Search-Efficacy of Modern Icons Varying in Appeal and Visual Complexity

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Abstract. Users' levels of satisfaction increase when their interactions are swift and they experience the interface as easy to use. Given that most interactions start with searching for the icon for the application you wish to use, characteristics affecting the efficacy of icon search are important. This study mimicked icon search on mobile devices in order to examine which characteristics were most important in determining speed of search and ease of interaction. Given what is known of visual search processing, it was not surprising that visual complexity was the primary determinant of search speed. The visual aesthetic appeal of the icons, often thought to be so important, had no significant effect on search time for icons. The reasons for this are discussed in the commentary on the role of visual complexity and aesthetic appeal when used in mobile application icon design.

Keywords: Icon design · Visual search · Evaluation · Complexity · Appeal

1 Introduction

Interface designers commonly use icons in menu design (Schröder and Ziefle 2006). Incorporating icons in a menu improves menu selection (Bailly et al. 2014) not least because icons are easier to search for and find in an interface than words (McDougall et al. 1999). Icons have the potential to communicate meaning effectively across language boundaries and support a universal mode of communication (Rogers 1989; Böcker 1996). Moreover, icons are typically small and therefore provide a good amount of information per pixel. However, because icons are small, they can be restricted in their ability to communicate complex meaning effectively. In addition, icons convey information semasiographically, in a nonverbal manner without a clear set of rules as would be the case for written language. This creates inherent ambiguity which must be resolved by designers and users alike (Carr 1986).

Well-designed icons can offer a user-friendly experience by simply being easier to search for. When it is easy to search for and find the icon you wish to use, ease of processing increases. When icons are designs using visual characteristics that contribute to their ease of use this, in turn, increases user satisfaction (Reber et al. 1998; Schwarz and Winkielman 2004; Alter and Oppenheimer 2009). Reducing the speed of processing in locating icons might seem a minimal advantage to overall usability.

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However, users notice performance costs as small as 150 ms (Gray and Boehm-Davis 2000). Since icon search is a task users perform repeatedly, time advantages can quickly add up. These timesavings positively affect user experience (McDougall and Reppa 2013).

This study focuses on the perceptual fluency of icon search, which refers to the ease of processing of an icon, as opposed to conceptual fluency, which involves elements of meaning. We propose that because the use of icons is proliferating on visual interfaces, visual search for icons, which is primarily perceptual, is an increasingly important component of icon and interface use. Interfaces, particularly those used for mobile phones, consist of application icons as a key entry point to functionality. Since a key part of what users have to do when using icons is to locate them amidst others in order to access the functions they represent, this experiment focuses on icon search performance. This search component has received relatively little research attention to date.

Because the functions and applications behind mobile application icons are themselves increasingly more complex, the icons similarly have increasing levels of visual complexity. Mobile gaming applications are a perfect example of this trend. Additionally, as the number of mobile applications increases, the design of the icons representing them increases in complexity as well. As the design space narrows with every new icon, icon designers naturally create more complex icons than they did before. It follows then that an understanding of how an icon's visual complexity interacts with other icon characteristics in affecting performance stands to benefit the mobile application icon designer.

2 Background

This study mimicked an icon search task on mobile devices in order to examine which characteristics were most important in determining speed of search and ease of interaction. Figure 1 in the Materials section illustrates the search task employed in measuring icon search time. First, the target icon was shown along with a next button. After the user clicked on the next button, a 9-icon matrix was displayed. The time from when the user clicked the next button to when they clicked on the target icon in the matrix was recorded as the target icon's search time. The distractor icons were of a heterogeneous mixture, according to the icon characteristics being tested.

Previous research using this search task found that an icon's visual complexity, measured using previously obtained subjective ratings and complexity metrics of an icon's complexity, affected search time significantly (McDougall et al. 1999). Users found simpler icons faster than complex ones. Other icon characteristics such as concreteness, familiarity, and aesthetic appeal had an impact on icon search (McDougall et al. 1999; McDougall and Reppa 2008; Reppa et al. 2008; Reppa and McDougall 2015).

