EXAMINING THE EFFECTS OF ICON CHARACTERISTICS ON ICON MENU SEARCH PERFORMANCE

by

Kara Mickey Smythwood II

A dissertation submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
Computing and Information Systems

Charlotte

2019

Approved by:

____

Dr. Mirsad Hadzikadic

____

Dr. Mark Faust

____

Dr. Heather Lipford

____

Dr. Siné McDougall

ABSTRACT

KARA MICKEY SMYTHWOOD II. Examining the Effects of Icon Characteristics on Icon Menu Search Performance. (Under the direction of DR. MIRSAD HADZIKADIC)

The use of icons is ubiquitous in the computing world of today with icon selection being a typical way to access documents and programs. Icons are used in a variety of ways: search, identification, and selection (mouse, touchpad, etc.). Users search for and identify icons on modern computing devices in order to select the appropriate one. Before being able to identify a new icon or recognize a previously used one, users must engage in a visual search of the interface to pinpoint the icon they wish to use. The icon search action is therefore inherently important since it kicks off each and every icon selection made. For this reason this dissertation focuses on the search aspect of icon usage.

Taking the time to examine how icon design characteristics contribute to icon usability behooves both icon and icon interface designers. Researchers have identified a handful of icon characteristics to predict icon usability. Important characteristics used in prior research using antiquated icon sets include visual complexity, and to a lesser extent concreteness, familiarity, and aesthetic appeal. These characteristics affect performance in searching for and locating icons [55]. Small time savings in icon search tasks add up quickly and contribute to smooth user experience [66]. The user's level of satisfaction increases when their interactions are swift and they experience the user interface as easy to use [66].

This dissertation examines the effects of icon characteristics on visual search efficacy

by employing a commonly used search task and by including mobile application icons in the stimulus sets. Icons were selected from the Google Play Store and from Apples App Store for search experimentation varying orthogonally on icon characteristics across visual complexity, concreteness, and aesthetic appeal.

An initial, pilot study employing a naturally occurring set of modern, mobile application icons revealed a joint interaction of complexity and appeal. Previous studies found icon appeal to quicken search only when the icon was already difficult to find, such as when the icon was complex. The pilot study found that appeal quickened search when the icon was simple. Although this finding was not exactly similar to prior work, the appearance of a join interaction between appeal and complexity was remarkable. To better balance the icon characteristics across the stimulus set all follow up studies used subsets of icons that were selected to be as uncorrelated on the three icon characteristics as possible. Unfortunately, efforts in balancing icon characteristics across groups for all three icon characteristics proved challenging, and so visual complexity and appeal were properly varied across four experimental groups for the more in-depth experiments.

All experiments, including the initial pilot studies, revealed that visual complexity was the main determinant of icon search time. Given that the icon stimulus set was derived from a mixture of several different icon sets, the variety and therefore the range of appeal across icons in the final stimulus set was greater than that of stimulus sets used in previous work. By including mobile application icons in the experiments, this dissertation makes ecologically valid design recommendations according to design characteristics of visual complexity and aesthetic appeal in modern application icon design.

Lastly, the diversified stimulus set of icons used in the main experiments is included for future researchers interested in icon search. The normed characteristic ratings on the Diversified Icon Stimulus set used in experimentation here provides a starting point for further investigation of icon search and of the user experience involved in icon search in general.

ACKNOWLEDGMENTS

I wish to thank those that have assisted me along the way: my mother Rebecca Smythwood who has put up with me for years and still supports my desire for intellectual pursuit, and my brother Nicholas Smythwood, who has always been there for me when I need him. I thank my colleagues Vikash Singh and Berto Gonzalez from the Human-computer Interaction Lab, Osa Omakaro and Scott Heggen from Jamie Payton's lab, Jamie Payton herself for encouraging me to pursue a Phd, and finally administrators Julie Fulton and Sandra Krausse. Thank you all for your support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Icons are ever-present. We see them on mobile phones, on computers and tablets. We see them as traffic signs when we travel [18]. We use icons to get things done, stay safe, socialize and enjoy ourselves [42]. Icons are an integral part of our lives. We enjoy the benefits of well-designed icons without even realizing just how powerful these small, often symbolic, images really can be.

Icons have the ability to communicate meaning effectively. They have an advantage over words in that they can be used across language boundaries and support a universal mode of communication [14] [67]. Icons are typically small and therefore provide a good amount of information per pixel. Conversely, since icons are small, they can be restricted in their ability to communicate complex meaning efficiently. 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 [19].

Despite this ambiguity, interface designers commonly use icons in menu design [70]. This is because incorporating icons in a menu is thought to improve selection of an interface's menu [4] [7] [20] not least because icons are easier to search for and find in an interface than words [56].

In addition, well-designed icons offer a user-friendly experience. When it is easy to find the icon you wish to use, ease of processing increases [66]. Visual characteristics of icons contribute to their ease of use, which in turn is known to increase user satisfaction [3] [64] [72].

We are interested in visual characteristics that affect the time to locate an icon among other icons in an interface. This research will focus on the ease of use associated with the ease of processing an icon. Visual search for icons is an important component of icon, and interface, use [65]. Users are increasingly required to search from a large number of icons on interfaces to access the functionality that they wish to use, but this search component has received relatively little research attention to date [10] [21] [40] [41] [45] [73].

1.1 Research Problem

Communicating meaning stands out as a primary feature of an effective icon. But before the user can establish a connection between an icon image and its meaning (recognition), the icon itself must be located among other icons in a typical menu interface. Designers often focus on communicating meaning in their icon image depictions. They may not realize that simplicity in design is not only an effective way to communicate clearly, but a simple icon is found faster than complex ones and that this advantage has been found to improve user experience ratings [66].

Although icons have the potential to benefit interface users, users unfamiliar with an icon interface struggle at first. Special groups especially, such as the young, the old, and the differently-abled, experience challenges in using new icon interfaces [10] [12] [13] [15] [60] [69] [71] [82] [86] . For instance, older users typically perform interaction tasks a bit slower than the average user and so their frustrations multiply with hard to find icons.

Members of these special groups are also often the users who are most likely to benefit from using icon interfaces. Icons are typically used in interfaces where the users may not have a good understanding of the labels that accompany them.

In fact, all users stand to benefit from time savings during icon interface interactions [32]. Although a seemingly small aspect, the icon's ability to be found stands out as a necessity in interacting with an icon interface [24] [25].

Experimental psychology studies have demonstrated that an icon's visual complexity affects its search time significantly [23] [28] [56] . Simpler icons are found faster than complex ones [16]. These findings suggest that the visual characteristics of an icon can affect the user's ability to locate that icon.

It is true that unlike novice users, expert users depend primarily on an icon's established location in their interface in determining where to look to pinpoint that icon. In typical icon interfaces, individual icons are often presented in certain locations, and users can learn these tendencies and get faster. But, users can also get faster at searching arrays of icons where the position of the icon is totally random such as after performing a sort on them. Nonetheless, both novices and experts rely on the speed at which they can search an interface and visual complexity slows search even after considerable experience with an icon set [54] [56] .

As a user searches for and finds a particular icon with repeated use, the time it takes for them to localize the icon decreases exponentially. With practice, the search time will eventually reach an asymptote and flatten out. In other words, repetition priming is the finding that with repeated exposure to visual objects (pictures or text) users respond faster (a form of learning) [87].

Other icon characteristics such as concreteness, familiarity, and aesthetic appeal have been found to affect icon search [56] [66]. Recent work has shown that the aesthetic appeal of an icon interacts with complexity in its effect on search time: visual search for complex icons was easier when icons were appealing [65]. This is important because of the increasing emphasis on creating appealing interfaces to enhance users experiences.

An icon's level of concreteness/abstractness has been associated with learning over repeated use of an icon with concrete icons being found faster than abstract ones during initial use. This is important because icons that represent real objects are more easily found and identified than unrealistic, abstract icons [56] [65].

Icon design guidelines, however, do not yet provide direction in considering these other icon characteristics and their joint effects. There is a need for industry to adapt their existing guidelines to current academic findings. A more detailed, and informative set of guidelines on balancing icon characteristics for best overall usability would provide icon and interface designers exactly what they need to make the necessary decisions in generating their final designs.

This thesis therefore investigates the relationships between key icon characteristics which may determine and facilitate ease of use, i.e. visual complexity, aesthetic appeal. We measure time-to-locate icons having different icon characteristics, in adherence to similar methods used by experimental psychologists and human-computer interaction researchers [5] [56] [65] [66] .

1.2 Original Contributions

Given the importance of replication of psychological experiments and the need to include real-world data in these experiments [61], we aim to re-examine previous findings in light of our work using existing mobile application icons. The design space for icons has changed and increased over the years as more pixels are available for icon expression and as icon designers continue to explore how their designs affect icon usability. Prior work examining the effects of icon characteristics on icon search was done using icons that would be considered outdated today [55] [66]. By choosing icons from modern mobile application computing to include in icon search experimentation, we intend to make recommendations to icon designers relevant to mobile application computing.

Utilizing similar methods as prior work, but with more modern icons such as those used in mobile computing, we explore whether unfamiliar icons varying in visual complexity, aesthetic appeal, and concreteness perform as icons did in prior work and if not, how their performance varies and why. By comparing and contrasting the results from prior work with the results from the work done in the interest of this dissertation, we wish to reach a greater understanding of how modern icons are searched for and found in an interface. The results of our experiments can also be used in comparison to validate or refute findings from prior work, as the experiments in previous work did not include icons used in everyday computing.

As in prior work, we wish to observe icon search performance during initial learning of an icon over repeated search. The first two experiments do not include this aspect, as they consist of a single block of search trials rather than repeated blocks. Experiments 1 and 2 differ from prior work in this way whereas Experiments 3 and 4 follow the experimental design from prior work that includes multiple blocks [55] [57] [52] [66] [65]. Repeated presentation of icons with systematic variation of visual characteristics as search targets allows for isolation of icon characteristics that are important primarily in search for unfamiliar icons.

Following the execution of the experiments mentioned herein, we aim to develop a model of icon search given the characteristic ratings of the icon. A simple linear regression model is used.

Lastly, given the results from the experiments conducted here as well as from prior similar work, we provide design guidelines for icon and interface designers concerned with user experience. In each experiment we explore how the findings of that experiment promote the emphasis of some design characteristics over others in architecting a particular user experience for users when they interact with an icon interface.

The following are my original contributions to the field of Human-Computer Interaction and Experimental Psychology:

- The creation of a diversified icon stimulus set, consisting of icons from existing, well-known icon stimulus sets as well as modern, mobile application icons.

- Validation of results from existing psychological experiments with up-to-date icon stimulus sets to provide an ecological perspective [2] [61] .

- A better understanding of the initial use and learning of unfamiliar icons by observing icon search over repeated use.

- The development of a model of icon search according to the icon's primary icon characteristics and the interactions between them.
- Informing interface design guidelines to improve usability and user experience.

1.3 Overview of Dissertation

Following this introductory section, Chapter 2 provides a literature review of relevant work. Chapter 3 describes our preliminary studies which includes the use of a mobile application icon set and another well-known icon set in testing the effects of icon characteristics on icon search. Chapter 4 details the creation of the Diversified Icon Stimulus Set whereas Chapter 5 describes its use in a series of experiments. Chapter 6 provides a linear regression model for icon characteristics and search time. Chapter 7 concludes the dissertation with a thorough discussion of experimental findings, recommendation to icon designers, and ideas for future research.

CHAPTER 2: LITERATURE REVIEW

Given that icon characteristics affect perception of and search for icons [56] [66], knowledge of these characteristics can be used to make recommendations and guidelines to icon interface designers. Prior research has often relied on subjective ratings of icons by independent groups of users in order to measure their characteristics (such as familiarity, meaningfulness, complexity and concreteness) [56] [66]. Other taxonomies have been proposed that classify icons according to the type of document or application that is opened when they are selected, but of the texts reviewed on the subject, no other taxonomy of factors better describes the set of characteristics that affect icon search specifically, as they mostly focus on object recognition and the user of metaphor in icon design [10] [21] [40] [41] [45] [73]. Hence, this thesis investigates how icon characteristics affect search performance.

Before discussing the icon characteristics themselves, we review the fundamentals of visual perception and visual search to educate the reader before delving into more specific matters related to icon search itself.

2.1 Visual Perception and Search

Visual perception is the process of recognizing, organizing, and interpreting sensory information [35]. Perception begins with early visual sensory processing, and ends in 2 visual perceptual pathways in the brain, the temporal lobe perceptual identification system, and the parietal lobe perceptual localization system (better known as the what and where pathways of vision). These 2 systems support perception for identification and perception for action [58]. Prior to these 2 pathways, early visual sensory processing in the occipital lobe will try to identify critical features of an object and build an initial model of edges, surfaces, and ultimately a 3D model of a visual object. This early visual processing begins with mapping luminance edges (precursor of shape processing), motion, color, texture, and brightness. These simple features can be used for visual search, as well as more complex combinations of simple features.

There are several running theories of visual search [34] [35] [38] [62] [77] [79] [80] [83] [84]. Treisman and Wolfe's visual search theories are the main theories recognized today. Treismans Feature Integration Theory separates the attentive from the pre-attentive, whereas Wolfes Guided Search Theory addresses the combination of top-down and bottom-up processing of stimuli [79] [84]. Elements of both models combine to provide a simple summary of the stages of visual search:

1) parallel extraction of low-level properties of a scene (color, shape)

2) pattern perception (divide into regions and simple patterns)

3) sequential goal-directed processing (hold in working memory, active attention).

Stage 1, also referred to as the Low-level stage or the Parallel stage involves the activation of neurons in the eye and brain responsible for different kinds of low-level information. An array of neurons work in parallel in this initial stage and it occurs automatically, with no directed attention. It is rapid as the information is transitory, briefly held in an iconic memory store. This bottom-up, data-driven model of processing is often called ”pre-attentive” processing. In this dissertation, we refer to this stage as the pre-attentive stage. A limited set of visual properties can be detected rapidly and accurately by the low-level visual system.

Stage 2 is known as the pattern perception stage, and Stage 3 is commonly referred to as the sequential, goal-directed stage. This is the purely top-down, attention-driven mode of processing. All of these stages happen very quickly most of the time, in well under half a second. Consideration of Feature Integration Theory (FIT) leads to a focus on simple feature versus conjunction of features search. Simple feature search would be searching for an icon that has red in it by doing a parallel search of the whole field that allows pop out of icons that have red in them. If your target icon is the only icon with a good deal of red in it, this search can be fast. More complex icons are likely to require search for a conjunction or combination of simple features. Under FIT, a conjunction search involves applying attention on a location-by-location basis to perceptually glue the correct features to the object representation being built. This results in a slower more effortful search. Wolfes theory adds the idea that bottom up features and patterns can be used to guide search, as well as high level information about objects found already earlier in the search. If you are searching for your coffee cup and you already found the coffee machine, you might use that location to concentrate your search.

