeuomorphic design and the

Table 2. Systematic overview of the characteristics of the design styles.

	Skeuomorphism	Flat design	Neubrutalism
Gradients	Yes	None	None
Textures	Yes	None	None
Colors	Lifelike	Bold	Vibrant
Depth	Through realistic (blurred) shadows	None	Through (pure black) shadows and outlines
Shapes	Simulate real life	Simple	Simple
Fonts	Simulate real life (e.g. handwritten, nine-segment, etc)	Sans Serif	Sans Serif

younger ones a flat design [12, 15, 21, 29]. However, there are some contradictions, flat design has both been preferred and not preferred aesthetically over Skeuomorphism in a user interface design context [2, 25].

Additionally, research investigating the relationship between emotions and user preference (aesthetically) found that icons that were thought of as disgusting had the strongest impact on user preference. Users showed a significant difference in preference, moving strongly towards a flat design. In opposition, when an icon was thought of as happy, the user preference moved more strongly towards a Skeuomorphic design [30].

3.8 Research objectives

Given the current lack of research on the design style Neubrutalism, the objective of this research is to place Neubrutalism within the established design styles based on aesthetic pleasure and understandability between age groups. To investigate this, the following research question will be tested: *Is there a significant difference in the different design styles (Skeuomorphism, Flat design, and Neubrutalism) on aesthetic pleasure and understandability between the younger (born after 1980) and older (born in or before 1980) generation?*.

Based on the previously mentioned related work, it is expected that Skeuomorphic design has a higher understandability than flat design for people born before 1980. [14, 27–29]. Additionally, based on earlier research, it is expected that the younger generation will score higher compared to the older generation on aesthetic pleasure in flat design, and the older generation will score higher on aesthetic pleasure in Skeuomorphic design compared to the younger generation [12, 15, 21, 29]. As this is an exploratory study about Neubrutalism, and since it is a new trend that has not been investigated yet, no grounded hypothesis about Neubrutalsim could be constructed. However, if Neubrutalism lives up to its claims, it should score higher on understandability compared to flat design. Since the style employs more depth and contrasts.

4 METHODOLOGY

The methodology will start with the research design of this study. After, the employed sampling method will be explained. Next, in the data collection section, the design implementation, materials, and procedure will be reported. At last, the data analysis will describe which statistical techniques were used to analyze the collected data.

4.1 Research Design

As mentioned in the related work, the objective of this study is to place Neubrutalism within the two well-researched design styles - Skeuomorphism and flat design - on aesthetic pleasure and understandability between the younger and older generation. This is an explorative study since Neubrutalism has not been investigated previously. To achieve this objective, the study has employed a quantitative approach consisting of a questionnaire, administered online. As it would allow participants to partake in the study at their own convenience. In this questionnaire, a survey to measure aesthetic pleasure and an icon search task to measure understandability was employed. The study was conducted in a between-subjects method for each of the different design styles: each participant only saw one of the three design styles. The reason for employing a between-subjects design is to mitigate the influence of order on the scores of aesthetic pleasure and understandability.

4.1.1 Independent variables. The independent variables measured in this study are the different types of UI design styles and the two age groups. The different types of design styles are the following three: Skeuomorphic, flat, and Neubrutalist design. The three design styles are placed in a smartphone homescreen context, in which multiple applications are portrayed (see Figure 4). The choice for a homescreen with multiple app icons was made because the understandability can still be determined through app icons without an interactive interface. Moreover, it still portrays an interface as a whole, which ensures that the aesthetics are not solely measured by the preference for a specific icon. Secondly, the age groups consist of a group born after 1980, namely the younger generation and a group born before 1980, namely the older generation. This division in age is based on the rough estimation of whether a participant was raised using digital devices. In other words, whether the participant is a digital native or not [3]. This distinction is made as it is believed that the difference in childhood familiarity with technology could influence the understandability and aesthetic pleasure of different design styles.

4.1.2 Dependent variables. The dependent variables are aesthetic pleasure and understandability. First, the metric of aesthetic pleasure is based on The aesthetic pleasure in Design (APiD) Scale [7]. To prevent a positive bias toward the designs, the scale was adjusted to make the statements more neutralized. Antonyms of the words used in the APiD were employed to create a bipolar 7-point Likert metric. For instance, the participants were asked to fill in their answers to the following statement: *"I ... to look at this homescreen"*. In which they could rate their opinion from *"Strongly like"* to *"Strongly detest"*. The questions are shown in Appendix A.

A 7-point Likert scale is preferred over a 5-point Likert scale because it invites participants to be less neutral [22]. Furthermore,

it has been shown that employing a bipolar 7-point Likert metric accomplishes the criteria of equidistance the best, compared to other Likert types metrics [16]. Moreover, it has been shown that a bipolar Likert scale gives the advantage of measuring intensity from both directions of an attribute. [9]

Second, the understandability was measured by employing an icon identification task, as can be viewed in Appendix B. The icon identification task allows the understandability of the design to be tested without implementing a functioning user interface, and it allows for measuring understandability unsupervised through an online questionnaire. It is therefore a common test to determine the understandability through error rate, accuracy, and/or speed [4, 10, 12, 29]. In this study, the icon identification task was executed from function to icon. This entailed that the participants were asked to identify which icon they thought is best fitting with a certain functionality. The assumption that users of mobile devices usually need to open a specific function on their phone is the reason behind this method design choice. Therefore, it is expected that it will mimic the real-world situation. In the icon identification task, the time of total time to complete the tasks was measured as the metric of speed. Moreover, the accuracy was measured by the total amount of correctly identified app icons.

4.1.3 Covariate. As there could be an influence of previous experience with the device, the covariate of technology experience has also been measured. Using a 7-point Likert question in which they could indicate their own estimated experience with technology.