Importantly, very little previous research has examined the effect of icon appeal on visual search (Reppa et al. 2008; Reppa and McDougall 2015). Given the importance of creating appealing as well as functional displays on mobile phones, the effect of appeal was also considered in this experiment. The little research published to date found that the aesthetic appeal of an icon interacts with its complexity in affecting search time: visual search for complex icons was easier when icons were appealing (Reppa and McDougall 2015).

This is important because of the increasing emphasis on creating appealing interfaces to enhance user experience. This area of work therefore investigates the relationships between key icon characteristics, which may facilitate ease of use by promoting perceptual fluency, i.e. visual complexity and/or aesthetic appeal.

A key aim of this experiment was to examine whether or not visual complexity and appeal had an effect on search for icons likely to appear on today's mobile devices. There has been limited research to date examining the effects of icon characteristics on visual search (McDougall et al. 2000, 2006; Reppa et al. 2008; Reppa and McDougall 2015). This work suggested that key determinants of visual search was icon complexity (simpler icons were found faster) and that this may interact with the visual appeal of the icons. However, the icon sets used in previous research were from a wide range of interfaces and were not representative of icons currently used in mobile computing. In order to make the icon sets used in the experiment more representative of current icon use, a set of icons from recent corpora was combined with icons representing mobile applications in current use (Prada et al. 2015; Smythwood and Hadzikadic 2019).

3 Hypotheses

Participants were asked to search for icons in displays. Based on the limited previous research to date, it was hypothesized that simpler icons would be located in displays more quickly than more complex icons (McDougall et al. 2000). Search was also expected to be particularly fast when icons were both simple and visually appealing (i.e. visual appeal would enhance search times creating an interaction between icon complexity and visual appeal; Reppa and McDougall 2015). Finally, it was expected that search performance would improve familiarity with icons over blocks of learning trials (McDougall et al. 2000; Reppa and McDougall 2015).

4 Method

4.1 Participants

Twenty-three students from the undergraduate research pool at the University of North Carolina at Charlotte participated in the visual search experiment. The students were from a mix of different majors taking courses to fill required electives. Each participant received research credit for completing the experiment.

Of the 23 total participants, 10 were male and 13 were female. The average age of participants was 24 years old. All student participants had normal or corrected-to-normal vision.

4.2 Materials

The trend toward increasing levels of complexity is reflected in the different icon stimulus sets used in experimentation to date. Figure 1 contains sample icons from each of the three different sets. Two are from existing icon corpora with ratings of icon characteristics designed to facilitate icon control and the third is a set of mobile application icons obtained from Google Play and Apple Store (McDougall et al. 1999; Prada et al. 2015). Icons from the first corpus have been used in icon studies over the past several years (McDougall et al. 1999), whereas those from the second have been created more recently for use in experimentation (Prada et al. 2015). The present research utilized icons from all three icon sets. By including icon sets of different types, the aim was to strengthen the validity and potential generalizability of our findings.

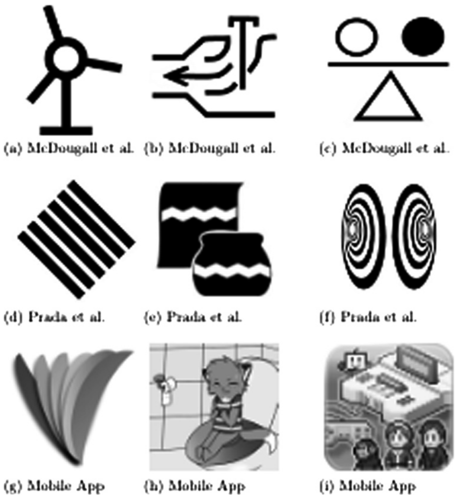

Fig. 1. Icons from each stimulus set used to construct the set used in this study.

The complexity and visual appeal of the icons was varied orthogonally creating four sets of six icons (see Fig. 2).

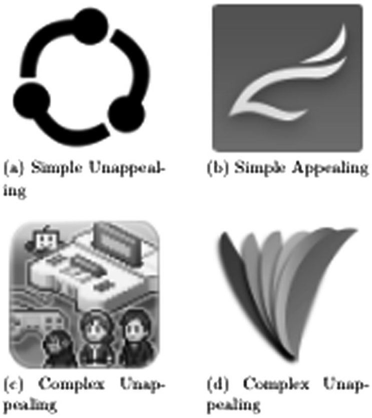

Fig. 2. Examples of each of the four types of icons created by varying icon complexity and visual appeal orthogonally.