These basic core theories of visual search motivate our exploration of icon characteristics that influence icon search times. Simple icons that depict the shape of a concrete object are likely to be easiest to find. Also, icons that are brighter, have a unique color, or are in motion against other stationary icons are likely to be found very quickly as one can do a parallel search for a simple perceptual feature.

2.2 Icon Search

Icon search can be broken down into search and identification phases. McDougall's work explains the reasoning behind considering these phases separately in testing the effects of the characteristics of icons on performance [56]. When a user is looking for an icon, they are typically either looking for an icon they already know, or they are looking for an icon that represents the function they wish to execute [56]. In the case of icon search for a match to a target icon held in memory, the user must find an icon that matches the image they have in mind.

Given that there are preattentive and attentive phases involved in any search task, it can be difficult to discover when low-level features provide advantage to the top-down search task. In our exploration of how particular icon characteristics affect icon menu search, an understanding of the theories around search will enable a proper discussion on what may be going on behind the scenes when we use icons.

2.3 Icon Characteristics Affecting Performance

As noted earlier, a number of icon characteristics have been found to determine the ease with which users search for the icon they wish to use on an interface. These include visual complexity, concreteness, and familiarity [51] [55] [56] and more recently aesthetic appeal [65].

2.3.1 Visual Complexity

In early icon research, Byrne discovered that simpler icons can be identified more easily than complex icons and furthermore, that visually simple icons are easier to find

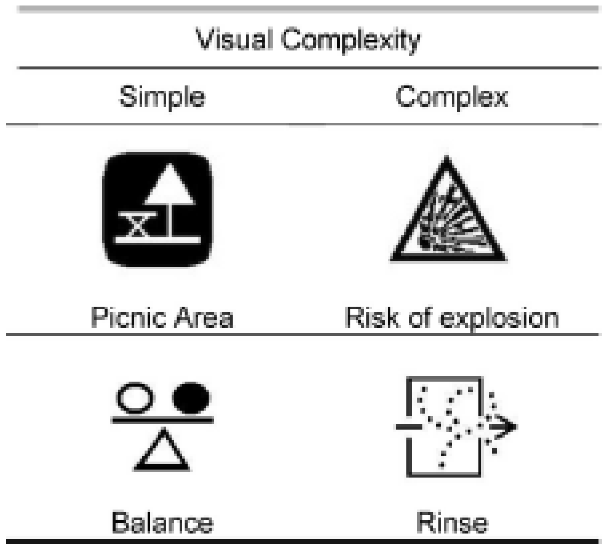


Figure 1: Examples of visually complex and simple icons.

in visual search [16] [17]. Furthermore, there are multiple papers in the literature that attempt to quantify an image's visual complexity [23] [28] [85]. Examples of complex and simple icons used in earlier research are listed in Figure 1 [55]. Although visual complexity was not a primary determinant of icon identification, evidence suggested that it is important in visual search for icons on an interface [40]. Furthermore, among the icon characteristics found to affect icon search, an icon's visual complexity was the most important determining factor [48] [49] [50].

Complex icons (targets) took longer for participants to locate in an array of other icons (distractors) than simple icons and this effect remained even after participants had gained considerable experience with the icon set [56]. This finding was important because reducing search times has been shown to correlate with improved user satisfaction rates [64] and even small reductions in search time added up over the course of interface use to provide a smooth user experience [32].

2.3.2 Familiarity

There are different ways to think about the icon characteristic of familiarity. One way refers to frequency of use or how often something has been encountered. For icons, familiarity increases as exposure to the icon increases [57] [87]. Another type of familiarity can be defined as how familiar the viewer is with objects presented in a stimulus. The viewer may be familiar with objects portrayed in the icon even if they have never seen the icon itself. For example, even though a user may be unfamiliar with a specific icon meant to indicate a picnic area, they are probably familiar with the picnic table depicted in said icon. The effects of this kind of familiarity, as referred to in previous work, can be examined using ratings of icon familiarity [56] [66].

Familiarity, as an icon characteristic, has been shown to have a small, but consistent effect on search performance [48] [50] [55] [56] [65] [66]. Furthermore, familiarity plays a substantial role in the perception of each of the other icon characteristics. The more familiar a user is with an icon or the objects in it, the greater their appraisal of the icon's simplicity, the icon's concreteness, and its aesthetic appeal [55].

Besides thinking of familiarity as a measure obtained with ratings, familiarity can also be thought of in terms of experience. The effects of this type of familiarity has been examined by presenting participants with icons over blocks of trials and is also referred to as experience [40]. By instituting repeated icon search across blocks of trials, we experimentally increase a participant's familiarity with the icons in the set.

If we start with unfamiliar icons, by the time participants complete a series of blocks they will be more familiar than they were at the start of the session. Choosing less

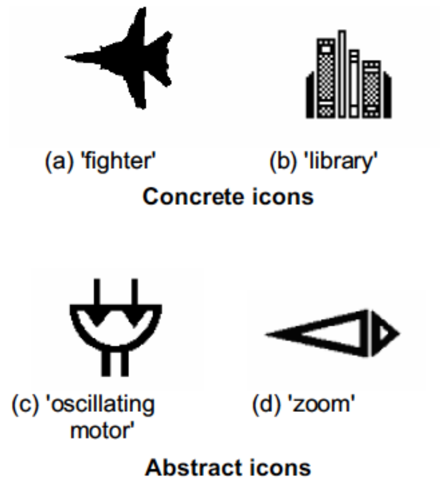


Figure 2: Examples of concrete and abstract icons.

familiar icons for use in our experiments, we aim to isolate the change that occurs in search as the user's familiarity with the icon increases with experience. Experiments 3 and 4 will use repeated blocks to manipulate icon familiarity within the experimental session to discover how icon characteristics affect search during learning.

2.3.3 Concreteness

Examples of concrete and abstract icons are listed in Figure 2 [55].

Concreteness, or how similar the objects in an icon are to people, places and things in the real world, is another icon characteristic that has been examined in some detail. Concreteness and complexity were once considered the same icon characteristic. Garcia's group developed a concreteness metric that did not differentiate between the two [30]. It measured the complexity of icons by counting the lines, arcs, and letters in the icon. Other studies, however, have demonstrated how complexity and concreteness are separate icon characteristics that affect performance in different ways [26] [27] [55]. When the concreteness and complexity of the icons was properly controlled, visual complexity primarily determined visual search times, while icon concreteness primarily determined the ease with which icons can be identified [40] [56]. Although icon complexity has been shown to affect search time to a far greater extent than concreteness, we include concreteness for examination since it has typically been viewed as a key icon characteristics in the research literature and has been shown to have some effect on search time [56].

In addition, semantic distance rather than concreteness is the icon characteristic most closely associated with icon identification (searching for an icon given its function name) [55]. However, in examining icon characteristics known to affect simple icon search (searching for an icon given the icon image), concreteness is a characteristic that refers to the icon image itself rather than its relationship with its identifying name.

As was mentioned in the section on familiarity, it is important to note that there can be strong correlations between icon characteristics' ratings. Forsythe et al. found, for example, that complex icons that users were familiar with were perceived to be "simpler" than icons of equal visual complexity that they were unfamiliar with [28]. Furthermore, concrete icons tended to be perceived as less complex because users view familiar icons as less complex [28].

2.3.4 Aesthetic Appeal

To illustrate how the icon characteristic of appeal can correlate with the other icon characteristics we examine how it can be combined with complexity and concreteness in creating the stimulus set for experimentation. Figure 3 provides examples of the

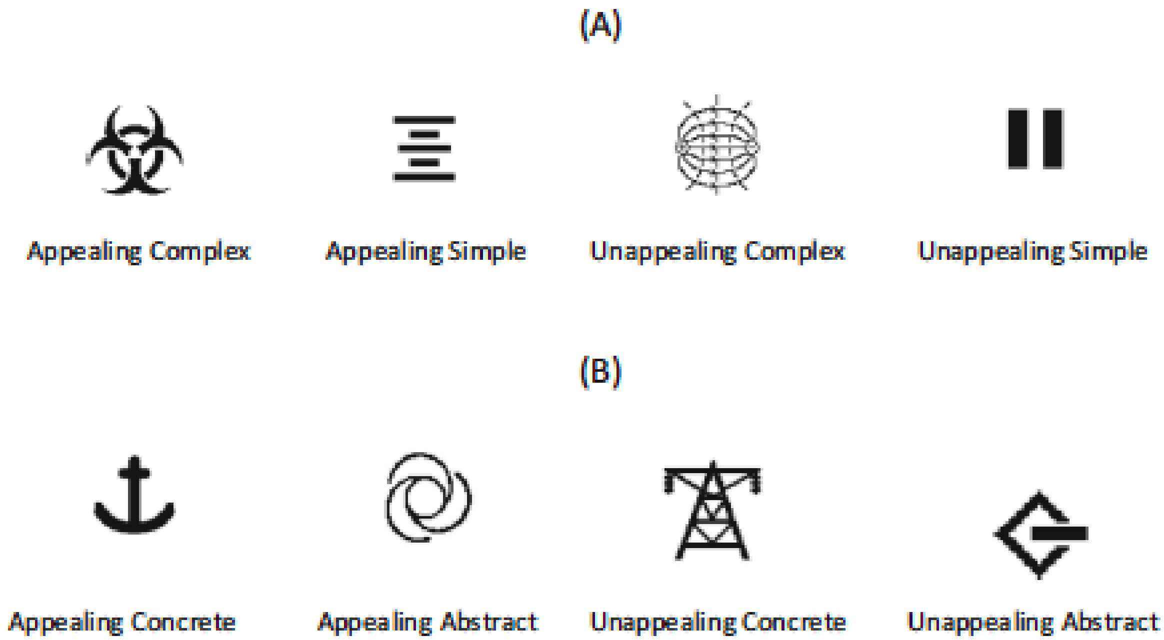


Figure 3: a Examples of icons used to test the effects of Appeal and Complexity. b Examples of icons used to test effects of Appeal and Concreteness.

icons used in the experiments varying on appeal and complexity (top row) and of icons varying on appeal and concreteness (bottom row) [55].

Aesthetic appeal of stimuli has been found to influence users' cognitive processing [11] [44] [43] [64] [76]. Recent research has focused on the effect of aesthetic appeal on icon search and its interplay with each of the three main icon characteristics in search performance: visual complexity, concreteness, and familiarity [28] [31] [33] [37] [65]. For example, visually complex icons were searched for and located better if the icon was also found to be visually appealing [66]. For simple icons, there was no necessary advantage found by increasing aesthetic appeal [66]. These studies also found that aesthetic appeal had a significant interaction with concreteness, with a time advantage given to abstract icons and not concrete ones [65] [66].

Previously it was stated that the visual complexity of an icon promoted its quick selection when the icon was simple. The aesthetic appeal of an icon may also influence an icon's quick selection. Happy faces are found faster in a crowd than other faces [77]. This supports the fact that emotion affects pre-attentive processing by speeding up search in the case of happy faces. The idea that emotional information is processed pre-attentively supports the idea that aesthetic appeal has a role, together with visual complexity, in affecting icon search times [8] [77].

Ease of processing as described in [53] addresses the connection between an icon's selectivity (speed of processing) and its appeal, which has been shown to have a strong influence on overall usability ratings. Ease of processing may explain the relationship between ratings of usability of an interface and icon appeal [3] [53].

2.4 Icon Stimulus Sets

To test icon search, experimenters use stimulus sets comprised of icons. As the design of icons changes over time, stimulus sets must be updated for experimentation to reflect findings relevant to the use of icons in modern computing [21] [75]. Especially with the advent of mobile application computing, the importance of icons and their design comes to the forefront. There is a plethora of different mobile applications available for download on mobile phones and as icons represent the point of access for each of those applications, icons that are used in this context warrant inclusion in stimulus sets for experimentation.

A history of icon stimulus sets includes Snodgrass and Vandervart's line drawings, McDougall's 259 icon set, and more recently the Lisbon Symbol Database [55] [63]

[78]. Snodgrass and Vandervart's stimulus set was created for experiments investigating the processing of pictures and words. The images were standardized on four variables: name agreement, image agreement, familiarity, and visual complexity [78]. McDougall et. al. created an icon set of 259 icons with subjective ratings on characteristics thought to represent the range of current icon applications. These icon characteristics included concreteness, visual complexity, meaningfulness, familiarity, and semantic distance (a measure of the closeness of the relationship between what is depicted in an icon and the function it is intended to represent). The Lisbon Symbol Database of 600 icon symbols provided norm ratings on a similar set of characteristics including visual complexity, concreteness, appeal, familiarity, and also emotionally-oriented characteristics valence and arousal [63].

One important contribution of this dissertation is that it provides important norm ratings on the 4 icon characteristics that have been found to impact icon search for 2 sets of icons. The Lisbon Symbol Database included icons on subjects such as social media and technology, transportation, leisure activities, and non-figurative symbols. The McDougal et. al. icon set consisted of icons from the areas of computers, traffic and public information, industrial, and household goods. Of course, mobile application icons cover the gamut from gaming to productivity tools to navigation and communication. These icon sets all attempt to include a mixture of icons varying in subject-matter. By including icons from each of the 2 icon sets with mobile application icons used today, we aim to continue this trend of including icons varying in subject-matter as our focus is not on the meaning that can be inferred from the icon image but instead the visual design of them.

2.5 Existing Icon Design Recommendations

Existing icon design guidelines and recommendations typically recommend 3 attributes in effective icon design: form, aesthetic unity, and recognition [46]. As icons save screen real estate in their miniature size and can enhance aesthetic appeal, there are times when the aesthetic interest of the icon may be the worth losing; too much attention paid to aesthetics in the design may lower the icon's recognition. And while a certain degree of realness may add interest to a design as well, it should not supersede its ability to function.

Form is another way of saying how something is made. Primary geometric shapes, circles, triangles and squares, create a visually stable foundation for icon design. See the figure below for an example of a geometrically designed icon versus an icon with an organic form [46]. Icon designers are encouraged to start drawing the largest, simplest shapes and then refining to a more detailed design, adding as much detail as needed for communicating the concept of the icon [46].

Aesthetic unity is another element that has received attention lately as an important aspect of icon design thought to affect icon usability [46]. These elements are often what we refer to as stylistic such as consistent line weights, whether the icon is flat, line, filled line or glyph, what colors are used in the design, etc. The term aesthetic unity can be used to refer to a single icon's design or the design style of a set of icons. Figure 5 illustrates the preference for a flat design rather than a 3-dimensional one.