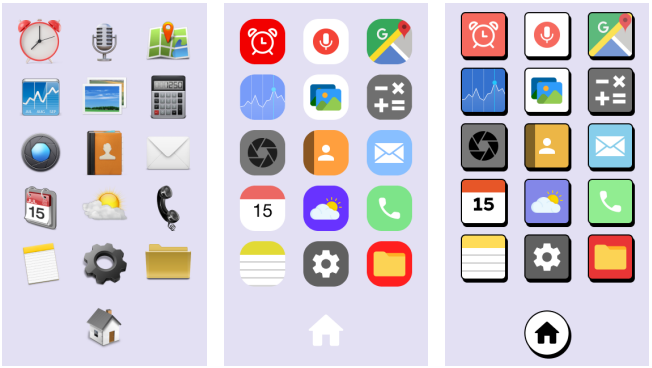
4.2 Sampling

Participants were recruited through convenience sampling, a non-probability sampling method, due to time constraints. To ensure that enough participants from the older generation were also represented, the snowballing method was also used. This was mainly done through multiple forms of social media and by asking people to further distribute the survey. Table 3 shows the distribution of participants. In total, 139 participants filled in the survey, of which 46 were born in or before 1980, and 89 after 1980. Divided per design style, 41 participants saw flat design, 45 saw Neuomorphic design, and 49 participants saw Skeuomorphic design.

Table 3. A table showing an overview of how many participants there were for each combination of age bracket and design style.

Age Bracket	Design Style	Amount
Born in or before 1980	Flat	12
Born in or before 1980	Neuomorphic	16
Born in or before 1980	Skeuomorphic	18
Born after 1980	Flat	29
Born after 1980	Neuomorphic	29
Born after 1980	Skeuomorphic	31

[9] Accessed on 14-06-2023, retrieved from: https://bellinislushie.com/blog/what-are-likert-scales-and-how-do-i-use-them-in-my-survey/.



(a) Skeuomorphism. (b) Flat. (c) Neubrutalism.

Fig. 4. The homescreen designs that were used in the study: Homescreens in the style of Skeuomorphism (a), flat design (b) and Neubrutalism (c).

4.3 Data Collection

This section will first show the implementation of the three designs. Then the needed materials will be noted and at last, the procedure will be explained.

4.3.1 Implementation of the three designs. Three homescreens were designed following the conventional guidelines for aesthetic styles of flat, Skeuomorphism, and Neubrutalism 4. In general, icons were kept as close as possible between design styles while still adhering to their own respective style. For example, the calendar icon has a Helvetica font in the flat design and Lexend Mega in the Neubrutalist design (as this is a typical Neubrutalist font[6]). Some icons were handmade, others were sourced from various publicly available sources.[10]

4.3.2 Materials. The materials required for this study were as follows:

- A questionnaire in Qualtrics (shown in Appendix B).
- The images of the three designs (shown in Figure 4).
- An informed consent form to ensure ethical compliance.
- Any computer or mobile device for the participants.

4.3.3 Procedure. The procedure was executed as follows.

- Participants were provided with a brief introduction to the study, including an overview of the experimental procedure and its objectives.
- The participants were asked to fill in an informed consent form before being allowed to continue the study. This form clarified their right to withdraw from the study at any time without providing a reason and assured the anonymization of their data to protect their privacy.

[10] App Stock Icon: Designed by Double-J Design, Apple Festival Icons. File Pictures Icon: Designed by Kyo-Tux, Phuzion Icons. Weather Icon: Designed by Oxygen Team, Oxygen Icons. Camera Shutter Icon: Designed by Wallec, Android Style Honeycomb Icons. Address Book Icon: Designed by RocketTheme.com, Free Web Icons. Mail Icon: Designed by zerode, Plump Icons. Calendar Icon: Designed by Iconshock, Real Project Management Icons. Calculator Icon: Designed by IconLeak, Atrous Icons. Settings Icon: Designed by Harwen, Pleasant Icons. Folder Icon: Designed by Oxygen Team, Oxygen Icons. Map Icon: Designed by WebIconSet.com, Mobile Icons. Miscellaneous sources: Icons8, Freepik.

- The participants were asked to fill in general questions regarding their gender, age, and whether they were born before/in or after 1980. Then, they were asked to rate their level of experience with mobile phones using a 7-point Likert scale (1 - Very inexperienced, 7 - Very experienced).
- The participants were exposed to only one of the three designs. The distribution of the three design styles among the participants was done randomly but equally distributed among the two age groups.
- The participants filled in the questionnaire APiD questionnaire, while still seeing the design on display.
- A short explanation of the object identification task was shown to the participants, in which it was explained that they needed to click on the correct icon as fast as possible. If this was done, they could go to the next question. To ensure that they understood the assignment, a test question was implemented.
- After completing a test question, the participants were shown the image of the design. This time they were asked to identify a certain icon by naming the functionality. For instance, 'Click on the icon which allows you to show your pictures', then it was expected for them to click on the gallery function in the image. This was done for ten of the fifteen icons. These were pre-selected through randomization.
- Upon completion of the questionnaire, participants were thanked for their contribution to the study. They were also provided with contact details in case they had any questions or wished to receive the study results.

4.4 Analysis method

The analysis was initiated by examining the data for missing values. The data set contained entries from mostly unfinished questionnaires, which were removed to ensure completeness of the data. This removal resulted in a data set devoid of any missing values. For ease of further analysis, categorical values were transformed to numeric where appropriate.

The key metrics for the study, namely the total time spent identifying app icons, the total app icons correctly identified, and the aesthetic pleasure score, were calculated for each participant. Specifically, the aesthetic pleasure score was derived from the mean of the five 7-point Likert-scale questions, yielding a continuous variable ranging from 1 to 7. This approach has been deemed effective for handling Likert-type data, especially for more abstract concepts, and has a reputation for leading to accurate hypothesis testing [26]. The choice to exclude the APiD questionnaire's concept coherence tests in this study was informed by the existing evidence that it adequately captures the complete concept of aesthetic pleasure in design [7].

Upon establishing these metrics, potential outliers were identified using Z-score and IQR methods. Consistency between both methods, after investigation, resulted in the removal of the identified outliers. Descriptive statistics were then calculated for these data points and explored in depth.

