

An Investigation of Computer Icon Design

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Abstract—This research evaluates the connections between icon concreteness and entropy and user performance and aesthetic response using a mixed methods approach (2x2 experiment and interview) (n = 30 undergraduate students). Participants were shown a total of 12 icons under 4 conditions (concrete/low entropy, concrete/high entropy, abstract/low entropy, abstract/high entropy), three times each. Response time and accuracy was evaluated and interview data assessed the relative attractiveness of icons on these categories. User performance was best for concrete icons, while abstract icons were identified more slowly and less accurately. Interviews revealed a general preference for concrete/high-entropy icons, which were described as easy to understand and aesthetically appealing, although some respondents preferred the aesthetic design of concrete/low-entropy icons. Abstract icons were viewed as ambiguous, with high entropy detracting from aesthetic appeal. The results suggest interaction between concreteness and icon entropy, indicating that further research is needed to justify us of these characteristics in icon design.

I. INTRODUCTION

One of the surprising aspects of computer interface design for business is that relatively little research has addressed the role of icon design aesthetics or usability aspects in user preferences. Much research to date has focused on the branding and brand awareness aspects of icons for apps and computer programs, but relatively little has focused on the usability and aesthetic appeal of those icons [1]. This situation has extended not just to desktop icons, but also to mobile functionality like NFC access [1]. At the same time, aesthetic design of icons may often be performed late in the interface design process and without regard to the computing context or environment [2]. This situation can lead to vastly different icon recognition and user performance in different icon sets, even those that represent the same functionality (such as OEM and branded interfaces for the same underlying mobile operating system functions) [3]. This research addresses the problem of connections between the functional design (concreteness and entropy) and aesthetics of an icon and user preferences for the icon appearance, to understand how this gap could be addressed in the icon design process.

II. LITERATURE

A. Icon design

A computer icon is a visual symbol that represents a single function within an operating system, such as launching a program, performing an action, or providing information [4]. The computer icon is an integral part of the graphical user

interface (GUI) of modern computing systems, and is present in both desktop computing systems and newer mobile computing systems. Historically, the design of computer icons has been an aesthetic practice, rather than one guided by principles of human-computer interface (HCI) or cognitive psychology knowledge [5]. More recent research has shown that icon design remains a largely aesthetic practice, despite more advanced knowledge about the visual characteristics of the icon and its effect on cognitive processing and usability [1], [2]. However, there have been changes in icon design over time that have affected usability and user appeal [6]. For example, Windows icons from pre-Windows 8 eras were found to now appear old-fashioned [6]. Icon characteristics that are known to influence user appeal can include concreteness, semantic distance, familiarity, and complexity [7], [8]. Other visual characteristics like entropy can also influence icon usability [9]. This research focused on icon concreteness and icon entropy.

B. Icon concreteness

Icon concreteness refers to the degree to which the icon directly represents a real-world object and associated concept or action [7], [8]. A concrete icon is a direct metaphor associating a real-world object with the computer function; for example, the use of a clock for time functions. An abstract icon is an indirect metaphor, requiring the user to expend more cognitive effort to understand the connection between function and action [10]. An example of an abstract icon is the use of a rabbit to indicate rapid processing [10]. Icon concreteness has been shown to influence both user performance (such as selection accuracy and response time) and the aesthetic appeal of the icon [10]. Specifically, these authors found that icon concreteness, along with familiarity, was an important predictor of both icon performance and aesthetic appeal of an icon [10]. This connection is a generalisation of a connection between aesthetic appeal and task performance, which also emerges in other contexts [11]. This later research found that aesthetically appealing icons, which were typically more concrete, could be more rapidly identified under complex search conditions [11]. Despite the clear advantages of icon concreteness, not all icons are concrete, both because of a limited set of direct visual symbols which cannot easily be overloaded and because of the primarily aesthetic concern of icon design [5], [10].