Finally, recognition is the third icon element that must be addressed during the

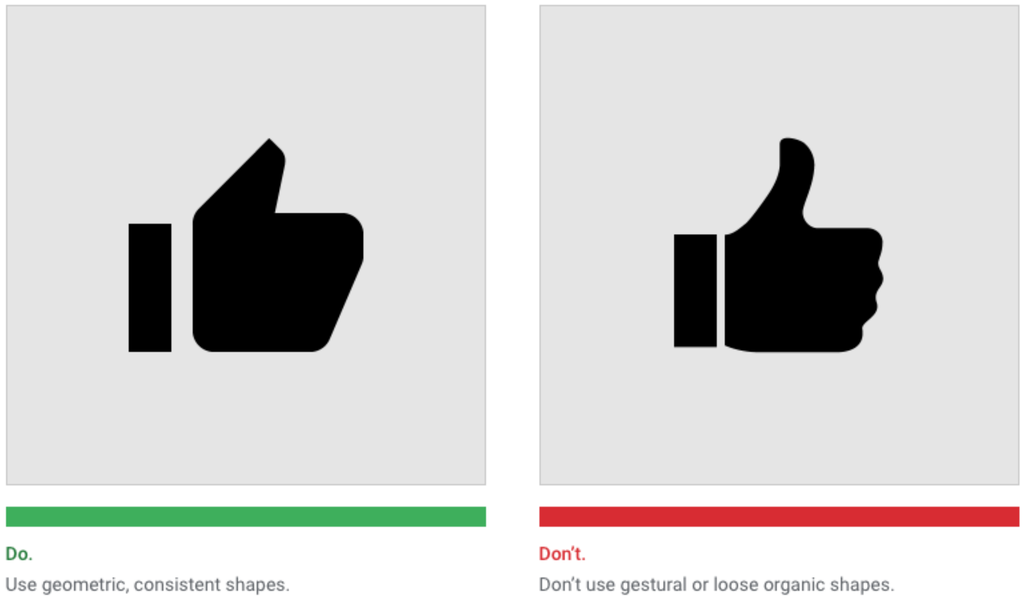


Figure 4: Geometric design is promoted as a better design than an organic one for system icons in Google icon design guidelines [1].

design activity [46]. The core of an icon's purpose is to communicate an object, idea, or action effectively to the user.

In relating these three icon design recommendations to the icon characteristics identified by experimental psychologists, we offer up the following explanation. The icon design characteristic of visual complexity relates to form and it may also relate to aesthetic unity, as the level of detail in an icon can be due to the level of ornamentation or added aesthetic detail. Also, the aesthetic of an icon may, instead, involve a reduced level of detail in an icon as some designers take away detail in their effort to ensure aesthetic unity. This occurs when icon designers attempt to make an icon simpler, rather than more complex as they also consider the icon's appeal.

The literature on icon design found online along with the guidelines set forth by Apple for IOS icons and for Android icons on the Google Playstore, all state that

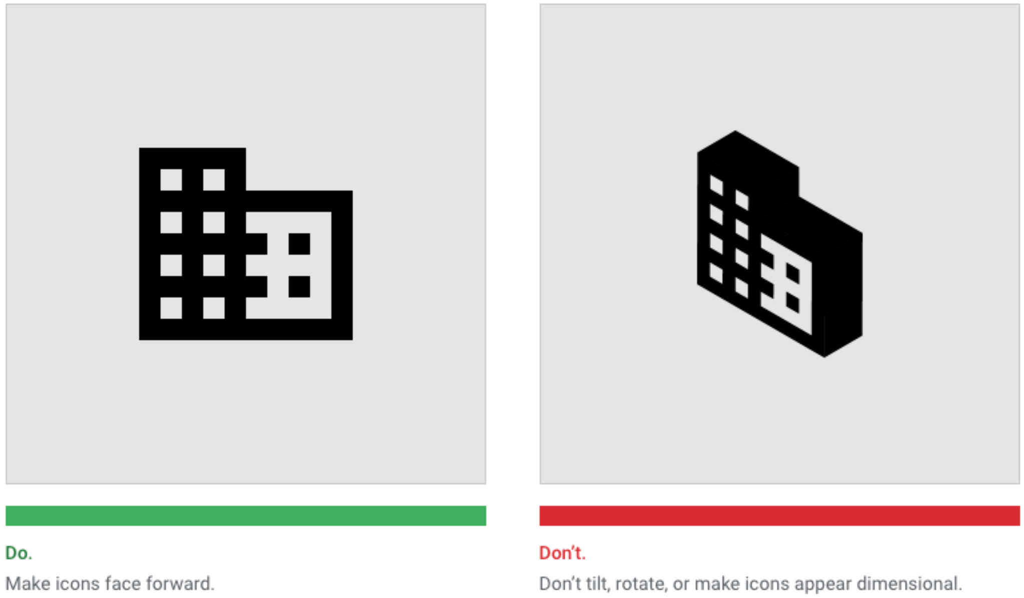


Figure 5: A 2-dimensional design is promoted as a better design than the more complex 3-dimensional image, having depth, for system icons in Google icon design guidelines [1].

an icon's level of detail should be just enough to communicate the idea behind the icon [1] [46] [6] [39]. Why is this? Icons are made to provide guidance to the user as to where to find and access the functionality they seek. Whether they have seen the icon before or not, simplicity in design stands out as the number one icon characteristic responsible for fast localization of icon stimuli. Humans are capable of processing simple visual information faster than complex information [74].

So the visual complexity of an icon can relate to its form and to its aesthetic unity, whereas recognition involves the accuracy of depiction in an icon and perhaps the familiarity of the icon as well. Concreteness and familiarity are the icon characteristics related to recognition. As concreteness is concerned with how real the objects in an icon appear, it follows that concrete icons are more easily recognized than abstract ones. Also, when an icon is more concrete the meaning behind the icon tends to be more easily understood by the user. Of course, this represents only a part of the story since a user may also recognize an abstract icon easily because they are already familiar with that particular icon design. One example would be the Twitter bird icon or the Facebook "f" icon. These icons are not terribly concrete but users are familiar with them since the applications associated with them are in greater use on the whole.

The four icon characteristics of visual complexity, aesthetic appeal, concreteness, and familiarity serve as the top subjective measures of icon design that represent how users judge icons designed according to existing guidelines about form, aesthetic unity, and recognition. We focus on the characteristics of any one icon that could influence its time to be found in a typical icon menu interface. In the interest of limiting the scope of our efforts to variation in form as it relates to images, we disregard icon labels in our examination of icon search. We also disregard variation in color as color is known to exhibit a strong effect on search time. We leave variation in icon color to future icon researchers.

CHAPTER 3: MECHANICAL TURK STUDIES

The purpose behind conducting the experiments described in this chapter was to replicate existing experimental methodology and design in testing for search time differences between icon characteristics with up-to-date icon sets [47] [56] [63]. We replicated previous experimental methodology discussed further in the Experimental Approach section.

Two experiments are presented in this chapter. Both experiments yielded results from running Amazon Mechanical Turkers through an icon search experiment that followed an experimental design used in existing icon search studies [55].

The first experiment employed an icon set selected from existing mobile application icons [47], whereas the second used icons selected from the Lisbon Symbol Database [63]. This first set of icons was new to the literature on icon search and icon ratings. The second set was created for the express purpose of experimentation and was the most recent icon stimulus set published that included the icon ratings we wished to examine [63].

In using modern sets of icons in testing icon search time using a modern mechanism of testing search performance which is known to have a good sample of users [36] [47] [63], these experiments investigated the main and joint interactions of design characteristics effects on search time.

3.1 Experimental Approach

The experiments examining icon characteristics all used the same search task in examining search efficacy of an icon [56] [65] [66]. The participant was presented with an icon for 2 seconds in duration, after which the participant was instructed to press a button to indicate they were ready for the next portion of the experiment. Then, a 3 X 3 matrix of icons was displayed with one of the icons in the matrix being identical to the initial, target icon. The participant was instructed to click on the icon matching the target icon and then to click another button to proceed to the next search task.

The layout of the search task (and of most icon menu interfaces) was intended to prevent grouping issues as icons within close proximity are automatically grouped together in visual processing [81]. The choice of which icons were to serve as distractors in the small matrix of equally-spaced icons was made according to which icons had already been used. Icons that had not previously been presented in the search trials were chosen to act as distractors, until all icons from each of the icon groups in the stimulus set had been used. Each of the icons from the set of 64 was used once as a target and 8 times as a distractor. This prevented the familiarity of any distractor (or target icon) from influencing search times any more than any other icon in the set. The placement of icons for any one search task trial was randomized throughout. An example of the search task is illustrated in Figure 6.

The presented icons varied depending on which icon characteristics were being examined. Previous experiments examined two icon characteristics at one time (i.e.

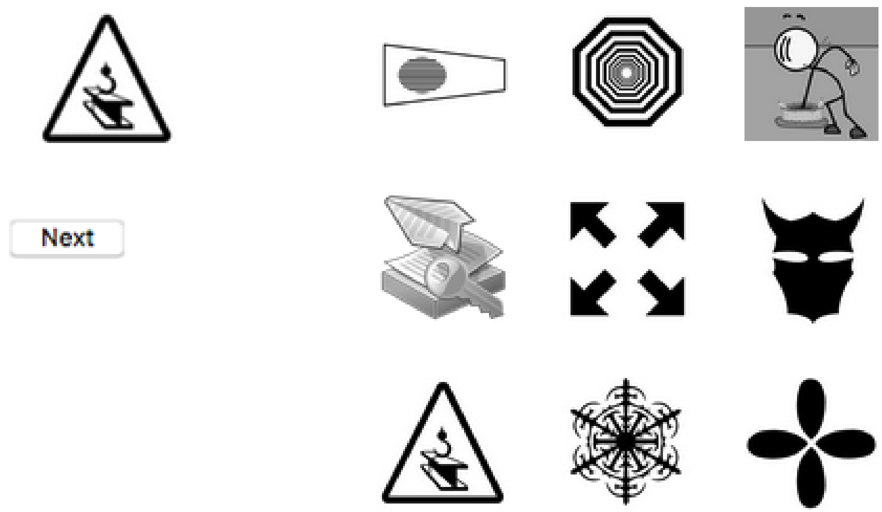


Figure 6: Example of an experimental trial.

visual complexity and appeal). The 4 groups used in analysis were based on a complete cross of 2 levels of each of the 2 characteristics, for example, simple-appealing, simple-unappealing, complex-appealing, and complex-unappealing. Figure 4 presents examples of icons from these groups.

3.2 Experiment 1: Searching for mobile application icons

Previous research has examined the effect of icon complexity and concreteness by varying these icon characteristics orthogonally in testing search [55]. See Figure7). These experiments involved presenting an icon briefly to participants and then asking them to search for the icon in a subsequent array of icons.

On the basis of this research they concluded that visual complexity was a key determinant of icon search time [55]. The effect of visual complexity on search time was significant with search times being longer for complex icons. This study did not find a main effect of concreteness, but post-hoc comparisons revealed a significant

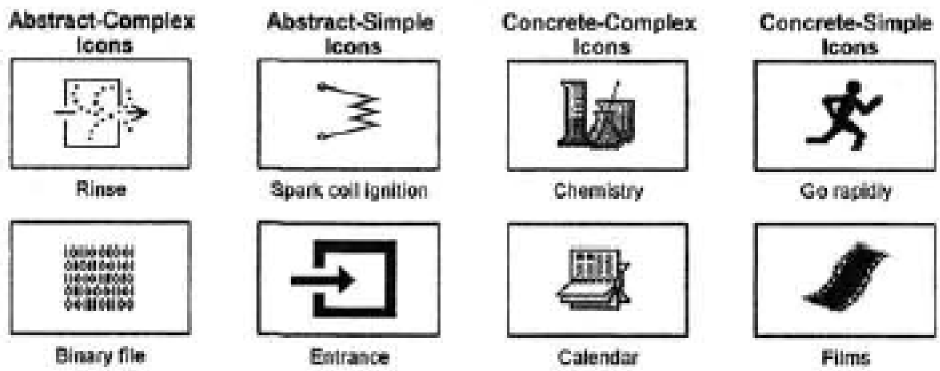


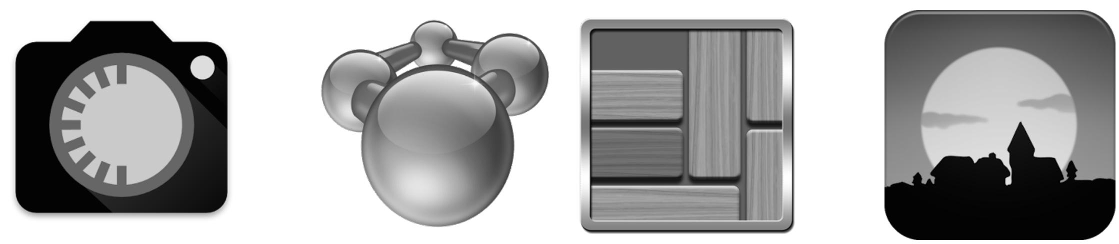
Figure 7: Four groups for analysis: Abstract-Complex, Abstract-Simple, Concrete-Complex, and Concrete-Simple.

effect of concreteness early in the experiment before participants became familiar with the icons (mean search times were faster for concrete than for abstract icons).

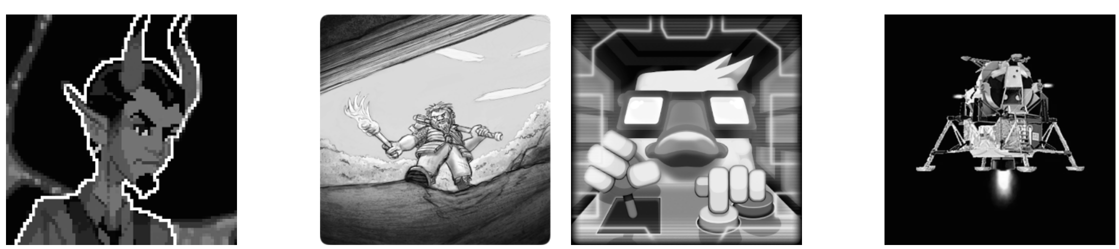
Importantly, very little previous research has examined the effect of icon appeal on visual search [65] [66]. Given the importance of creating appealing as well as functional displays on mobile phones, the effect of appeal was also considered in this experiment.

In Experiment 1 conducted for this dissertation, the appeal of the icons presented in the mobile search task was varied as well as icon complexity and concreteness, yielding 8 types of icons or icon groups (see Figure 8). This made it possible to examine any main effects of any of the icon characteristics as well as any joint effects between the three.

Previous studies examined effects of search using a 2x2 design, whether it be complexity and appeal or complexity and concreteness. We chose to expand to a 2x2x2 design to allow for a more complete examination of the ways that the important icon characteristics studies in the past work together to influence icon search time. This design permitted verification of previous findings of 2-way interactions involving characteristic pairs, with 3 distinct 2-way interactions comprised of all possible pairings of the 3 characteristics being examined for statistical significance. Plus, the brand new ability to assess the existence of a 3-way interaction of all 3 characteristics working together to influence icon search times. Moreover, we used a new set of mobile application icons that have not been studied before in the icon search literature. These are important firsts in the icon search research area.