To validate the assumptions of AN(C)OVA tests, normality and homogeneity of variance checks were performed. The relationships between the covariate and dependent variables were visually inspected through plots. The Shapiro-Wilk method was used for normality tests, and Levene's tests to assess homogeneity of variance. Two-way ANOVA tests, instead of ANCOVA tests, were conducted due to the absence of a linear relationship between the covariate (experience) and the outcome variable (aesthetic pleasure). Post-hoc tests using Tukey's HSD method were conducted to further explore the results of the ANOVA tests. For the non-normally distributed dependent variables, as there is no omnibus test available, non-parametric Kruskal-Wallis tests were employed for each pairwise combination of independent and dependent variables. A Bonferroni correction was applied to the results of these tests to reduce the chance of Type I errors (false positives) caused by conducting multiple pairwise tests and to increase statistical power.

5 RESULTS

The following section presents the results of the statistical analyses conducted on the collected data. The significance level chosen for the tests was set at 0.05.

Table 4 provides descriptive statistics for the variables grouped by age bracket and design style. The table includes the mean and standard deviation (SD) for aesthetic pleasure, total app icons correctly identified, and total time spent identifying app icons. Additionally, Table 5 presents descriptive statistics by age bracket alone, and Table 6 presents descriptive statistics by design style alone.

Normality tests using the Shapiro-Wilk method revealed that among the dependent variables, only aesthetic pleasure was normally distributed (W = 0.983, p = .08). Time spent identifying app icons (W = 0.901, p < .001) and app icons correctly identified (W= 0.633, p < .001) were found to be non-normally distributed. Further examination of Q-Q plots confirmed that only aesthetic pleasure followed a normal distribution (Figure 5).

To assess the homogeneity of variance (an assumption for the subsequent ANOVA test), Levene's tests were conducted for aesthetic pleasure with both independent variables: age bracket and design style. The tests found homogeneity of variances for both age brackets (Levene statistic: 0.019, p = .89) and design style (Levene statistic: 1.352, p = .26).

A scatter plot was created to examine the potential relationship between the covariate (experience) and the outcome variable (aesthetic pleasure) for each combination of groups (see Figure 6). Visual inspection of the plots did not reveal a linear relationship between the two variables. As a result, two-way ANOVA tests were conducted instead of ANCOVA tests for aesthetic pleasure.

The two-way ANOVA (type 2 sum of squares) investigating aesthetic pleasure revealed a significant influence of design style on it ($F(2, 134)$ = 3.404, p = .04). Further investigation using a post-hoc Tukey HSD test indicated a statistical significant difference in aesthetic pleasure derived from Skeuomorphic and flat design styles (mean difference = -0.76, 95% CI [-1.38, -0.14], p' = .01). It was observed that, on average, Skeuomorphic designs rendered an aesthetic pleasure that was lower by 0.76 units as compared to flat designs.

The ANOVA further revealed a significant interaction effect between age bracket and design style on aesthetic pleasure ($F(2, 134)$

Table 4. Descriptive Statistics, grouped by age bracket and Design Style.

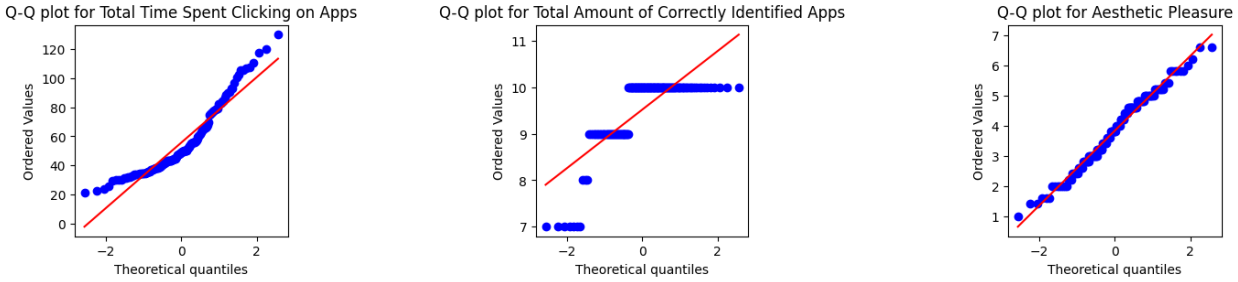
Group		Aesthetic Pleasure		App Icons Correctly Identified		Time Spent Identifying App Icons	
Age Bracket	design style	Mean	Sd	Mean	Sd	Mean	Sd
Born in or before 1980	Flat	4.27	1.14	9.33	0.99	88.00	20.50
Born in or before 1980	Neubrutalism	3.56	0.99	9.06	0.85	71.40	20.60
Born in or before 1980	Skeuomorphism	4.08	1.58	8.94	1.16	72.40	23.60
Born after 1980	Flat	4.13	1.22	9.76	0.44	48.90	17.60
Born after 1980	Neubrutalism	4.01	1.04	9.79	0.62	47.10	17.60
Born after 1980	Skeuomorphism	3.21	1.15	9.68	0.48	39.50	9.65

Table 5. Descriptive Statistics, grouped by Age Bracket.

Age Bracket	Aesthetic Pleasure		App Icons Correctly Identified		Time Spent Identifying App Icons	
	Mean	Sd	Mean	Sd	Mean	Sd
Born in or before 1980	3.95	1.30	9.09	1.01	76.1	22.5
Born after 1980	3.77	1.20	9.74	0.51	45.0	15.7

Table 6. Descriptive statistics, grouped by Design Style.

Design Style	Aesthetic Pleasure		App Icons Correctly Identified		Time Spent Identifying App Icons	
	Mean	Sd	Mean	Sd	Mean	Sd
Flat	4.17	1.19	9.63	0.66	60.30	25.70
Neubrutalism	3.85	1.03	9.53	0.79	55.70	21.90
Skeuomorphism	3.53	1.38	9.41	0.86	51.60	22.60



(a) Time Spent Identifying App Icons. (b) App Icons Identified Correctly. (c) Aesthetic Pleasure.

Fig. 5. Q-Q plots for Time Spent Identifying App Icons (a), App Icons Identified Correctly (b), and aesthetic pleasure (c).