C. Icon entropy

Icon entropy refers to the amount of visual variation within a computer icon [12]. At the pixel level, entropy may be measured in the extent to which the pixels are similar or different; a single-colour visual image has the lowest level of

entropy, with increasing variation in colour representing higher levels of entropy [12]. Typically, a black and white or single-colour and white icon will be perceived as low-entropy, while a multi-colour icon will be perceived as high-entropy [13]. While it is not directly measured by humans, icon entropy is still perceived, typically as ‘sameness’ or similarity of the visual characteristics of the icon (for example, similar colours) [9]. A low-entropy icon will be perceived as having a high level of visual consistency or sameness, while a high-entropy icon will be perceived as having a high level of visual inconsistency or differentness. Entropy, like concreteness, has effects on user performance for icons. For example, users may classify items in a display based on their level of complexity, although they may differ in how they do so [12]. Users may also use entropy as one of the characteristics to determine whether icons are similar or different [9]. However, the extent to which icon entropy influences user performance and aesthetics has not been studied as much as concreteness.

III. RESEARCH METHODOLOGY

The research was designed as a two-stage mixed methods study, incorporating a 2x2 (concreteness: concrete/abstract; entropy: high/low) experimental design with a qualitative survey. A sample of 30 volunteer participants were selected from information systems undergraduates who were not currently enrolled in HCI classes. The participants completed a symbol-meaning matching task to collect accuracy and response time data, followed by a brief interview to collect data about the aesthetic appeal of the icons and user impressions.

The experiment was conducted with a set of 12 icons including 3 in each category (concrete/low entropy; concrete/high entropy; abstract/low entropy; abstract/high entropy). The icons used are shown in Figure 1. Each icon was shown three times in random order, resulting in 36 trials per participant (1,080 trials in total). Results for the experiment were analysed using cross-tabulations. The very high accuracy rate (only 7 incorrect answers in total) means that there is a ceiling effect in place, which can result in inaccurate estimates of error and statistical significance [14]. Furthermore, the low frequency of some cell data (under 1 in some categories) meant that chi square calculations were not appropriate. Therefore, it is not possible to tell whether this data has statistically significant differences in distribution.

The interviews were conducted in approximately 10 minutes per participants, following the experimental trial to avoid introducing familiarity effects. During the interviews, participants were shown each icon, again presented in a random order, and asked what their impressions were of the icon. Participants were not guided as to what aspect of the icon should be focused on or what characteristics they should address. Responses were noted for each icon before moving to the next icon. The interview data was analysed using content analysis, with the main impressions of each icon derived from the overall response set.