(a) Simple Unattractive Abstract
(b) Simple Unattractive Concrete
(c) Simple Attractive Abstract
(d) Simple Attractive Concrete



(e) Complex Unattractive Abstract
(f) Complex Unattractive Concrete
(g) Complex Attractive Abstract
(h) Complex Attractive Concrete

Figure 8: Examples of icons used. One icon from each group is presented here.

3.2.1 Hypotheses

We aim to replicate prior findings using a new, more ecologically valid set of icons not tested in the icon search literature before, and with three important icon characteristics studied in same search experiment. By including three characteristics together at once, we aim to extend prior work by looking for a complex 3-way interaction that might shed more light on how complexity, concreteness, and appeal work together to influence icon search. Given what is known from previous studies, we posit the following six hypotheses:

1. Complex icons will be found more slowly than simple icons, replicating prior findings of a main effect of complexity [56] [65].

2. Neither concreteness nor appeal alone will contribute significantly to search time, replicating the general lack of main effects of each of these effects in prior studies of icon search [65].

3. Concreteness and appeal will have a significant interaction [65].

4. Appealing, abstract icons will be found faster than unappealing abstract icons [65].

5. Complexity and appeal will have a significant interaction [65].

6. Appealing, complex icons will be found faster than unappealing complex icons [65].

3.2.2 Method

3.2.2.1 Materials

Our stimulus set consisted of mobile application icons from Google Play Store and Apple AppStore which were then modified to grey-scale. We created an icon set in grey-scale for the purpose of singling out the effects of form from the pre-attentive effects of color. The effect of color in visual processing was strong and before including that in this line of research, we wished to concentrate on form [22]. Icons that were likely to be unfamiliar to participants were obtained by choosing icons from the New Releases category of applications.

Prior to carrying out the experiment, subjective ratings of icons on the four primary characteristics were obtained using an online survey. These ratings were then used to create an appropriate set of icons in the search task examining the time taken to locate mobile application icons in a display. Nine Amazon Mechanical Turk workers were asked to rate a set of 180 icons on visual complexity, concreteness, familiarity, and aesthetic appeal. Instructions for rating icons on the four characteristics of interest can be found in Appendix A.

The ratings were then used to select sixty-four of the 180 icons for use in the search experiment. Icons were selected for each of the 8 icons types using the ratings obtained with 8 icons of each type being selected to create a set of 64 icons (See Appendix B for a full repository of the 64 icons). The icons in the 180 set of mobile application icons were rated on a scale from -2 to 2 (or a scale of 5 on a Likert scale).

The method used to arrive at our final set of sixty-four was as follows. We discarded familiar icons and chose icons that were on the low end of the familiarity spectrum within the set. We did an initial sort of all 180 icons on complexity, attractiveness and concreteness, and then performed median splits on each characteristic, starting with appeal, then complexity, and finally concreteness. Afterwards there were some groups consisting of less than the 8 required for our planned experimental setup. For this reason we moved some icons from other groups into the groups lacking a full eight. For example, we chose an icon from another group with similar ratings on two

Table 1: Pearson Correlations Between Icon Characteristics.

	Complexity	Attractiveness	Concreteness	Familiarity
Complexity	1	.080	.606**	.128
Attractiveness	.080	1	.260*	.225
Concreteness	.606**	.260*	1	.370**
Familiarity	.128	.225	.370**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

of the characteristics and with a relatively close rating on the third characteristic. We made a handful of such adjustments. We checked statistics (F and t tests) on the groups to ensure the correct allocation of icons.

Correlations between icon characteristics in the final stimulus set are listed in Table 1. We analyzed the three factor structure (complexity, attractiveness, and concreteness) using simple effects with one manipulation. Statistics for the resulting groups can be seen in the following figures. All efforts were made to balance the icon characteristics across groups. Rating averages for each group are listed in Table3. It should be noted that the complexity-concreteness correlation of .61 proved troublesome. Later we examined our results with this correlation in mind.

In the figures means and standard errors for the high and low icon sets are presented for each characteristic as a function of the other 2 characteristics across 3 figures. Means that are more than 2 standard errors apart, which appears to be all of them in all 3 of the figures, were deemed to have been effectively separated. Each figure demonstrates the separation of average ratings of the icons on the vertical characteristic being rated into 4 high and 4 low icon subsets on that characteristic.

Table 2: Icon Group acronyms for high-low on each of the icon characteristics: Complexity, Appeal, Concreteness.

Factor		High		Low
Complexity	C	Complex	S	Simple
Aesthetic Appeal	A	Attractive	U	Unattractive
Concreteness	C	Concrete	A	Abstract

Table 3: Means for each Icon Group (on a scale from -2 to 2). See High-Low table for Icon Group acronyms.

Icon Group		Complexity	Appeal	Concreteness
CAA	average	**0.68**	**0.38**	**-0.24**
	std. dev.	0.23	0.20	0.15
CAC	average	**0.86**	**0.43**	**1.00**
	std. dev.	0.55	0.18	0.27
CUA	average	**0.29**	**-0.54**	**-0.64**
	std. dev.	0.12	0.40	0.27
CUC	average	**1.04**	**-0.24**	**0.78**
	std. dev.	0.29	0.12	0.57
SAA	average	**-0.61**	**0.34**	**-0.63**
	std. dev.	0.37	0.12	0.23
SAC	average	**-0.19**	**0.26**	**0.49**
	std. dev.	0.29	0.40	0.32
SUA	average	**-0.81**	**-0.33**	**-0.95**
	std. dev.	0.44	0.13	0.14
SUC	average	**-0.02**	**-0.40**	**0.26**
	std. dev.	0.15	0.11	0.34

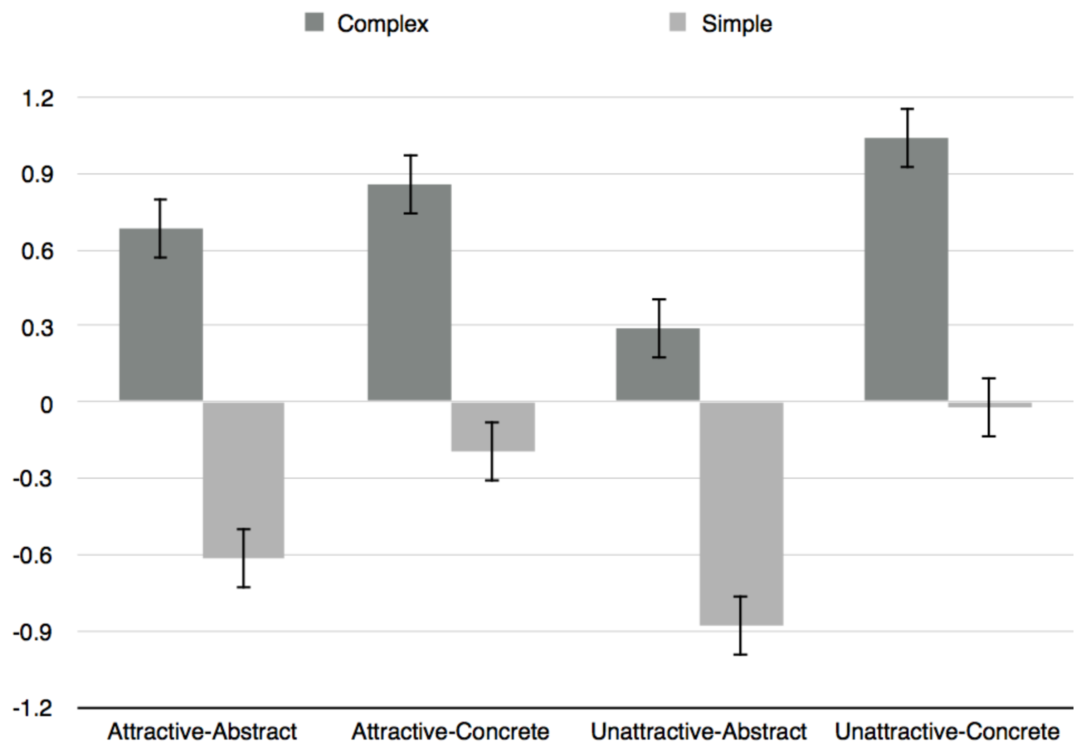


Figure 9: Means and standard errors for Complexity across groups.

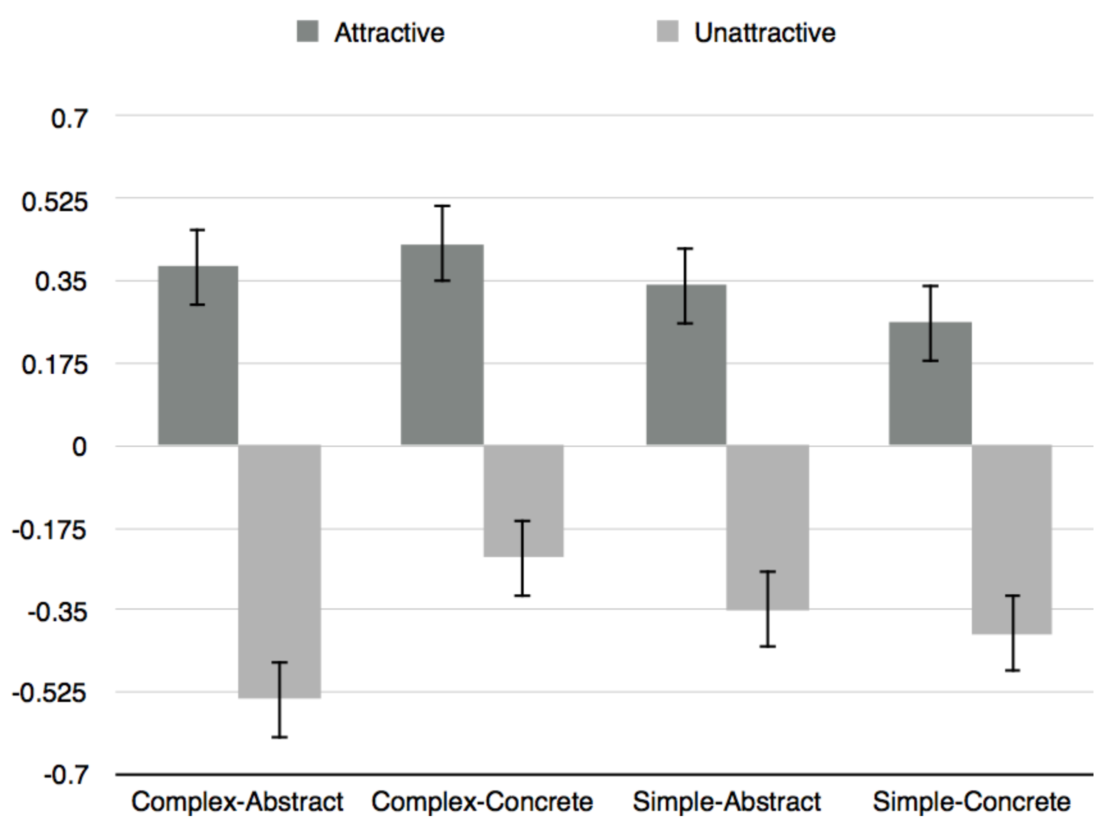


Figure 10: Means and standard errors for Attractiveness across groups.

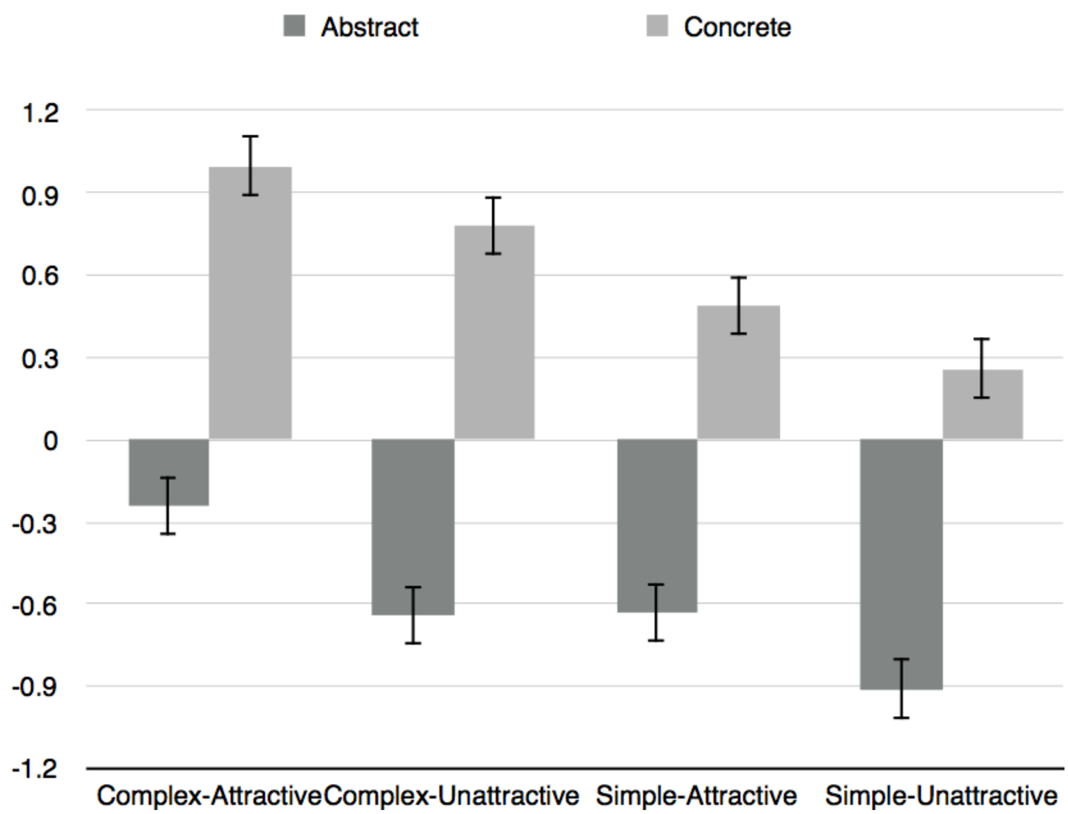


Figure 11: Means and standard errors for Concreteness across groups.

3.2.2.2 Participants

Fifteen Amazon Mechanical Turkers participated in the icon search portion of the experiment. Each participant was compensated $3 for their time. Nine males and six females completed the online survey. Their ages ranged from 25 to 64 with most participants in the 25-34 age range. Mechanical Turk participants were chosen because there is good variation in Mechanical Turkers' backgrounds and, as a result, they are more representative of the greater population than the sample populations of students used in most academic studies [36].

3.2.2.3 Design

A 2 x 2 x 2 design (complex/simple, appealing/unappealing, concrete/abstract) was used in this experiment. Since each participant received the same treatments in the same session, our design was within-subjects with the dependent variable of response time (RT). The treatments were randomized. Independent variables included the three primary icon characteristics: complexity, concreteness, and aesthetic appeal.