= 3.310, p = .04). A subsequent Tukey's HSD test for this interaction term pointed out a statistically significant difference in aesthetic pleasure between Skeuomorphic and flat design styles for participants born after 1980 (mean difference = -0.92, 95% CI [-1.82, -0.03], p' = .04). In this age bracket, Skeuomorphic designs were associated with an average aesthetic pleasure that was 0.92 units lower than that derived from flat designs. However, no significant differences were observed for any other combinations of design styles and age brackets.

Interestingly, when conducting a type 3 sum of squares factorial ANOVA analysis, there was only a significant influence on aesthetic pleasure by the interaction of age bracket and design style (F(2, 134) = 3.310 p = .04) but not by solely design style (F(2, 134) = 1.367, p = .26). Since there is an interaction effect present, the Type 3 results can be considered more powerful, indicating that only the interaction term can be considered of significant influence.[11]

For the non-normally distributed dependent variables, non-parametric Kruskal-Wallis tests were conducted for individual pairwise comparisons. The p-values were then adjusted using the Bonferroni correction (corrected p-values are denoted as p'). age bracket showed a significant relationship with both time spent identifying app icons

[11]Retrieved from https://mcfromnz.wordpress.com/2011/03/02/anova-type-iiiiii-ss-explained/ on 14-06-23.

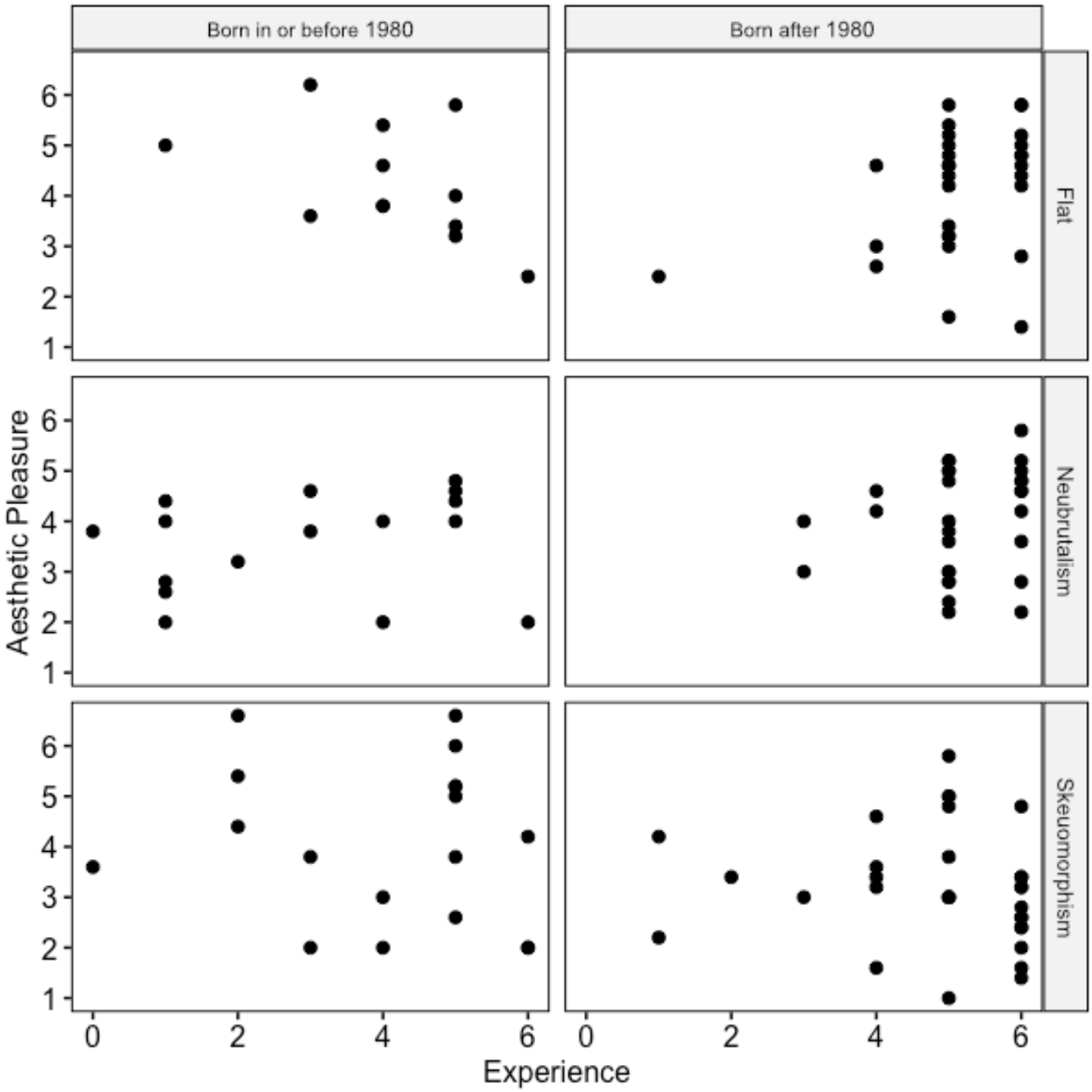


Fig. 6. Scatter plot showing the relationship between experience and aesthetic pleasure for each group.

($\chi^2(1) = 54.21$, $p < .001$, $p' < .001$) and app icons correctly identified ($\chi^2(1) = 19.33$, $p < .001$, $p' < .001$).

The correlation between age as a continuous variable and the dependent variables was also tested. The result shows a significant positive correlation with time spent identifying app icons (r=0.66, $p < .001$) and a significant negative correlation with app icons correctly identified (r=-0.40, $p < .001$).

6 DISCUSSION

The purpose of this research was to compare three different design styles, namely Skeuomorphic, flat design, and Neubrutalism, on

aesthetic pleasure and understandability between younger (born after 1980) and older (born in or before 1980) generations. In the following sections, the results will be interpreted, after which a conclusion will be drawn including the implications. Then, the limitations are discussed, followed by suggestions for future work.