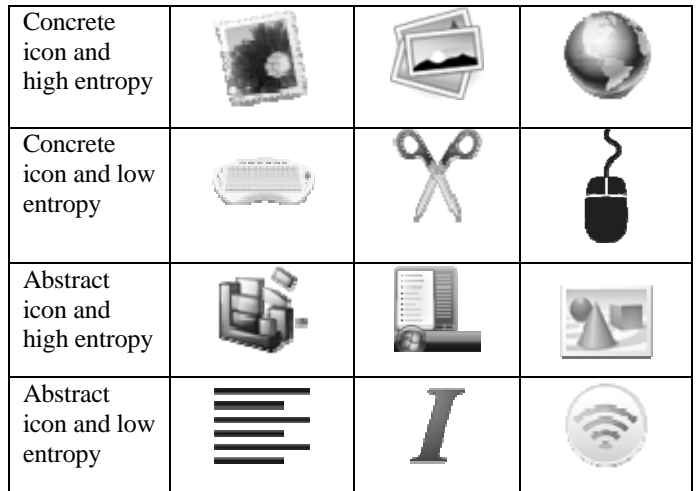


Fig. 1. Icons used in the study

IV. RESULTS

For the accuracy and response time categories, respondents were evaluated on their worst trials. Table 1 summarizes the cross-tabulations for icon conditions (concreteness x entropy) and response time (<5 seconds, 5 to 8 seconds, and 8+ seconds). This shows that the concrete/low entropy icon condition was the easiest for participants, with 100% of participants identifying the icons correctly within five seconds. After that was the concrete/high entropy condition, where all 30 participants identified the icon within five seconds, but two respondents were incorrect. The abstract/high entropy condition can be considered next. 29 out of 30 participants identified the icon within five seconds, but two of these responses were incorrect. One participant took 8+ seconds to identify the icon correctly. Finally, the most difficult condition for respondents was abstract/high entropy, where only 25 participants identified the icon within five seconds (two incorrectly) A further 3 participants took 5 to 8 seconds to identify the icon correctly, while two respondents took more than 8 seconds to identify the icon (one correct, one incorrect). Thus, while it is not feasible to determine whether these differences are statistically significant, it is possible to see that there are some distribution differences.

TABLE I. CROSS-TABULATION OF ACCURACY AND RESPONSE TIME

| Response time | Correct / Incorrect | Concrete and high entropy | Concrete and low entropy | Abstract and high entropy | Abstract and low entropy |
|---------------|---------------------|---------------------------|--------------------------|---------------------------|--------------------------|
| <5 secs | Correct | 28 | 30 | 27 | 23 |
| | | 93.3% | 100% | 90% | 76.7% |
| | Incorrect | 2 | 0 | 2 | 2 |
| | | 6.7% | 0% | 6.7% | 6.7% |
| 5 to 8 secs | Correct | 0 | 0 | 0 | 3 |
| | | 0% | 0% | 0% | 10% |
| | Incorrect | 0 | 0 | 0 | 0 |
| | | 0% | 0% | 0% | 0% |
| 8+ secs | Correct | 0 | 0 | 1 | 1 |
| | | 0% | 0% | 3.3% | 3.3% |
| | Incorrect | 0 | 0 | 0 | 1 |
| | | 0% | 0% | 0% | 3.3% |

The interview results generally supported the preference for concreteness over abstractness, although a clear preference for high entropy or low entropy was not consistently found. Participants had a general aesthetic preference for the concrete/high entropy icons, which they identified with characteristics like “easy to recognise”, “easy to understand”, “easy to guess”, “pretty”, and “colourful”. However, a few participants preferred concrete/low entropy icons, stating that they were also “easy to recognise” but indicating that they were “better design” and “more modern” than the high-entropy icons. In contrast, respondents described the abstract/high entropy icons as “confusing”, “hard to understand”, and “cluttered”. Abstract/low entropy icons may also be described as “confusing”, “hard to guess”, or “ambiguous”, but were less likely to be described using negative visual indicators. Experience did play a role in this, with users with high familiarity with the icons not typically describing them as “confusing”.

V. RESULTS

The quantitative responses and interview results suggest that there may be interaction between icon concreteness and icon entropy in both the user’s cognitive processing and the aesthetic appeal. Under concrete conditions, users were equivocal about the aesthetic impact of entropy; while most preferred the high-entropy condition, it did not appear to have a significant effect on user performance. In contrast, under abstract conditions, high-entropy icons were described in negative aesthetic terms, but they also appeared to lead to somewhat better performance than in low-entropy conditions. It is possible that this is because when processing an abstract icon, a distinct visual aesthetic catches the attention of the user and leads to faster processing. This type of effect has been seen for visual appeal under complex search conditions in previous research as well [11]. Of course, the total effects of both concreteness and entropy may be overcome by user experience, as suggested by the interviews here as well as in previous research [7]. Thus, both icon concreteness and icon complexity may be most important during the learning stage, when users are still developing cognitive routines that associate the visual symbols and their meaning [7]. However, given that minor variations between OEMs for the same functions in the same OS is now used as a branding technique [3], many users may persist in a state of semi-unfamiliarity with their computing system. Thus, this effect should not be discounted even if it disappears on development of familiarity.