These studies included a number of blocks of trials to examine how performance changed over time. Previous studies required participants to come back a day later to perform a second round of trial blocks [48] [52] [57] [65] [66]. This was not a realistic expectation for Mechanical Turkers. Each HIT or Human Intelligence Task begins and ends in the same session.

Each session consisted of a single block of 64 search trials with no repetition of targets for any one participant. This prevented assessment of learning over blocks of trials. For each icon search trial, the nine icons presented to the user were equally

Figure 12: Example of an experimental trial.

distanced from each other in a matrix or tic-tac-toe design (See Figure 11). Each icon in the 64 icon set was used once as the target. The algorithm then randomly chose a target location randomly for each trial (See Appendix F for code). The distractor positions were also randomized with icons from each group being used equally across all search trial conditions.

3.2.2.4 Procedure

After the participant accepted the Mechanical Turk HIT, they were told they would be presented with an icon for 2 seconds before they would be expected to click a Next button to continue to a 3 x 3 matrix of icons and search for the target. See Figure 12 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.

Each participant was compensated $3 for completing the experiment. From the beginning they were informed that if too many of their icon selections took too long, they would not receive compensation. Additionally they were informed that if they did not complete all trials, this too would prevent them from receiving payment. These efforts were made to encourage attentiveness and provide incentive for finishing all trials. Since the participant's attention was important for proper experimentation, the experiment was designed to take 15 minutes to complete including all sixty-four search trials and a demographic survey.

3.2.3 Results

Errors accounted for 2.10% of all trials. There were no differences in errors between any of the eight conditions (p values>0.05). Correct group means are shown in Table 4. We used an alpha level of 0.05 for all statistical tests and partial eta-squared as a measure of effect size.

A between-subjects (icon items) ANOVA on correct icon RT (Table 5) revealed that the main effect of Complexity was significant, $F(1,56)=23.783$, $p<0.01$, partial eta-squared = 0.298. Neither concreteness' nor aesthetic value's main effects were significant: concreteness, $F(1,56)=0.167$, $p>0.05$, partial eta-squared = 0.003; aesthetic value, $F(1,56)=0.086$, $p>0.05$, partial eta-squared = 0.002. Interestingly, there was a significant interaction between complexity and aesthetic appeal ($F=4.747$, $p<0.05$, partial eta-squared = 0.078), with shorter RT for appealing than unappealing simple icons, $t(31)=4.90$, $p<0.01$. There was no such difference for complex icons. See Figure 13.

Table 4: Mean Search Time with Standard Deviations (msec).

Complexity	Appeal	Concreteness	Mean	Std. Deviation
Simple	Unappealing	Abstract	1578	273
		Concreteness	1605	129
	Appealing	Abstract	1469	96
		Concreteness	1503	176
Complex	Unappealing	Abstract	1634	162
		Concreteness	1780	128
	Appealing	Abstract	1855	201
		Concreteness	1720	140

Table 5: Between-Subjects ANOVA on Icon Characteristics. A by-item analysis.

Source	df	F	Sig.	Partial Eta Squared
Complexity	1	23.783	0.000	0.298
Appeal	1	0.086	0.770	0.002
Concreteness	1	0.167	0.685	0.003
Complexity * Appeal	1	4.747	0.034	0.078
Complexity * Concreteness	1	0.083	0.774	0.001
Appeal * Concreteness	1	2.557	0.115	0.044
Complexity * Appeal * Concreteness	1	2.816	0.099	0.048
Error	56			

No significant three-way interaction was found between icon characteristics, $F(1, 56)=3.93$, $p>0.05$, partial eta-squared = 0.048. No other interaction was found to be significant.

Table 6: Hypothesis table with true/false indicators for Mechanical Turk search experiment response time results.

	Hypothesis
T	Complex icons will be found more slowly than simple icons.
T	Neither concreteness nor appeal alone will contribute significantly to search time.
F	Concreteness and appeal will have a significant interaction.
F	Appealing abstract icons will be found faster than unappealing abstract icons.
T	Complexity and appeal will have a significant interaction.
F	Appealing complex icons will be found faster than unappealing complex icons.

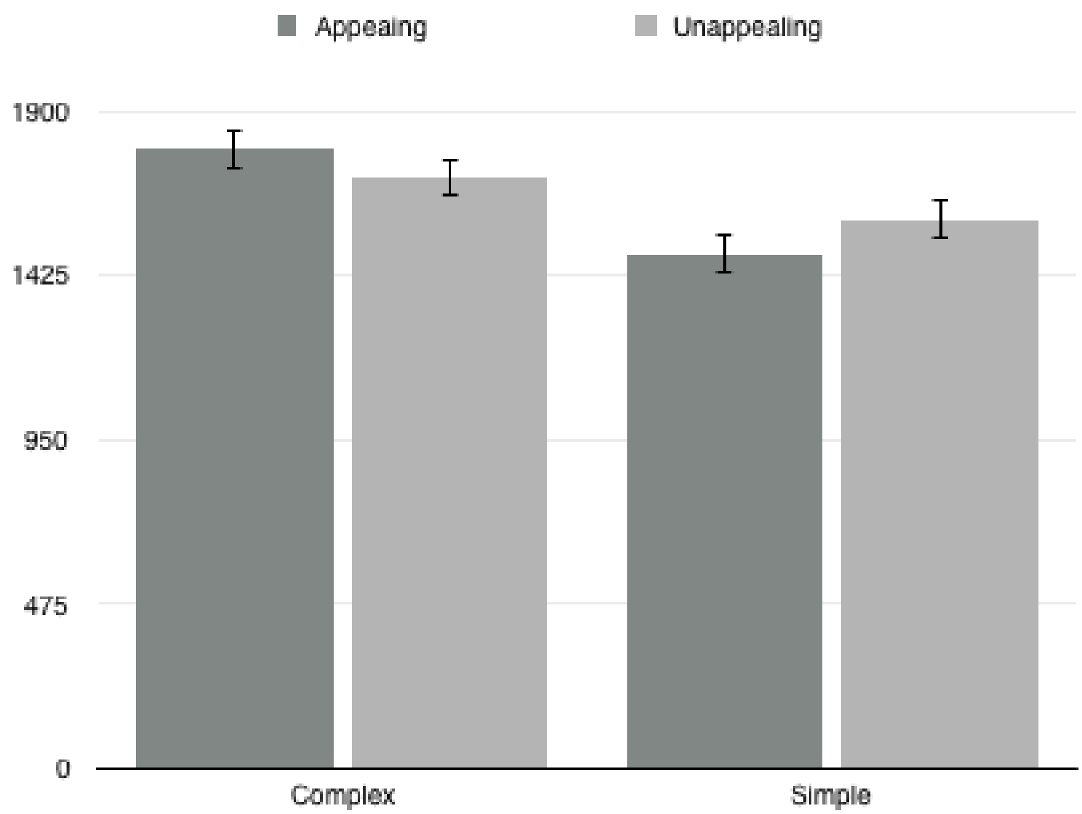


Figure 13: Mean response time in milliseconds.

3.2.4 Discussion

In accordance with previous research, it took longer for participants to find complex icons than simple icons (See Table 5) [66]. Ensuring that there was a difference for complexity, we can then examine possible interactions between other icon characteristics and complexity. Similarly, in keeping with previous findings, neither concreteness nor icon appeal had a significant effect on search time. Unlike in previous studies, concreteness and appeal did not share a significant interaction. The third hypothesis was not correct in this case.

Complexity and appeal had a significant interaction. Hypothesis five was found true. The most interesting finding from the results was the significant difference found between simple-appealing and simple-unappealing icon groups. This trend was found in older studies but for complex icons [65] [66] . Complex-appealing icons were found faster than complex-unappealing icons.

Oddly enough, this trend among complex icons was not found in our study. There was no significant difference found between appealing and unappealing icons for the complex group. The sixth hypothesis was not found to be true.

Effect sizes were small. We accounted for the small effect sizes by considering the difficulty with procuring accurate search times from an online experiment. Without controlling for the environment, the accuracy of recorded search time may have faltered.

Previous work revealed a strong effect size for visual complexity (ε^2=0.83) in a similar experiment examining visual complexity, aesthetic appeal and blocks [66].

And although aesthetic appeal by itself failed to have a significant main effect, the Complexity X Aesthetic Appeal interaction was significant ((ε^2=0.28) [66]. This effect size was not as pronounced as that of visual complexity by itself, but it was sizable. These types of effect sizes were along the lines of what we were expecting.

3.2.5 Conclusions

According to the results from our study, we can give recommendations to icon designers that want to create easily "findable" icons. The number one recommendation would be to keep the icon design simple. Participants were faster at locating simple icon targets.

Importantly, this experiment also showed that visual complexity combined with icon appeal to enhance search performance. Since simple, appealing icons were located faster than simple, unappealing ones, we conclude that aesthetic appeal and visual complexity have a joint effect on performance. Although the former study revealed that aesthetic appeal affected task performance only when the task was difficult, such as when the icon was complex, our study's findings reflect that simple icons that are easy to find can also benefit from the advantage afforded by appeal.

The finding of this 2-way interaction that includes appeal is an important finding in this experiment. The fact that appeal played a part in a joint interaction suggests that the newer literature looking at appeal may be on to something [66]. The present study supports the proposition that aesthetic appeal can bias perceptual systems by giving priority to appealing stimuli. This finding is relevant since it has significant implications for interface design.

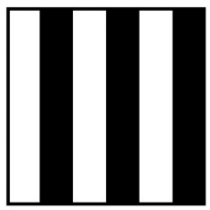
3.3 Experiment 2: Searching for public information icons

After Experiment 1, since we were concerned that our findings were due to a stimulus set not truly balanced across icon characteristics, we used a new standardized icon set next.

Experiment 2 used previously rated icons in an online search performance task. These icon ratings were collected by a group in Portugal [63]. The Lisbon Symbol Database consists primarily of signs/icons used to convey public information. A subset of 64 pulled from the 600 icon Lisbon Database was used in this experiment and ratings which Prada et al. had obtained of visual complexity, concreteness, appeal, and familiarity were used to create 8 types of icons varying in the same manner as in Experiment 1 (see Figure 13). Icons were selected for groups according to their ratings. All icons were rated relatively low on familiarity while the icon ratings on the other characteristics varied across groups. The visual search task employed was identical to Experiment 1.

This study replicated the methodology used in icon visual search experiments conducted by McDougall and others [48] [52] [57] [65] [66]. These studies included blocks of trials in order to examine how performance changed over time. As in Experiment 1 participants in Experiment 2 were Mechanical Turk Workers completing one block of search trials in a single session.

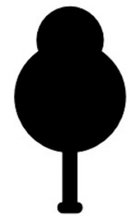
Given that it was expected that similar findings might be obtained as those in previously published works, hypotheses for this experiment remained the same as that for Experiment 1. Since the results from the first experiment and previous



(a) Simple Unappealing Abstract

(b) Simple Unappealing Concrete

(c) Simple Appealing Abstract



(d) Simple Appealing Concrete

(e) Complex Unappealing Abstract

(f) Complex Unappealing Concrete

(g) Complex Appealing Abstract

(h) Complex Appealing Concrete

Figure 14: Examples of icons used. One icon from each group is presented here.

findings may have resulted from differences between icon stimulus sets used in each respective experiment, the Lisbon set was used in search experimentation to see if previous results on icon characteristics hold up using an icon set created in the icon ratings community more recently [63].

3.3.1 Hypotheses

Since the findings from Experiment 1 differed from prior work, we continued testing hypotheses according to results from previous studies [55] [65]. Given what is known from previous studies, we posit the following six hypotheses:

1. Complex icons will be found more slowly than simple icons [56] [65].

2. Neither concreteness nor appeal alone will contribute significantly to search time [65].

Table 7: Pearson Correlations Between Icon Characteristics in the selected 64 icons for use in experimentation.

	Complexity	Appeal	Concreteness	Familiarity
Complexity	1	.254*	.061	-.121
Appeal	.254*	1	-.049	.043
Concreteness	.061	-.049	1	.489**
Familiarity	-.121	.043	.489**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

3. Concreteness and appeal will have a significant interaction [65].

4. Appealing, abstract icons will be found faster than unappealing abstract icons [65].

5. Complexity and appeal will have a significant interaction [65].

6. Appealing, complex icons will be found faster than unappealing complex icons [65].

3.3.2 Method

3.3.2.1 Materials

As noted earlier a subset of 64 of the icons from the Lisbon Symbol Database were employed in this experiment [63]. Pearson correlations between icon characteristic ratings for the 64 icons chosen are listed in Table 7.

There is a lack of correlation between concreteness and complexity in the correlation matrix (.061). Correlation between concreteness and complexity has disappeared compared to the first preliminary experiment.

This pattern of correlations here is different to the pattern observed in Experiment 1. This may explain how findings using the Lisbon Symbol Database icons differ from

Table 8: Pearson Correlations Between Icon Characteristics for all 600 icons in the Lisbon Symbol Database.

	Complexity	Appeal	Concreteness	Familiarity
Complexity	1	.103**	-.042**	.061**
Appeal	.103**	1	.424**	.470**
Concreteness	-.042**	.424**	1	.709**
Familiarity	.061**	.470**	.709**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 9: Mean ratings and standard deviations for the 64 Lisbon Symbol Database icons used in experimentation. Ratings were on a Likert scale from 1 to 7.

Icon Group		Complexity	Appeal	Concreteness
CAA	average	**5.02**	**4.73**	**2.52**
	std. dev.	0.47	0.55	0.30
CAC	average	**4.17**	**4.09**	**4.48**
	std. dev.	0.58	0.49	0.81
CUA	average	**4.61**	**3.21**	**3.07**
	std. dev.	0.54	0.24	0.36
CUC	average	**4.13**	**3.00**	**4.10**
	std. dev.	0.44	0.24	0.47
SAA	average	**2.81**	**3.86**	**2.72**
	std. dev.	0.29	0.22	0.33
SAC	average	**2.66**	**4.16**	**3.82**
	std. dev.	0.64	0.47	0.52
SUA	average	**2.55**	**3.13**	**2.64**
	std. dev.	0.50	0.31	0.42
SUC	average	**3.06**	**3.05**	**3.83**
	std. dev.	0.45	0.31	0.42

those using the mobile application icons.

When choosing to use icons from the Lisbon Symbol Database, we considered if cultural differences might be cause for concern. The Lisbon Symbol Database raters were Portuguese. We realized that cultural differences affect the perception and use of icons [18] [41]. For example, the direction that users read influenced their preference patterns for icons [49]. But since both Portuguese and Americans read in the same direction, we concluded that this kind of difference would not affect the ratings.