6.1 Interpreting the results

For starters, the results of the more appropriate[12] and powerful type 3 factorial ANOVA for this study, indicate that the interaction of age bracket and design style have a significant effect ($F(2, 134) = 3.310$ $p = .04$). This indicates that the effect of design style and age on aesthetic pleasure is not independent, but are rather intertwined with each other. Consequently, the overall impact of design style on aesthetic pleasure may only be significant in certain Age Brackets. This notion is supported by a post-hoc Tukey's HSD test, which reveals a substantial disparity in aesthetic pleasure, derived from Skeuomorphic and flat design styles for participants born after 1980. A mean difference of -0.92 (95% CI [-1.82, -0.03], $p' = .04$) illustrates this disparity. In simpler terms, we can be 95% confident that the actual mean difference in aesthetic satisfaction for post-1980 participants, between Skeuomorphic and flat design, ranges from 0.03 to 1.82 points lower for Skeuomorphic design. However, this difference is not observed for those born in or before 1980, or for any other combination of styles and age brackets. This could either mean that the other age brackets are agnostic to design style in terms of aesthetic pleasure, or that our study is not sufficiently powered to detect such differences.

Looking at the time spent identifying app icons and app icons correctly identified, the age bracket shows a significant relationship with both variables. According to the Kruskal-Wallis tests, the older generation (≤ 1980) spends significantly more time identifying app icons than the younger one (> 1980, with a mean difference of 31.1 seconds ($\chi^2(1) = 54.21$, $p < .001$, $p' < .001$). Additionally, the older generation correctly identifies fewer app icons than the younger one, with a mean difference of -0.65 ($\chi^2(1) = 19.33$, $p < .001$, $p' < .001$).

When further analyzing age, and exploring it as a continuous variable (as opposed to two categorical values), two correlations are found. There is a significant positive correlation between age and the time spent identifying app icons ($r = 0.66$, $p < .001$). This implies that as age increases, the time required to identify app icons tends to increase as well. Additionally, there is a significant negative correlation observed between age and the number of app icons correctly identified ($r = -0.40$, $p < .001$), indicating that as age increases, the number of app icons correctly identified app icons tends to decrease. It is important to underline here, that these findings signify correlations, and do not necessarily indicate causation. That said, when these correlation results are considered in conjunction with the Kruskal-Wallis test outcomes, there is a strong indication that age is likely to have a significant impact on both the time expended and the accuracy in identifying app icons. Interestingly, the design style does not significantly impact these two dependent variables, suggesting that while design style influences aesthetic preferences, it does not translate to understandability in terms of time spent and accuracy in identifying app icons.

While interpreting these results, it is important to consider that the data for time spent identifying app icons and app icons correctly identified in our samples are not normally distributed, leading to the use of non-parametric tests, which are robust but may have less statistical power.

To answer the research question, there are significant differences between the design styles on aesthetic pleasure and understandability between the younger and older generation. The results indicate the following. First, the Skeuomorphic design was expected to have a higher understandability than the flat design, especially for people born before 1980. This hypothesis could not be confirmed, as there was no significant difference found between the three design styles and time, and between the three design styles and correctly identified app icons. Consequently, correctly identified app icons and time are both components of understandability. However, there were significant differences between the two age groups in general. In which the younger generation was faster and identified app icons more app icons correctly compared to the older generation. Since the data was not normally distributed, no interaction effect could be measured, which could explain why the effect that was found in the literature was not supported by the data. The observed gap between age groups might be attributed to the fact that older participants are not typically classified as "digital natives," as per the terminology used in this study. Consequently, their technological fluency might not be as proficient, thereby affecting their understandability of User Interface regardless of design style.

Second, it was expected that the younger generation would score higher on aesthetic pleasure in flat design compared to the older generation. This hypothesis is supported by the results. As there was a significant interaction effect present between the younger generation and design styles Skeuomorphic and flat on aesthetic pleasure. In which flat design scored higher than Skeuomorphic design. This effect has been supported by the studies that compare Skeuomorphic design to flat design based on different ages. In opposition, it was expected that the older generation would score higher on aesthetic pleasure in Skeuomorphic design compared to the younger generation. Based on our results, this hypothesis could not be confirmed, since there was no significant interaction effect of the older generation and the design styles.

At last, no research has been conducted regarding Neubrutalism. Therefore, there were no founded expectations for this design style on understandability and aesthetics. Based on our results, there were no significant differences regarding Neubrutalism. Interestingly, but non-significant, in almost every comparison of means of the design styles on aesthetic pleasure, speed and correctly identified applications, Neubrutalism placed itself in the middle of the three design styles. Except for the older generation on aesthetic pleasure, there it had the lowest mean score compared to the three design styles. What is noteworthy, is that Neubrutalism in the younger generation on aesthetic pleasure did not score as low, and was on average somewhat similarly scored to flat design.

[12] when compared to a Type 2 Sums of Squares Factorial ANOVA

6.2 Limitations

A limitation of the study is that design styles as a whole can be vague and are subjective constructs of a collection of guidelines, so it can be difficult to objectively test these. In order to circumvent these subjective influences as much as possible, the guidelines for the different design styles were followed as closely as possible, and variations were kept to a minimum. However, there still could be some differences between the same design styles.

Another limitation in the performed study is the way the designs have been tested; which was through an image of a homescreen with app icons. As there are countless ways to test different implementations of designs, e.g., through different apps or through clickable interfaces, there are implementations that have not been tested and that are missing from the interpretation. If multiple different implementations of the design styles were included, external validity would have been increased.

Lastly, there are some possible unintended variations in the way the questionnaires were taken. Since the questionnaire was made in English and part of our targeted audience was older, there is a chance that their level of English was insufficient to understand the questions. Some participants actually reached out to explain that relatives were unable to fill in the questionnaire due to their level of English. This also attributes to the possible slowness of participants, as they took extra time to read through the questions. Partially contributing to this uncertainty is the fact that the surveys were not taken in a controlled environment, which decreases the internal validity. Letting participants take the survey in a controlled environment would have drastically decreased the number of participants.

6.3 Future work

One observation of this work is that people born after 1980 scored the Neubrutalism interface relatively high based on the aesthetic pleasure mean, compared to Skeuomorphism and compared to people born before 1980. However, no significant difference has been found for Neubrutalism compared to Skeuomorphic and flat designs. Therefore, future work could focus on comparing these design styles for the younger generation only, to see if Neubrutalism scores also better in aesthetic pleasure compared to Skeuomorphic design (similar to the higher score of the aesthetic pleasure of flat design compared to Skeuomorphic design, as stated in previous literature [12, 15, 21, 29]).