VI. CONCLUSION

It is not surprising that this research has shown a complex relationship between the nature of the visual metaphor of an icon (concreteness), the level of similarity within the image (entropy), its aesthetic appeal, and user performance. As previous research has shown, user performance characteristics and visual appeal can be attributed to the same icon characteristics, one of which is concreteness [10]. However, this research has a more important implication, which is that different icon characteristics can influence users in different contexts. As the interview showed, when the icon was concrete, the entropy level was not a determinant of

preference; however, when the icon was abstract, entropy could make a difference in how recognisable the icon was, leading to potential performance differences. Thus, these characteristics do not work on their own. Instead, they are only three of a complex set of icon and system characteristics, along with user preferences, that influence the usability of the icon. To date, these factors have not really been considered in practice, with icon design remaining mainly an aesthetic or artistic activity. However, as computing environments become more varied and systems become more complex, it may be important to take such interactions into account more and more to deliver effective, usable new systems.

VII. RECOMMENDATIONS

The main recommendation of this research is that more research should be directed to understanding the interaction between icon characteristics, system context, and user characteristics. Although there is a large body of research on icon characteristics and user performance, most such research is relatively shallow, focusing on only a small number of such characteristics (typically only three to four). Furthermore, the research is not comprehensive in terms of system types or user characteristics like age or culture that could influence icon characteristic interactions. By broadening the scope of research into icon characteristics and response, it would be possible to identify more interactions between icon characteristics. This could provide more concrete recommendations for icon design, to overcome obvious limitations like a limited number of direct visual metaphors for system functions.

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REFERENCES

- [1] Pykkönen, M. et al., 2012. Designing tangible user interfaces for NFC phones. *Advances in Human-Computer Interaction*, January.
- [2] Yan, R., 2011. Icon design study in computer interface. *Procedia Engineering*, Volume 15, pp. 3134-3138.
- [3] Koutsourelakis, c. & Chorianopoulos, K., 2010. Unaided icon recognition in mobile phones: A comparative study with young users. *The Design Journal*, 13(3), pp. 313-328.
- [4] Huang, S. -M., Shieh, K. -K. & Chi, C. -F., 2002. Factors affecting the design of computer icons. *International Journal of Industrial Ergonomics*, Volume 29, pp. 211-218.
- [5] Goonetilleke, R. S., Shih, H. M., On, H. K. & Fritsch, J., 2001. Effects of training and representational characteristics in icon design. *International Journal of Human-Computer Studies*, 55(5), pp. 741-760.
- [6] Silvennoinen, J. & Jokinen, J., 2016. *Aesthetic appeal and visual usability in four icon design eras*. s.l., ACM, pp. 4390-440.
- [7] McDougall, S. J. P., Curry, M. B. & de Bruijn, O., 1999. Measuring symbola and icon characteristics: Norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols. *Behavior Research Methods*, 31(3), pp. 487-519.
- [8] Satcharoen, K, 2017. Usability of icon interface for Thai teenagers. PhD Thesis, The University of Buckingham, UK
- [9] Castro, L. & Wasserman, E. A., 2013. Humans deploy diverse strategies in learning same-different discrimination tasks. *Behavioural Processes*, Volume 93, pp. 125-139.
- [10] McDougall, S. J. P. & Reppa, I., 2008. Why do I like it? The relationships between icon characteristics, user performance and

aesthetic appeal. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 52(18), pp. 1257-1281.

- [11] Reppa, I. & McDougall, S., 2015. When the going gets tough the beautiful get going: aesthetic appeal facilitates task performance. *Psychonomic Bulletin and Review*, 22(5), pp. 1243-1254.
- [12] Young, M. E. & Wasserman, E. A., 2001. Entropy and variability discrimination. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 27(1), pp. 278-293.
- [13] Tatu, A. et al., 2010. *Visual quality metrics and human perception: an initial study on 2D projections of large multidimensional data. I.* s.l., ACM, pp. 49-56.
- [14] Norman, D. A. & Bobrow, D. G., 1976. On the analysis of performance operating characteristics. *Psychological Review*, 83(6), p. 508.