3.3.2.2 Participants

Twenty-seven Amazon Mechanical Turkers participated in the experiment. Twenty males and seven females completed the online survey. Their ages ranged from 25 to 54 with most participants in the 25-34 age range. Three of the 27 checked the first age range of 18-24, 11 indicated the age range 25-34, 9 checked the third age range of 35-44, and there were 4 participants who indicated the age range from 45-54.

3.3.3 Results

Analysis of findings revealed the statistics listed in Table 10. Complexity was the single significant determinant for search time, $F(1, 56) = 14.346$, $p<0.01$, partial eta-squared = 0.204. Search times were longer for complex icons compared to simple icons.

3.3.4 Discussion

The results from each of the two experiments described in this chapter agree on the fact that visual complexity has a significant effect on the search time of an individual icon. Without agreement between experiments, the joint effect of icon appeal and

Table 10: Between-Subjects ANOVA on Icon Characteristics. A by-item analysis.

Source	df	F	Sig.	Partial Eta Squared
Appeal	1	1.035	0.313	0.018
Complexity	1	14.346	0.000	0.204
Concreteness	1	0.007	0.933	0.000
Appeal * Complexity	1	0.001	0.973	0.000
Appeal * Concreteness	1	3.025	0.087	0.051
Complexity * Concreteness	1	0.022	0.882	0.000
Appeal * Complexity * Concreteness	1	1.226	0.273	0.021
Error	56			

Table 11: Hypothesis table with true/false indicators according to results from Experiment 2 using Mechanical Turkers to test search time for icons.

	Hypothesis
T	Complex icons will be found more slowly than simple icons.
T	Neither concreteness nor appeal will contribute significantly to search time.
F	Concreteness and appeal will have a significant interaction.
F	Appealing abstract icons will be found faster than unappealing abstract icons.
F	Complexity and appeal will have a significant interaction.
F	Appealing complex icons will be found faster than unappealing complex icons.

visual complexity was only apparent in the first experiment.

With the aim of resolving differences in findings between Experiments 1 and 2, we can examine Figures 6 and 13 which illustrate how different the nature of the icons in the search sets for Experiments 1 and 2 were. This is despite the fact that the visual complexity, concreteness and appeal of each of the icon sets were carefully controlled. There are a number of reasons why the findings obtained in Experiment 2 are so different in comparison to those in Experiment 1.

Using memory compression as a rough indication of icon visual complexity [28], it is clear that the mobile application icon stimulus set has many icons that are considerably more complex than the icons in the Lisbon stimulus set. While there is much overlap in degrees of complexity between the two icon sets when it comes to file size value, the icons in the Lisbon Symbol Database have a lower average memory compression value than the mobile application set.

The nature of the icon sets themselves (mobile application icons versus public information icons) may have made comparison difficult. Public information icons used here were black and white images whereas the mobile application icons were grayscale. Designers of mobile application icons use color and shading in their designs. Since the mobile application icons were originally in color and then adjusted to grayscale for experimentation, color variations appeared as shading in the final icon stimulus. Layers of shading add to the relative complexity of an icon. Again, the mobile application icon set may have consisted of icons with higher levels of complexity than other icons.

The fact that ratings were obtained for each set individually also contributed to variations in results. The ratings were collected from different populations. Experiment 1 used Mechanical Turk workers to obtain icon ratings whereas Experiment 2 relied on ratings provided by Portuguese university students [63].

In general, collecting icon ratings in the same way and at the same time would ensure greater continuity in ratings. Improving our rating collection process will promote the robustness of this research.

3.3.5 Next Steps

Indeed it seems likely that a combination of factors can be used to explain differences in findings between the two experiments. Ratings were obtained separately for each set of icons used in Experiments 1 and 2; however, the Lisbon icon set is fundamentally different to the mobile icon set. This may mean that participants rating the concreteness, complexity and appeal for the Lisbon icon set would rate each icon characteristic relative to the rest of that particular set. Similarly, participants rating the characteristics of the mobile icons, would rate concreteness, complexity and appeal relative to the rest of the mobile set. Thus, what might be rated as relatively appealing for one set would not be seen as appealing for another set, and so on. In this way, even though the concreteness, complexity and appeal of the icons was carefully controlled, the experiments were based on different sets of ratings and so, theoretically may have suffered from the Rating Relatively Problem. That is, the ratings were subjectively quite different for each set since each set differed so fundamentally. Thus what might be seen as visually complex in one set for example might be seen as visually simple in another (c.f. Figures 7 and 13). If this hypothesis is correct, this may well explain the differences in findings between Experiments 1 and 2.

CHAPTER 4: DIVERSIFIED ICON STIMULUS SET

One way of resolving these potential differences between icons sets would be to combine all icons into a much more varied icon rating sample and obtain ratings when each dimension (visual complexity, concreteness, appeal and familiarity) varied more widely. In this way, the precise reasons for the differences in findings between Experiments 1 and 2 can be examined while at the same time providing the basis for further experiments involving those icons.

The 200 total icons from which the Diversified Icon Stimulus Set will be selected consist of:

1. The original set of 64 mobile app icons from Experiment 1

2. The original set of 64 Lisbon Symbol Database icons used in Experiment 2

3. A selection of 72 other icons to add to the variety of the set.

The selection of the other 72 icons will consist of:

1. a varied selection of icons from the Lisbon set; variation in concreteness, complexity and appeal (n=24)

2. a varied selection of mobile icons again where possible varying concreteness, complexity and appeal (n=24)

3. a selection from the McDougall et al. set of icons which will be selected to provide some very abstract and unappealing icons (n=24) [55].

The ratings obtained using a varied icon set will make it possible to examine the Rating Relativity Problem by comparing ratings obtained in Experiments 1 and 2 with new ones. If restricting the icon set being rated means that participants adjust their ratings accordingly, the ratings obtained in Experiments 1 and 2 will differ from those obtained in Experiment 3. If ratings do differ, then the new ratings will provide the basis for appropriate experimental control in Experiment 3.

4.1 Rating Relativity Hypothesis

Appendices C, D and E list the original ratings of the mobile application icons used in the preliminary study along with ratings collected within the mixed group of 200. Table 12 presents the correlation coefficients between these two different sets of ratings for the same 64 mobile application icons used in experimentation. Table 13 presents the correlation coefficients between these two different sets of ratings for the same 64 Lisbon icons.

For all characteristics, whether comparing mobile icons or comparing Lisbon icons, correlations were significant. This makes sense since each of the sets were selected from larger sets to include icons with varying characteristics for experimentation purposes. With the exception of the correlation for familiarity, all correlation coefficients were considerable. Familiarity was not considerable since for experimentation in this dissertation, icons were selected that were largely unfamiliar purposefully to test the effects of learning icon search for unfamiliar icons. This trend, therefore, is due to a purposeful restriction in range. It should also be noted that familiarity is also a characteristic which varies highly between individuals. Since each ratings session employed a separate group of individuals, this variation may also be responsible for the relatively small correlation coefficient of familiarity for both sets of icons.

Table 14 illustrates the differences between these two different sets of ratings for the same 64 mobile application icons used in experimentation. Table 15 illustrates the differences between these two different sets of ratings for the same 64 Lisbon Symbol Database icons.

Complexity was an icon characteristic that "suffered" from rating relativity. When the more complex icons from the mobile application icons were combined with the simpler icons from the Lisbon and McDougall icon sets, the mobile application icon ratings increased. Likewise, when the simpler icons from the Lisbon Symbol Database set were combined with the more complex icons from the mobile icon set, the Lisbon icon ratings decreased. One icon's rating is only as "good" as the set it is rated with. Ratings on icon characteristics are made relative to other icons rated together with the other icons in the stimulus set.

Complexity, concreteness, and familiarity icon ratings all reflected rating relativity. Comparing icon ratings taken using the preliminary stimulus set and ratings obtained using the Diversified Icon Stimulus Set, it is apparent no matter what icon characteristic, that individual icon ratings are made relative to the set in which they are being rated. T tests reveal significant differences for all three of these icon characteristics.

Aesthetic appeal ratings for the Lisbon icons also followed this trend with icons rated in the diversified set rated lower on appeal than when rated with other Lisbon

Table 12: Correlations for mobile application icon characteristics when rated with other mobile icons opposed to when rated within a more diversified set.

Icon Characteristic	N	Correlation	Sig.
Complexity	64	0.875	0.000
Aesthetic Appeal	64	0.674	0.000
Concreteness	64	0.773	0.000
Familiarity	64	0.371	0.003

Table 13: Correlations for Lisbon Symbol Database icon characteristics when rated with other Lisbon icons opposed to when rated within a more diversified set.

Icon Characteristic	N	Correlation	Sig.
Complexity	64	0.865	0.000
Aesthetic Appeal	64	0.620	0.000
Concreteness	64	0.852	0.000
Familiarity	64	0.270	0.031

icons. For mobile application icons, appeal ratings were not significantly different when rated within different groups. This is perhaps because modern, mobile application icons varies sufficiently on appeal.

The Rating Relativity Hypothesis was demonstrated to be true in this chapter. The evidence supported creating a more inclusive set of icons in the rating exercise for the full experiments described in Chapter 5 than the sets that were used in the preliminary experiments described in Chapter 3. The resulting Diversified Icon Stimulus Set therefore was developed for more accurate measurement of icon search with icons varying sufficiently on the characteristics under review.

Table 14: T tests for mobile application icon characteristics when rated with other mobile icons opposed to when rated within a more diversified set.

Icon Characteristic	Mean	Std. Dev.	Cohen's d	t	Sig.
Complexity	0.75	0.49	1.53	12.27	0.00
Aesthetic Appeal	0.08	0.50	0.15	1.21	0.23
Concreteness	0.57	0.70	0.81	6.49	0.00
Familiarity	-0.43	0.77	-0.56	-4.52	0.00

Table 15: T tests for Lisbon Symbol Database icon characteristics when rated with other Lisbon icons opposed to when rated within a more diversified set.

Icon Characteristics	Mean	Std. Dev.	Cohens d	t	Sig.
Complexity	-1.20	0.53	-2.27	-18.16	0.00
Aesthetic Appeal	-0.75	0.57	-1.32	-10.55	0.00
Concreteness	-0.35	0.46	-0.77	-6.12	0.00
Familiarity	-0.54	0.48	-1.13	-9.08	0.00

4.2 Ratings collected from undergraduate students as opposed to Mechanical Turk Workers

In addition to the ratings collected in this chapter in efforts of remedying the Rating Relativity Hypothesis, icon ratings were collected from the University of North Carolina at Charlotte's undergraduate student sample population. As this sample was the same that was used in the full experiments described in the next chapter to test search time over blocks of trials, we collected new ratings post-search-experiment to round out our analysis and to provide any additional insights that might emerge.

The statistics on the rating collected using undergraduate students compared to those collected from Mechanical Turkers is listed in the tables below. The post-hoc analysis at the end of Chapter 5 uses the undergraduate ratings to re-analyze the icon search findings from Experiment 4, which can also be found in Chapter 5.

Undergraduate students rated the complexity of icons selected for experimentation significantly higher on complexity and on appeal. See means in Table 16 and t tests for paired differences in Table 18. Although students rated concreteness and familiarity higher in general, no significant difference between means was found for these latter two icon characteristics. These statistics reveal a pattern of difference in ratings between the two different sample populations. Although the ratings were both made

Table 16: Means and standard deviations for icon ratings made by Mechanical Turkers and by undergraduate students for each icon characteristic for the 64 icons originally selected for the icon search experiments in Chapter 5.

		Mean	N	Std. Dev.
Pair 1	complexityMTurkers	3.33	64	1.27
	complexityStudents	3.62	64	1.14
Pair 2	appealMTurkers	3.22	64	0.55
	appealStudents	3.44	64	0.58
Pair 3	concretnessMTurkers	3.32	64	1.17
	conretenessStudents	3.41	64	1.01
Pair 4	familiariityMTurkers	2.32	64	0.41
	familiarityStudetns	2.43	64	0.71

Table 17: Correlations across icon ratings made by Mechanical Turkers and by undergraduate students for each icon characteristic.

		N	Correlation	Sig.
Pair 1	complexityMTurkers & complexityStudents	64	0.69	0.00
Pair 2	appealMTurkers & appealStudents	64	0.33	0.01
Pair 3	concretnessMTurkers & conretenessStudents	64	0.62	0.00
Pair 4	familiarityMTurkers & familiarityStudetns	64	0.29	0.02

in the same manner, as in they were both conducted by asking the participants for ratings for the same 200 icons, since the populations were generally different in age, the mean ratings differed mildly.

The correlations between icon ratings between the two samples were all significant with complexity and concreteness with the highest levels of correlation (.69, .62) and with appeal and familiarity considerably less correlated (.33, .29). Considering the restriction in range purposefully implemented for familiarity, the smaller correlation coefficient for familiarity made sense. Aesthetic appeal, however, was not purposefully restricted in range but the ratings for appeal for each of the sample populations varied less across the icon set than complexity and concreteness in general (std. deviations of .55 and .58).

Table 18: Paired differences for icon ratings made by Mechanical Turkers versus those made by undergraduate students for each icon characteristic.

Paired Differences (M Turkers v. Students)	Mean	Std. Dev.	d	t	Sig.
complexity	-0.29	0.96	-0.30	-2.43	0.02
appeal	-0.21	0.66	-0.33	-2.61	0.01
concreteness	-0.08	0.96	-0.09	-0.68	0.50
familiarity	-0.11	0.71	-0.15	-1.22	0.23

CHAPTER 5: SEARCH-EFFICACY OF ICONS VARYING ON APPEAL AND VISUAL COMPLEXITY

After running Experiment 1 and 2 using two different icon stimulus sets to test icon search time, choosing a new icon set to use in subsequent testing and analysis became paramount.

The Diversified Icon Stimulus Set presented in Chapter 4 served as the test set in experiments 3 and 4. In the remaining experiments we used the diversified set to test icon search over repeated use. In experiment-speak this means we ran icon search experiments in blocks of search trials. This enabled proper examination of the process involved when learning to search for an icon.

Experiment 3 differs from 4 in that for one experiment the participants used a touchpad for their interactions, whereas in Experiment 4 the users used a mouse which was the device used in previous studies [55] [65]. In efforts to give previous results the chance for exhibition, we chose to round out our experimentation by employing the mouse as the device for interaction.

A post-hoc analysis of Experiment 4 using ratings from undergraduate students rather than Mechanical Turk Workers, ends this chapter covering the search-efficacy of icons varying on appeal and visual complexity.

5.1 Experiment 3: Searching for icons that were rated in consideration of the Rating Relativity Hypothesis

Prior to carrying out the search experiment, participants were asked to rate the complexity, appeal, familiarity, and concreteness of mobile application icons as well as icons from stimulus sets used in similar experiments. The ratings were then used to select appropriately controlled icons for the search task. We created a combined icon set in grey-scale and black-and-white in order to control for the effects of color [22]. In this experiment, the appeal of the icons presented in the search task was varied orthogonally with icon complexity.