Besides, to make the study more reliable, more diverse interface designs could be evaluated which could take the differences between the same design style into account, this could increase the external validity.

In addition, one of the drawbacks of this study is that only two aspects of usability have been tested, namely aesthetic pleasure and understandability. This is because only a homescreen interface with app icons was evaluated, and not a working interface that can be interacted with. A follow-up study could focus on the other aspects of usability as well, such as learnability and operability, creating and evaluating an interactive interface for all three design styles. Then the effect of the fact that Neubrutalism creates more contrast and depth in the design styles could better be tested.

Last, when doing future research, the survey should be available in different languages, to not exclude people with less knowledge of the English language and to reduce misinterpretation of the questions due to lack of knowledge of English words.

7 CONCLUSION

This study aimed to investigate the influence of three design styles - Skeuomorphic, Flat, and Neubrutalism - on aesthetic pleasure and understandability, considering two distinct age groups (people born before 1980, or those after). Our results did not confirm all our hypotheses: while the younger generation did find the flat design more aesthetically pleasing, the older generation's expected preference for Skeuomorphic design was not significant. Furthermore, the anticipated superior understandability of Skeuomorphic design was not observed.

Despite these findings, significant age-related differences were noted in both aesthetic pleasure and understandability, underscoring the importance of considering generational variances in user interface design. The study also revealed interesting, albeit non-significant, insights about the Neubrutalism design style that could be explored further in future research.

However, the study's limitations suggest future research could benefit from diverse design testing methods, consideration of other usability aspects, and making surveys accessible in multiple languages. Conclusively, the results suggest that there are differences between Skeuomorphism and flat design, specifically with the younger generation on aesthetic pleasure. However, the impact of design style appears less profound than the impact of age group, which markedly shows differences between both groups on aesthetics and understandability.

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A BIPOLAR QUESTIONNAIRE

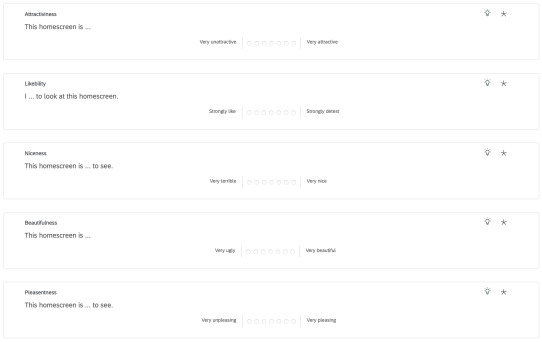


Fig. 7. Bipolar 7-point Likert metric used in the questionnaire.

Utrecht University

Introduction & consent form

Usability Across Generations: Comparing Skeuomorphic, Flat, and Neubrutalist User Interface Design

Research Team: Lukas Stemerdink, Mirre Dona, Sarah Tol, Samuel Spithorst

Affiliation: Utrecht University, Princetonplein 5, Utrecht, Netherlands, 3584CC

Purpose of the Research
This research study aims to investigate the perceived usability of three different user interface (UI) design styles: skeuomorphism, flat design, and Neubrutalism. We are interested in understanding how these design styles influence aesthetic pleasure and understandability among different age groups.

What Will Happen During the Study?
If you agree to participate in this study, you will be asked to:

1. Provide some general demographic information, including your gender, birth year, and experience with technology.
2. Complete an online questionnaire about your opinion and your perception of mobile phone UI design style.
3. Participate in an icon identification task, where you will be asked to identify certain icons based on their functionality.

The entire survey should take approximately 5 minutes to complete.

Data Collection and Use
We will collect data through the online questionnaire and the icon identification task. This data will be used to analyze the influence of UI design styles on aesthetic pleasure and understandability. We intend to make the data available for reuse in future research studies.
Your Rights as a Participant
Your participation in this study is entirely voluntary. You have the right to withdraw your consent and discontinue participation at any time without any negative consequences. You also have the right to request a copy of the final research report.
Confidentiality
Your responses will be anonymous. We will not collect any personal information that could be used to identify you. All data will be stored securely, and only the research team will have access to the data.
Data Sharing
The anonymized data collected in this study may be shared with other researchers for future research purposes. However, any data shared will not contain information that could identify you.
Questions?
If you have any questions about this study or your rights as a participant, please feel free to contact any of the team members:

- Lukas Stemerdink, a.m.e.stemerdink@students.uu.nl
- Mirre Dona, m.a.l.dona@students.uu.nl
- Sarah Tol, s.tol@students.uu.nl
- Samuel Spithorst, s.f.spithorst@students.uu.nl

By clicking accept, you acknowledge that you have read and understood the information above, and you agree to participate in this research study.

◯ Accept
◯ Refuse

General questions

What year were you born in?

◯ Before 1980
◯ After or in 1980

https://survey.uu.nl/Q/EditSection/Blocks/Ajax/GetSurveyPrintPrevie...textSurveyID=SV_4VdLsl567NeYwh8&ContextLibraryID=UR_2t7WccOG1OeWK22

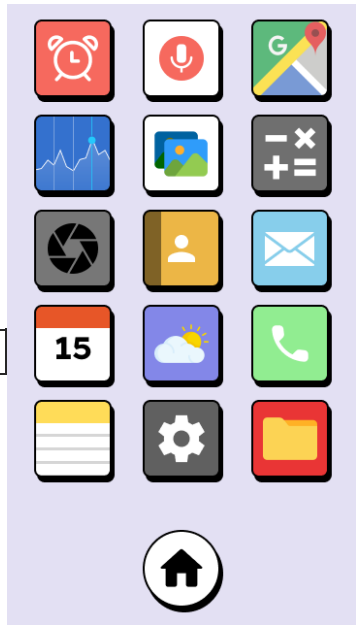
What gender do you identify with?

◯ Male
◯ Female
◯ Non-binary
◯ Other
◯ Prefer not to answer

What is your age?