Measuring Icon Complexity and Visual Appeal; Creating the Test Icon Set
Fifty university undergraduate participants were asked to rate a set of 200 icons on visual complexity, concreteness, familiarity, and aesthetic appeal on a scale of 1–7. Instructions for rating icons on the four characteristics of interest were as follows:

> Visual Complexity: Rate the icon's visual complexity, its level of detail (1 = very simple, 7 = very complex)
> Aesthetic Appeal: Rate the aesthetic value, beauty, attractiveness of the icon (1 = very unappealing, 7 = very appealing)
> Familiarity: Rate how familiar you are with the icon, or how often you have seen it before (1 = very unfamiliar, 7 = very familiar)
> Concreteness: Rate the concreteness/abstractness of the icon, how realistic it looks (1 = very abstract, 7 = very concrete).

The ratings were then used to select twenty-four of the 200 icons for use in the search experiment. Icons were selected for each of the four icon types using the ratings obtained (see Fig. 2). Figure 2 above includes an example icon from each Complexity-Appeal group. As can be seen from Table 1, it was possible to vary icon complexity and appeal while holding familiarity and concreteness relatively constant. Table 1 provides the ANOVA across icon characteristics. Table 1 includes mean ratings for each Complexity-Appeal group across all four icon characteristic ratings collected.

Table 1. Mean and standard deviations for each icon characteristic across the stimulus set. F-values from ANOVA and Newman-Keuls analysis of the four icon type groups.

Icon Design Char.	Type of icon								F(3, 23)	Newman-Keuls
	CA		CU		SA		SU			
	M	SD	M	SD	M	SD	M	SD		
Appeal	3.94	0.23	3.24	0.18	3.72	0.23	3.06	0.21	*21.8	CA, SA > CU, SU
Complexity	4.39	0.40	4.07	0.34	3.16	0.56	2.97	0.31	*16.4	CA, CU > SA, SU
Concreteness	3.58	0.95	3.49	0.73	2.89	0.54	2.76	0.24	2.31	CA, CU, SA, SU
Familiarity	2.43	0.51	2.41	0.48	2.35	0.59	1.97	0.38	1.13	CA, CU, SA, SU

Note: CA = complex and appealing, CU = complex and unappealing, SA = simple and appealing, SU = simple and unappealing.
* $p < 0.05$

4.3 Procedure

The participants were told they would be presented with an icon for 2 s before they would be expected to click a "Next" button to continue to a 3 × 3 matrix of icons. See Fig. 3 for an example trial. They were instructed to click on the target icon as quickly as possible once they clicked the "Next" button. Their first choice was the only icon selection they would be allowed to make; after which they could continue to the next trial by clicking another "Next" button.

There were series of 24 search task trials, with each icon being shown once in each block of trials as the search target. Icons appearing as distractors were controlled so that a mix of two of each of the four types of icons appeared as background distractors equally often in each block of trials. There were six blocks of trials for each participant. Participants were given short breaks between blocks of trials.

Fig. 3. Icon search task.

4.4 Design

A 2 × 2 × 6 design was employed with icon complexity (Complex/Simple), icon appeal (Appealing/Unappealing) and blocks of trials (Blocks 1–6) as within-subjects factors. All factors were repeated measures taken from the same participants. Response time was used to measure ease of visual search.

We ran blocks of trials with short breaks between. The effect of learning icons over time was mimicked by presenting participants with blocks of search trials. We conducted the experiments in the controlled environment of a lab. Running multiple blocks enabled examination of learning effects over time and the lab environment facilitated accurate measurement. It allowed us to answer the question of whether the same predictive "rules" apply when users have learned the icon set they are searching for.

5 Results

Errors accounted for 1.5% of all trials. There were no differences in error rates between any of the conditions (p values < .05). We used an alpha level of .05 for all statistical tests and partial eta-squared as a measure of effect size. Bonferroni corrections were used throughout. Figure 4 illustrates the mean response times for each type of icon presented across six blocks of learning trials.