Participants were asked to search for icons in displays. They completed blocks of trials to examine the effects of the icon characteristics on learning.

The purpose for this experimentation was two-fold:

1) Examine whether different patterns of findings emerge when aesthetic appeal and visual complexity are manipulated orthogonally using the Diversified Icon Set.

2) Examine whether the effects seen on the first trial change as a result of learning.

5.1.1 Hypotheses

The search task was carried out following the same procedure as that of earlier studies. The three hypotheses being investigated were the following:

1. Complexity effects are significant. Complexity effects do not diminish with learning [56].

2. Concreteness effects diminish after 3-4 learning trials [56]. Concreteness effects will have an interaction with Block.

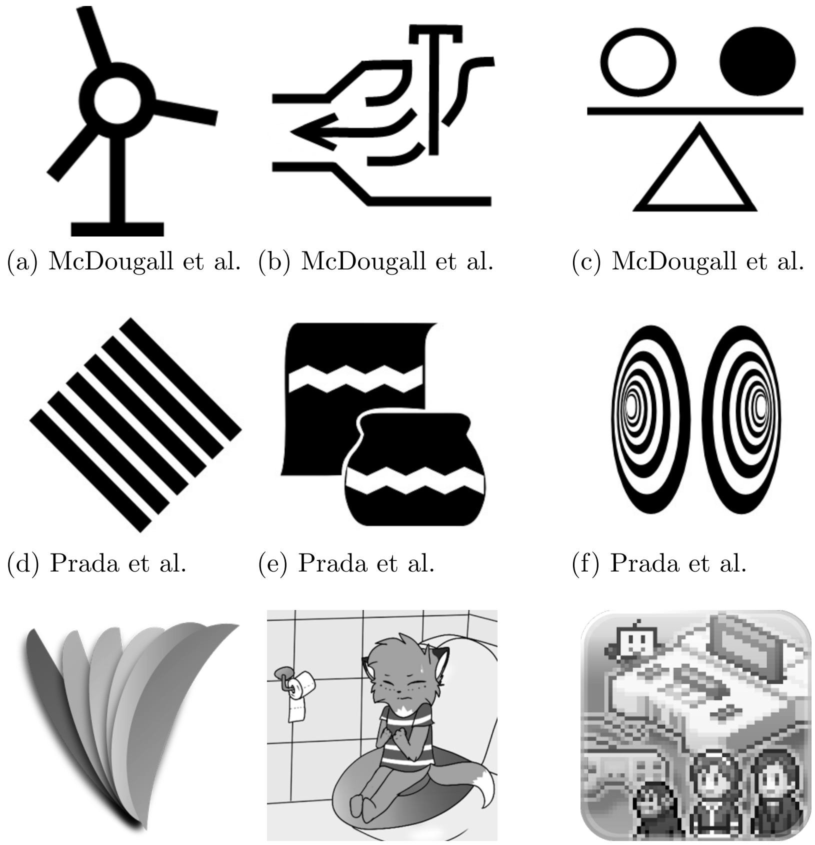
3. Appeal's effects might not be significant by itself but as a joint effect with one of the characteristics mentioned above [65].

5.1.2 Method

5.1.2.1 Materials

The trend towards icon complexity is reflected in the different icon stimulus sets used in experimentation to date. Figure 15 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 [55] [63]. Icons from the first corpus have been used in icon studies over the last several years [55], whereas those from the second have been created more recently for use in similar experimentation [63]. The present research utilized icons from all three icon sets. By including icon sets of different types, the aim was to strengthen the experimental validity and potential generalizability, of our findings.

Researchers concerned with investigating icon search and identification typically choose an icon stimulus set already in wide use to provide results that can be easily compared with others' research [55] [68] [78]. While this is a great way to communicate findings effectively, in this study, we combined icons from an established icon stimulus set with icons selected from real-world mobile applications to provide an up-to-date stimulus set that is both indicative of icons used in everyday life as well as icons traditionally used in similar studies.



(a) McDougall et al. (b) McDougall et al. (c) McDougall et al.

(d) Prada et al. (e) Prada et al. (f) Prada et al.

(g) Mobile App (h) Mobile App (i) Mobile App

Figure 15: Examples of icons from each stimulus set.

The traditional icon stimuli came from the Lisbon Symbol Database and from the set used in McDougall's original experiments [56] [63]. These icons were all black-and-white representations. Our mobile application stimuli consisted of icons from Google's Google Play and Apple's App Store, modified to grey-scale.

We created a combined icon set in grey-scale and black-and-white for the purpose of singling out the effects of form from the preattentive effects of color and form. The effect of color in visual processing was strong and before including that in this line of research, we wished to concentrate on form [22].

Thirty Amazon Mechanical Turk workers were asked to rate a set of 200 icons on

(a) Simple Unappealing Abstract

(b) Simple Unappealing Concrete

(c) Simple Appealing Abstract

(d) Simple Appealing Concrete

(e) Complex Unappealing Abstract

(f) Complex Unappealing Concrete

(g) Complex Appealing Abstract

(h) Complex Appealing Concrete

Figure 16: Examples of icons used. One icon from each group is presented here.

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:

(i) Visual Complexity: Rate the icon's visual complexity, it's level of detail (1= very simple, 7= very complex)

(ii) Aesthetic Appeal: Rate the aesthetic value, beauty, attractiveness of the icon (1= very unappealing, 7= very appealing)

(iii) Familiarity: Rate how familiar you are with the icon, or how often you have seen it before (1= very unfamiliar, 7= very familiar)

(iv) 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 64 of the 200 icons for use in the search ex-

(a) Simple Unappealing

(b) Simple Appealing

(c) Complex Unappealing

(d) Complex Unappealing

Figure 17: Examples of icons used. One icon from each Complexity-Appeal group is presented.

periment. Icons were originally selected based on the 8 groups created by considering the three characteristics of visual complexity, appeal and concreteness with 8 icons in each of the 8 groups (See Figure 16). Once it was understood that it was not possible to control for concreteness in the stimulus set, a subset of 56 icons were selected from the original 64. Orthogonal variation of icon complexity and appeal resulted in four sets or groups of icons with 14 icons in each set: complex-appealing, complex-unappealing, simple-appealing, and simple-unappealing icons. It was possible to vary icon complexity and appeal while holding familiarity constant for each type of icon. However, it was not possible to control for concreteness in the same manner (See Table 20). Icon concreteness was therefore included as a covariate in subsequent analyses.

Table 19 includes mean ratings for each Complexity-Appeal group across all four

Table 19: Means and standard deviations for Complex-Appeal Groups across all 4 icon characteristics.

		N	Mean	Std. Deviation
Complexity	Complex Appealing	14	4.46	.56
	Complex Unappealing	14	4.43	.77
	Simple Appealing	14	2.45	.57
	Simple Unappealing	14	2.08	.39
	Total	56	3.36	1.24
Appeal	Complex Appealing	14	3.75	.31
	Complex Unappealing	14	2.89	.31
	Simple Appealing	14	3.59	.25
	Simple Unappealing	14	2.74	.37
	Total	56	3.24	.53
Familiarity	Complex Appealing	14	2.36	.36
	Complex Unappealing	14	2.39	.33
	Simple Appealing	14	2.28	.59
	Simple Unappealing	14	2.24	.31
	Total	56	2.32	.41
Concreteness	Complex Appealing	14	3.65	1.39
	Complex Unappealing	14	4.42	.83
	Simple Appealing	14	2.76	.69
	Simple Unappealing	14	2.44	.27
	Total	56	3.32	1.17

icon characteristic ratings collected. Figure 17 lists an example icon for each of the four icon groups. See Appendix for a full repository of the 56 icons.

5.1.2.2 Participants

Participants were 21 undergraduates from the undergraduate research pool. The students were a mix of different majors taking courses to fill required electives. Each participant received research credit for completing the experiment. Of the 21 total

Table 20: Icon characteristic correlations for Diversified Icon Stimulus Set.

	Appeal	Complexity	Concreteness
Appeal	1	.195	-.031
Complexity	.195	1	.620**
Concreteness	-.031	.620**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 21: Means for each icon characteristic across the stimulus set with F values from ANOVA and Newman-Keuls analysis of the four icon type groups.

Icon Characteristic	Icon Group Means				F(3, 52)	Newman-Keuls
	CA	CU	SA	SU		
Appeal	3.75	2.89	3.59	2.74	*36.46	CA, SA>CU, SU
Complexity	4.45	4.43	2.45	2.08	*65.13	CA, CU>SA, SU
Concreteness	3.65	4.42	2.76	2.44	*14.18	CU>CA>SA, SU
Familiarity	2.36	2.39	2.28	2.24	0.40	CA, CU, SA, SU

* p<0.01

participants, 10 were male and 11 female. The aver age of participants was 24 years old.

5.1.2.3 Device

The experiment was conducted using an Apple MacBook Pro with a 2.4 GHz Intel Core i5 processor and a 13.3 inch color display. The response time accuracy for this device is within 1 millisecond [59]. Participants searched and selected using the MacBook's touchpad.

5.1.2.4 Procedure

The participants were told they would be presented with an icon for 2 seconds before they would be expected to click a "Next" button to continue to a 3 x 3 matrix of icons. See Figure 18 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 56 trials in each block of trials, which each icon being shown once in each block of trials as the search target. Icons appearing as distractors were controlled

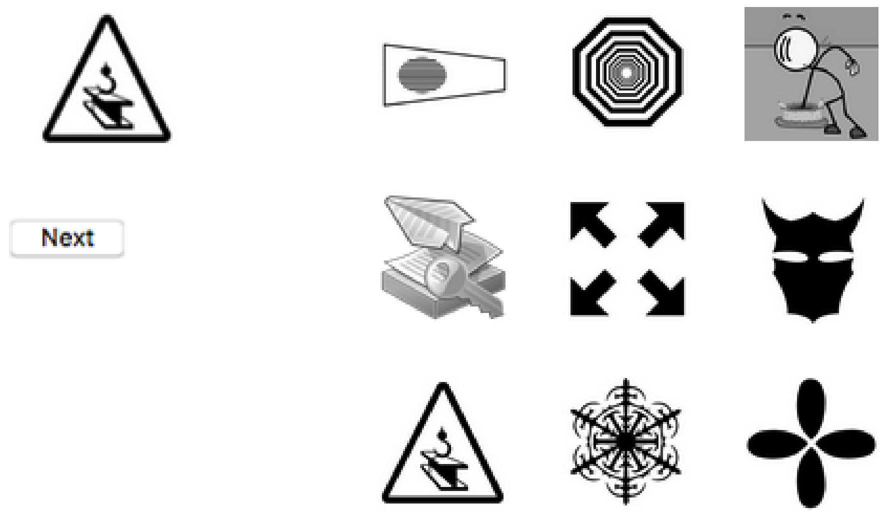


Figure 18: Example of an experimental trial.

so that a mix of 2 of each of the 4 types of icons appeared as background distractors equally often in each block of trials.

Participants were given short breaks between blocks of trials. The effect of learning icons over time was mimicked by presenting participants with blocks of search trials. 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.

5.1.2.5 Design

The experiment followed a 2 X 2 X 5 design with icon complexity (Complex/Simple), icon appeal (Appealing/Unappealing) and blocks of trials (Blocks 1-5) as between-subjects factors. Response time was used to measure ease of visual search.

Each participant was given research credit for completing the experiment. Participants were encouraged to focus during their search trials.

We ran blocks of trials with short breaks between. The effect of learning icons

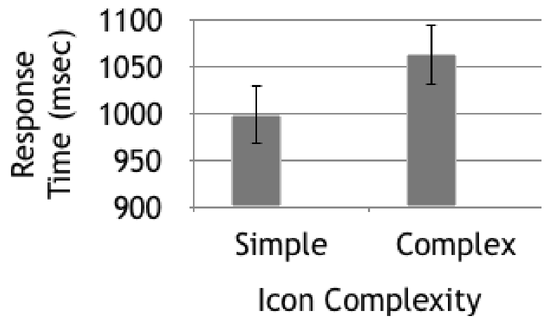


Figure 19: Mean response time in milliseconds for Complexity.

Table 22: Complexity and Appeal Groups' Descriptive Statistics.

Complexity	Appeal	Mean	Std. Dev.
Simple	Appealing	1012	23
	Unappealing	986	25
Complex	Appealing	1065	22
	Unappealing	1059	26

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.

5.1.3 Results

Errors accounted for 1.5% of all trials. There were no differences in error rates between any of the conditions (p values>0.05). Figure 19 presents the mean response times for Complexity groups. Figure 20 illustrates the mean response times for Complexity-Appeal groups set forth in Table 22.

We used an alpha level of 0.05 for all statistical tests and partial eta-squared as a measure of effect size. Bonferroni corrections were used throughout.

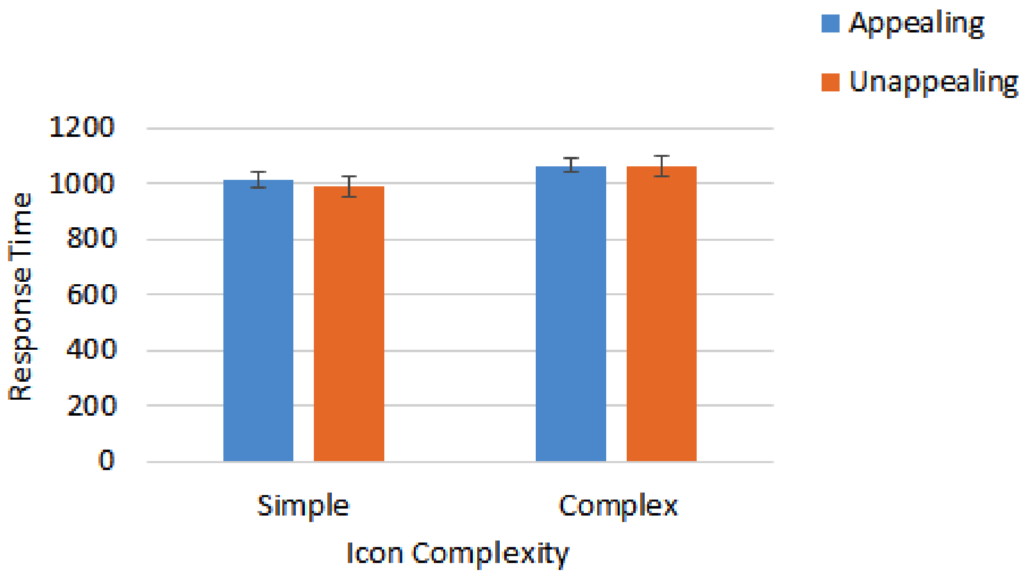


Figure 20: Mean response time in milliseconds for Complexity-Appeal.

Table 23: Between-Subjects ANOVA on Icon Characteristics.