Select the answer that fits best with your own opinion

	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
I have experience with technology	◯	◯	◯	◯	◯	◯	◯



Aesthetics of neubrutalism

Closely inspect the homescreen of this interface

This homescreen is ...

Very unattractive ◯ ◯ ◯ ◯ ◯ ◯ ◯ Very attractive

I ... to look at this homescreen.

Strongly like ◯ ◯ ◯ ◯ ◯ ◯ ◯ Strongly detest

https://survey.uu.nl/Q/EditSection/Blocks/Ajax/GetSurveyPrintPrevie...textSurveyID=SV_4VdLsl567NeYwh8&ContextLibraryID=UR_2t7WccOG1OeWK22

This homescreen is ... to see.

Very terrible ○ ○ ○ ○ ○ ○ ○ Very nice

This homescreen is ...

Very ugly ○ ○ ○ ○ ○ ○ ○ Very beautiful

This homescreen is ... to see.

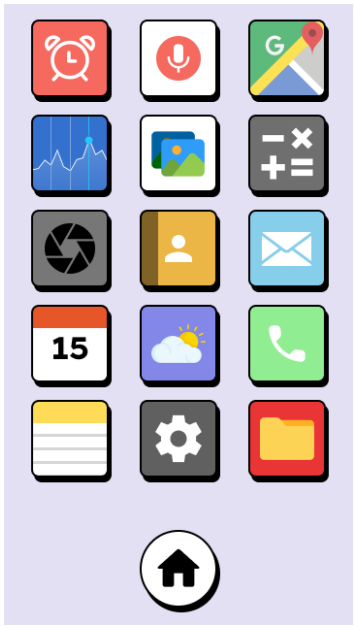
Very unpleasing ○ ○ ○ ○ ○ ○ ○ Very pleasing

Understandability neubrutalism

In the following section we will ask you to identify an icon by us describing a functionality. Click on the corresponding icon as fast as possible. You are only allowed to click on one icon. First, there is one practice question.

This is a practice question. Click on the icon where you can get back to the homescreen.

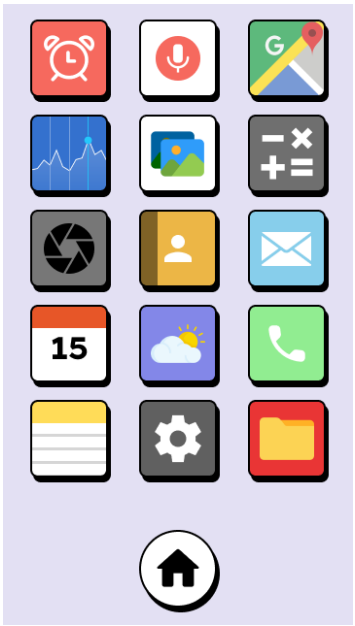
When you have clicked on an icon, please continue with the following questions.



The answers of the following questions will be used in the research. Your answering time is measured, as such, please, **answer** each of the following questions **as quick as possible**

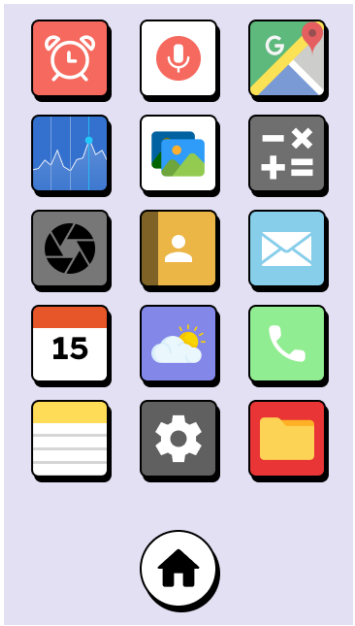
Click on the icon where you can record audio.

When you have clicked on an icon, please continue with the following questions.



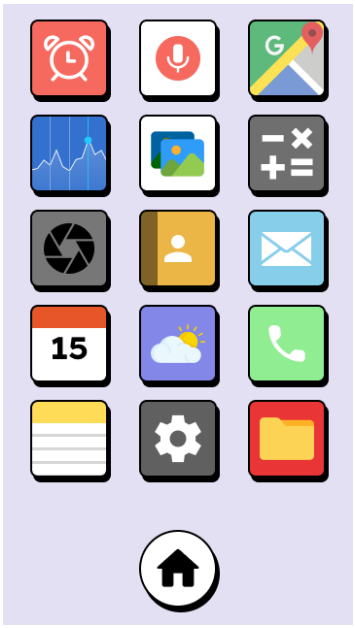
Click on the icon where you can take pictures.

When you have clicked on an icon, please continue with the following questions.



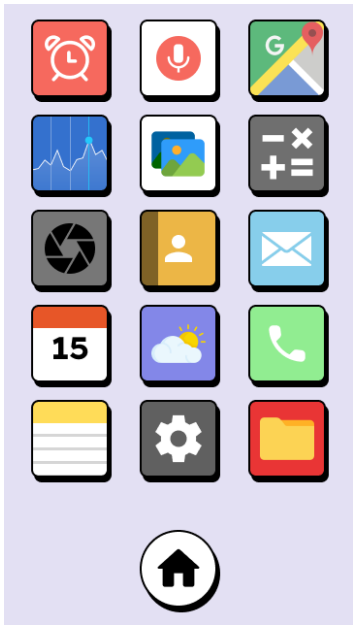
Click on the icon where you can access your files.

When you have clicked on an icon, please continue with the following questions.



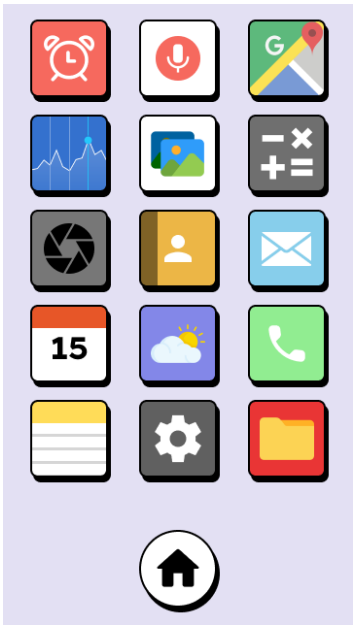
Click on the icon where you can make a phone call.