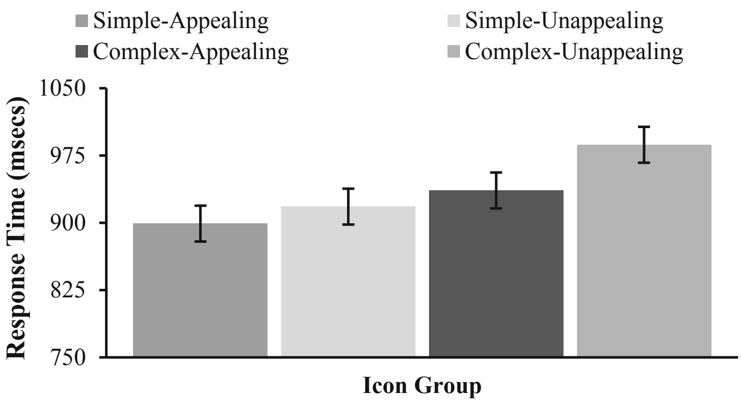

Fig. 4. Mean response time in milliseconds for Complexity-Appeal groups

By-items analysis of variance was carried out to examine the effects of icon complexity (complex vs simple) and visual appeal (appealing vs unappealing) on search response times. The analysis of variance revealed that icon complexity significantly affected search times, F(1, 20) = 4.55, p = .045, eta-squared = .185, with search times for complex icons being longer than for simple (means for simple and complex here). However, there was no main effect of icon appeal on visual search, F(1, 20) = 1.98, p = .175, eta-squared = .090. Neither was there a joint interaction between complexity and appeal on icon search time, F(1, 20) = .421, p = .524, eta-squared = .021.

Tests of within-subjects effects on complexity, appeal, and block revealed a significant effect of learning on search time across blocks, F(4, 100) = 5.13, p = .000, eta-squared = .204. Tests of within-subjects contrasts revealed a difference in search time between Blocks 1 and 2 (F(1, 20) = 4.75, p = .041, eta-squared = .100) and between Blocks 5 and 6 (F(1, 20) = 5.15, p = .034, eta-squared = .205). There were no other significant effects.

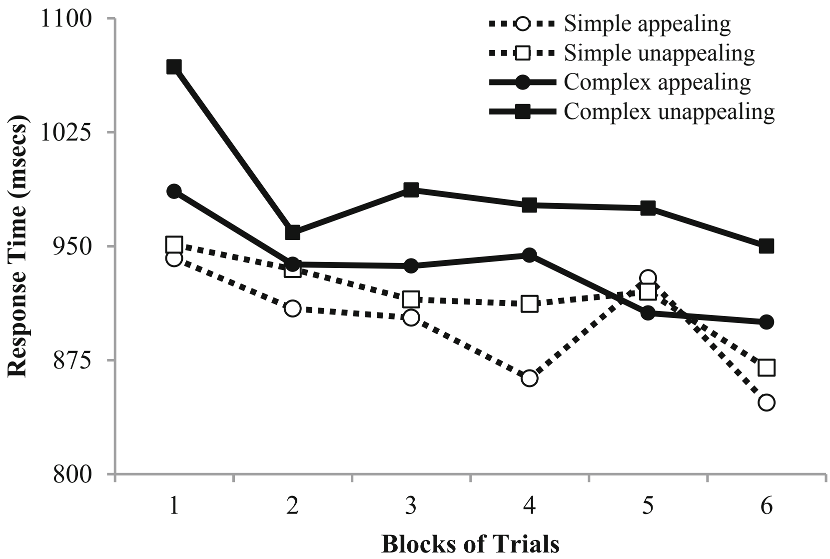

Fig. 5. Response times for each type of icon presented in the search task across blocks of trials

6 Discussion

The results from our study revealed the role of visual complexity in icon search was significant. In concert with previous findings, we found that simple icons were found faster than complex ones (McDougall et al. 2000). Also previously, icon appeal and visual complexity exhibited a joint effect on search performance (Reppa et al. 2008; Reppa and McDougall 2015). Those findings suggested that when the icon was complex, appeal provided a significant time advantage (Reppa et al. 2008).

A key aim of the present experiment was to examine whether or not visual complexity and appeal had an effect on search for icons likely to appear on today's mobile devices. There has been only limited research to date examining the effects of icon characteristics on visual search (McDougall et al. 2000, 2006; Reppa et al. 2008; Reppa and McDougall 2015). The previous work that has been done was performed with icon sets that were not representative of icons currently used in mobile computing. In order to make the icon sets used in the experiment more diverse and representative of current icon use, a set of icons from previously existing corpora was combined with icons representing mobile applications currently used.