When you have clicked on an icon, please continue with the following questions.



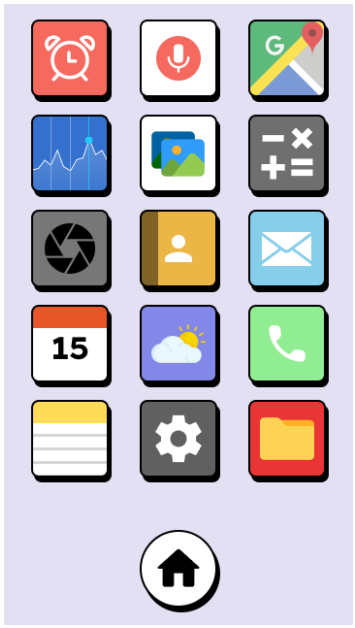
Click on the icon where you can view your images.

When you have clicked on an icon, please continue with the following questions.



Click on the icon where you can look up the weather forecast.

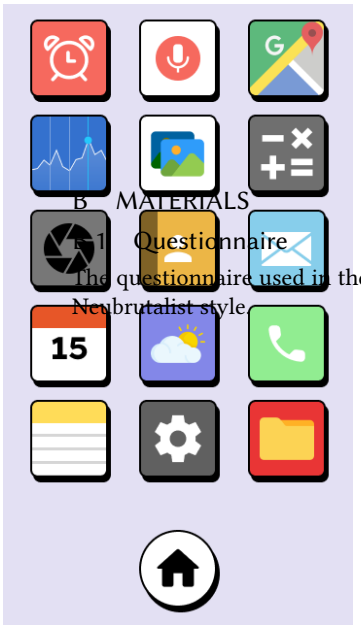
When you have clicked on an icon, please continue with the following questions.



Click on the icon where you can alter your settings.

When you have clicked on an icon, please continue with the following questions.

Qualtrics Survey Software 15/06/2023, 12:30



Click on the icon where you can check your calendar.

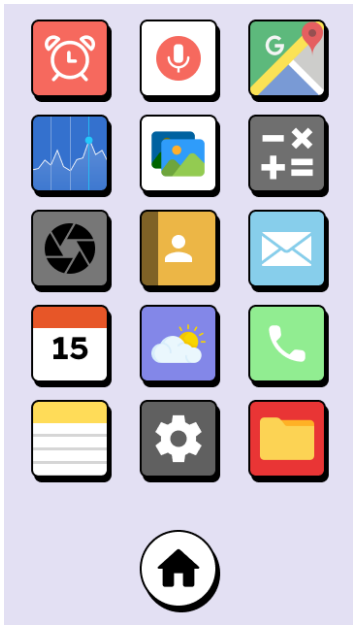
When you have clicked on an icon, please continue with the following questions.

B MATERIALS

B.1 Questionnaire

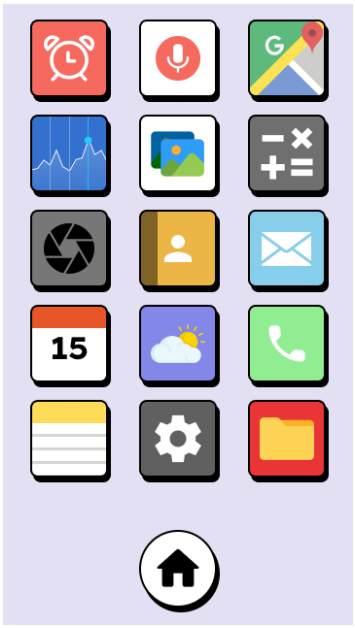
The questionnaire used in the study, showing the participant the Neubrutalist style.

Qualtrics Survey Software 15/06/2023, 12:30



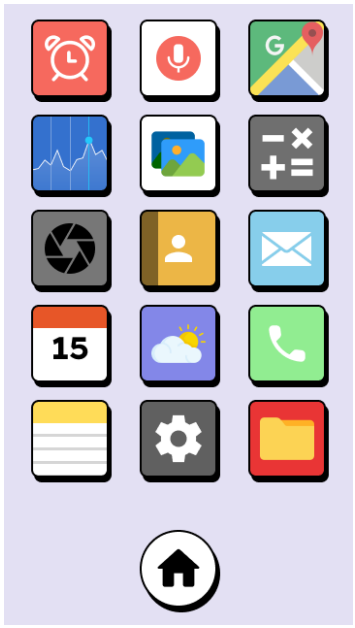
Click on the icon where you can write notes.

When you have clicked on an icon, please continue with the following questions.



Click on the icon where you can view your contacts.

When you have clicked on an icon, please continue with the following questions.



Email address for a chance to win a voucher

Enter your email address if you would like to enter the draw for a chance to win a voucher of your choice worth 20 euros.

*Not required and it will not be linked to your survey answers. Also, the email addresses will be removed after the price has been rewarded to the winner.

B.2 Survey flow

The questionnaire used a controlled randomized flow, making sure that the young and old age groups are separated and that the styles are evenly randomized. To illustrate the flow used in the survey, a flow diagram is shown in Figure 8.

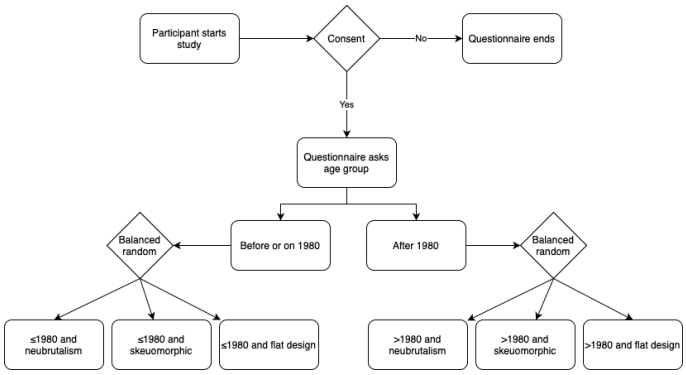


Fig. 8. Flow diagram of the flow used in the questionnaire.