Was the role of these characteristics the same as for other previous icon sets in a visual search task? Findings were mixed.

6.1 Visual Complexity

As previously, it took longer for participants to find complex icons than simple icons (Reppa et al. 2008; McDougall et al. 2000). The importance of complexity in visual search has been well documented (Treisman 2003; Wolfe 2012). Treisman's Feature Integration Theory, first introduced in her seminal paper in 1980, proposed that when stimuli differ on a single dimension, finding the different stimulus is instantaneous - it "pops out" from a search display. However, when stimuli are more complex, visual search response times are longer, increasing incrementally in accordance with the size of the search set. This process of visual search, which Treisman suggested was hard-wired, is still a basic premise of visual processing (Treisman 2003). Wolfe's Guided Search Theory suggests that visual search is most commonly a combination of both bottom-up and top-down processing (Wolfe 2012). Attention is directed in both a bottom-up and top-down manner where processing priority guides visual search (Wolfe 1994; Wolfe 2012). Nevertheless, both theories take into consideration a preattentive stage where our visual system takes in low-level information and without our knowing begins to make sense of it before, or while at the same time, allowing a directed effort to localize stimuli. It is because of the preprocessing done in this preattentive stage that an icon's visual complexity affects total search time. Given the primarily pre-attentive role of stimulus complexity, it is therefore not surprising that differences between simple and complex icons emerged with visual search times being longer for complex icons. This effect does not diminish over time and remains significant even when participants have learned the visual search task and become familiar with the icons across a series of blocks of trials. See Fig. 5. This was consistent with current findings (McDougall et al. 1999).

6.2 Aesthetic Appeal

Icon appeal did not appear to affect search times. Importantly, in contrast to earlier findings reported (McDougall and Reppa 2008), this experiment showed that visual complexity did not act together with icon appeal to enhance visual searching of interfaces. These earlier findings suggest that when the task was difficult, such as when the icon was complex, appealing icons were found more quickly in visual search than unappealing icons (McDougall and Reppa 2008). The findings from the present study therefore suggest that aesthetic appeal does not bias perceptual systems by giving priority to attractive stimuli, unlike detecting faces in a crowd where happy or appealing faces are found first (Becker et al. 2011).

Since the icon characteristics used in devising the search experiment were balanced across complexity and appeal while concreteness and familiarity were controlled, the results offer an "objective" look at top predictors of search performance. Recent efforts to examine the combined effects of 3 icon characteristics yielded confounding results given the existence of confounding variables (Smythwood and Hadzikadic 2019), while previous, relevant work suffered from the confounding variable of familiarity when testing for complexity-appeal search time differences (Reppa and McDougall 2015).

Our results were dependent on the range of visual complexity and the range of appeal among our icon types in the stimulus set. By including icons from existing mobile applications, we were able to include a broad variety of icons varying significantly in visual complexity as well as appeal. The variety of icons presented may mean that visual appeal becomes a less distinctive icon characteristic which does not 'stand out' visually in a way that is likely to aid visual search and suggests that the effects of appeal may depend on the contextual effects of the search set. In practical terms, when icon sets are diverse in nature, visual appeal may be less important in determining how quickly users can locate icons.

7 Conclusions

7.1 Implications for Interface Design

Icons designed with particular design characteristics in mind facilitate the visual processing involved in icon menu search. Given the ubiquity of icon menu interfaces in modern mobile computing, advantages in visual processing easily compound to provide smooth and fluent user experiences. This research has shown that the duration of visual search for icons is likely to be least when:

- icons are simple rather than complex
- icon appeal may not affect search times for icons on a display however, other research has shown that it may affect users' attitudes towards the display (Reppa and McDougall 2015).

7.2 Lesson Learned

To provide ecological validity to the results of experiments that use design artifacts as stimuli, it is good to incorporate real-world stimuli that are currently in use. As a design space expands, previous research must be revisited in order to extend the discussion. By incorporating more current and varied stimuli with existing corpora, we were able to provide a more comprehensive picture of the effects of visual complexity and appeal on the search of icons.

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