Source	df	F	Sig.	Partial Eta Squared
Intercept	1	571.050	.000	.918
Concreteness	1	.852	.360	.016
Complexity	1	4.648	.036	.084
Appeal	1	.497	.484	.010
Complexity * Appeal	1	.195	.661	.004
Error	51			
a Computed using alpha = .05				

As might be expected from Figure 19 and Table 23, the by-items analysis of variance revealed that icon complexity significantly affected search times, F (1,51)=4.65, p=.036, η^2=.084, with search times for complex icons being much longer than for simple. However, there was no effect of icon appeal on visual search, F (1,51)=.50, p=.484, η^2=.010.

The effect of learning on search times across blocks of trials was also significant, F (4, 204)=2.84, p=.025, η^2=.053. When concreteness was considered as a covariate, there was no main effect of concreteness, F (1, 51)=.852, p=.360, η^2=.016, but there was a significant interaction between concreteness and blocks of trials, F (4, 204)=3.20, p=.014, η^2=.059. Tests of within-subjects contrasts revealed a difference in search time between concrete and abstract icons in initial blocks of trials (Block 1 vs. Block 2, F (1, 51)=7.03, p=.011, η^2=.121; Block 2 vs. Block 3, F (1, 51)=9.17, p=.004, η^2=.152) but not in later blocks of trials (Block 3 vs. 4, F (1,51)=.001, p=.973, η^2=.000; Block 4 vs. 5, F (1,51)=.61, p=.438, η^2=.012).

5.1.4 Discussion

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 [54] [56] [65] [66]. The previous work that has been done was performed with icon sets which 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? Well, yes and no.

5.1.4.1 Visual Complexity

Yes, the role of icon complexity was the same as in previous research using different icon sets: it took longer for participants to find complex icons than simple icons [56] [66]. The importance of complexity in visual search has been well documented [79] [84]. 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.

5.1.4.2 Concreteness

Although it was possible to vary icon appeal and complexity orthogonally while holding icon familiarity constant, it was not possible to control for icon concreteness. The possible effects of icon concreteness on visual search were therefore considered by including this as a covariate in the by-items analyses of visual search times. The role of icon concreteness in visual search was very similar to that reported in previous studies. Concrete icons were found more quickly than abstract icons in the first several blocks. The effects of icon concreteness on visual search appeared to be associated with early learning of the task and the icons and were short-lived; its effects were found only in the first 2-3 blocks when participants learn icons or initially become familiar with them [55]. Thereafter, icon concreteness had no further effect on search times.

5.1.4.3 Aesthetic Appeal

Icon appeal did not appear to affect search times. Importantly, in contrast to earlier findings reported [66], this experiment showed that visual complexity did not act together with icon appeal to enhance visual searching of interfaces. These earlier findings suggests 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 [66]. It is not clear why this disparity between findings has arisen.

5.1.5 Conclusions

Taken together, these findings suggest that both icon complexity and concreteness affect search times in visual displays but that the effects of icon aesthetic appeal on visual search are less apparent. The effect of icon complexity on visual search, in line with Treisman's Feature Integration Theory, is the result of bottom-up, hard-wired, processing and differences in search time between simple and complex icons remain irrespective of the opportunity to learn the icon sets. The effects of icon concreteness, by contrast, appear to be top-down in nature. When participants are able to ascertain the meaning of the icons through learning across trials, the initial advantage in visual search for concrete icons disappears.

5.1.6 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:

(i) icons are simple rather than complex

(ii) icons are concrete, using visual metaphors to convey meaning, at least during initial learning

(iii) once icon sets are learned, and when icon sets are likely to be used habitually on an interface, there may be little need to ensure that they are concrete

(iv) 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 [65].

5.2 Experiment 4: Searching for icons with student participants using a mouse.

This second experiment aimed to procure more accurate time measurement data by using a standard mouse for the icon search experiment. Participants were instructed to use a touchpad in Experiment 3. After reviewing previous works employing the same search task on PCs [56], we were convinced that using a mouse would yield good results and might finally uncover the aesthetic appeal effect found in previous work [65] [66]. A more in-depth analysis can be found in the final chapter.

The purpose remained the same for this experiment as the last and was two-fold:

1) Examine whether different patterns of findings emerge when aesthetic appeal and visual complexity are manipulated orthogonally using the Diversified Icon Set.

2) Examine whether the effects seen on the first trial change as a result of learning.

5.2.1 Hypotheses

The search task was carried out following the same procedure as that of earlier studies. The three hypotheses being investigated are the following:

1. Complexity will have a main effect on search time [55]. Complexity effects do not diminish with learning [56].

2. Concreteness effects diminish after 3-4 learning trials [56]. Concreteness and Block will have a significant interaction.

3. Appeal's effects might not be significant by itself but as a joint effect with one of the characteristics mentioned above [65].

5.2.2 Method

5.2.2.1 Materials

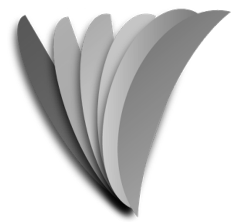
Two hundred icons were rated online using Amazon's Mechanical Turk in the creation of the Diversified Icon Stimulus Set. The ratings were then used to select fifty-six of the 200 icons for use in the search experiment. Icons were selected for each of the 4 icon types using the ratings obtained. Orthogonal variation of icon complexity and appeal resulted in four sets or groups of icons with 14 icons in each set: complex-appealing, complex-unappealing, simple-appealing, and simple-unappealing icons. Refer to figures in the previous section that present representative icons for Experiment 3.

Table 24 includes mean ratings for each Complexity-Appeal group across all four icon characteristic ratings collected. See Appendix for a full repository of the icons

(a) Simple Unappealing

(b) Simple Appealing

(c) Complex Unappealing



(d) Complex Unappealing

Figure 21: Examples of icons used. One icon from each Complexity-Appeal group is presented.

used in Experiments 3 and 4. One icon was traded out for another icon for a better balance of concreteness across experimental groups.

5.2.2.2 Participants

Participants were 23 undergraduates from the undergraduate research pool. The students were 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, 11 were male and 12 female. The average age of participants was 24 years old. All participants had corrected-to-normal vision.

5.2.2.3 Device

The experiment was conducted using an Apple MacBook Pro with a 2.4 GHz Intel Core i5 processor and a 13.3 inch color display. The response time accuracy for this device was within 1 millisecond [59]. Participants used a standard mouse to search

Table 24: Means and standard deviations for each Complexity-Appeal group across all four icon characteristics.

		N	Mean	Std. Deviation
Complexity	Complex Appealing	14	4.59	0.81
	Complex Unappealing	14	4.43	0.77
	Simple Appealing	14	2.45	0.57
	Simple Unappealing	14	2.08	0.39
	Total	56	3.39	1.31
Appeal	Complex Appealing	14	3.76	0.32
	Complex Unappealing	14	2.89	0.31
	Simple Appealing	14	3.59	0.25
	Simple Unappealing	14	2.74	0.37
	Total	56	3.24	0.54
Concreteness	Complex Appealing	14	3.72	1.50
	Complex Unappealing	14	4.42	0.83
	Simple Appealing	14	2.76	0.69
	Simple Unappealing	14	2.44	0.27
	Total	56	3.34	1.20
Familiarity	Complex Appealing	14	2.36	0.37
	Complex Unappealing	14	2.39	0.33
	Simple Appealing	14	2.28	0.59
	Simple Unappealing	14	2.24	0.31
	Total	56	2.32	0.41

Table 25: Icon characteristic correlations for Experiment 4 icon stimulus set.

	Appeal	Complexity	Concreteness
Appeal	1	.245	.010
Complexity	.245	1	.650**
Concreteness	.010	.650**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 26: Means for each icon characteristic across the stimulus set with F values from ANOVA and Newman-Keuls analysis of the four icon type groups.

Icon Characteristic	Icon Group Means				F(3, 52)	Newman-Keuls
	CA	CU	SA	SU		
Appeal	3.76	2.89	3.59	2.74	*55.38	CA, SA>CU, SU
Complexity	4.59	4.43	2.45	2.08	*35.85	CA, CU>SA, SU
Concreteness	3.72	4.42	2.76	2.44	*13.23	CA, CU>SA, SU
Familiarity	2.36	2.39	2.28	2.24	0.41	CA, CU, SA, SU

* $p<0.01$

for and click on icons. The error rate for using the mouse was +/- 30 seconds, which is comparable to the error rates quoted in previous studies where a mouse also served as the input device [56] [65] [66].

5.2.2.4 Procedure

The participants were told they would be presented with an icon for 2 seconds before they would be expected to click a "Next" button to continue to a 3 x 3 matrix of icons. See Figure 22 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 56 trials in each block of trials, which 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 2 of each of the 4 types of icons appeared as background distractors equally often in each block of trials.

Participants were given short breaks between blocks of trials. The effect of learning icons over time was mimicked by presenting participants with blocks of search trials. 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.

5.2.2.5 Design

A 2 X 2 X 5 design with icon complexity (Complex/Simple), icon appeal (Appealing/Unappealing) and blocks of trials (Blocks 1-5) as between-subjects factors. Response time was used to measure ease of visual search.

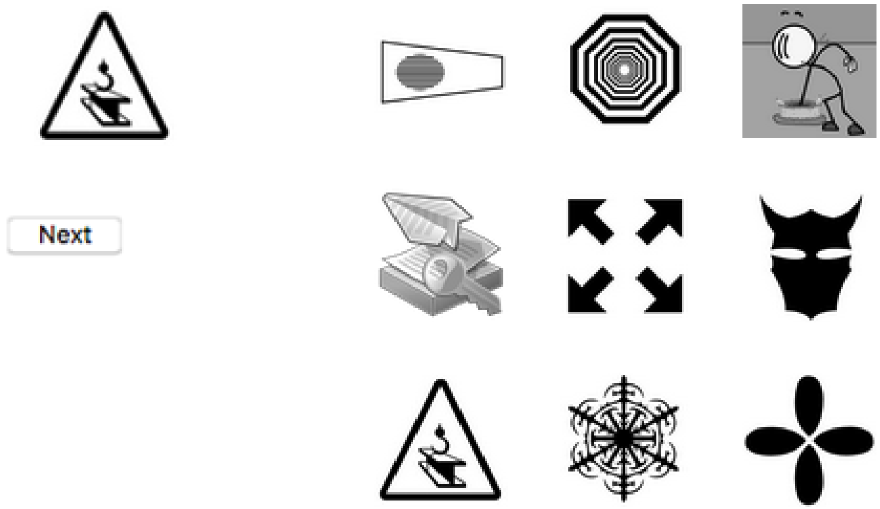


Figure 22: Example of an experimental trial.

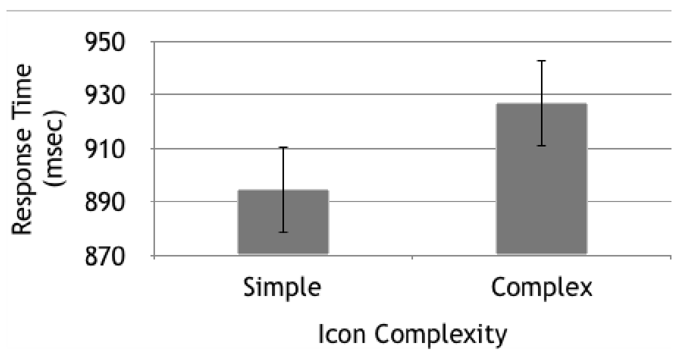


Figure 23: Mean response time in milliseconds for Complexity.

5.2.3 Results

Errors accounted for less than 1.5% of all trials. There were no differences in error rates between any of the conditions (p values>0.05). We used an alpha level of 0.05 for all statistical tests and partial eta-squared as a measure of effect size. Bonferroni corrections were used throughout.

The by-items analysis of variance (see Table 28) revealed that icon complexity significantly affected search times, F (1,52)=6.041, p=.017, η^2=.104, with search

Table 27: Complexity and Appeal Groups' Descriptive Statistics (msec).

Complexity	Appeal	Mean	Std Error
Simple	Appealing	887	13
	Unappealing	901	13
Complex	Appealing	924	13
	Unappealing	929	13

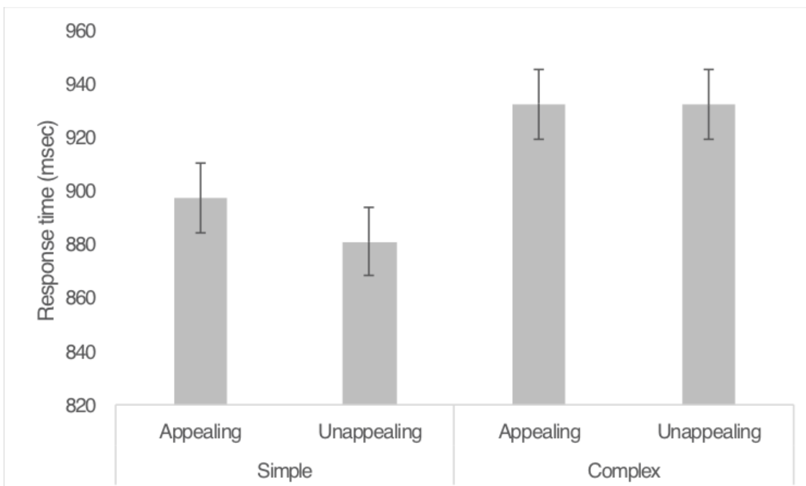


Figure 24: Mean response time in milliseconds for Complexity-Appeal groups.

Table 28: Between-Subjects ANOVA on Icon Characteristics.

Source	df	F	Sig.	Partial Eta Squared
Intercept	1	19334.675	0	0.997
Complexity	1	6.041	0.017	0.104
Appeal	1	0.546	0.463	0.01
Complexity * Appeal	1	0.105	0.748	0.002
Error	52			
a Computed using alpha = .05				

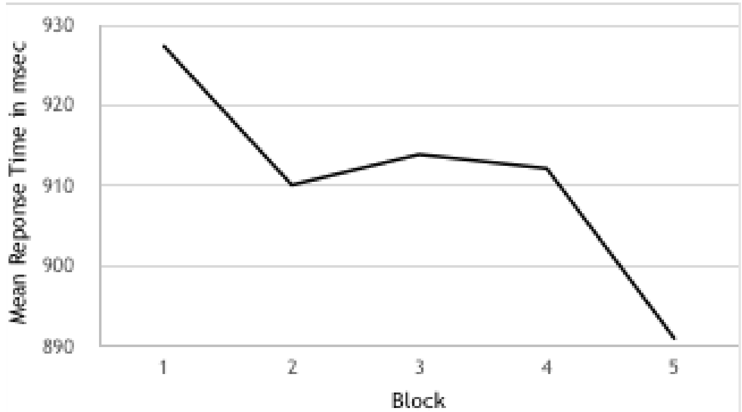


Figure 25: Mean response time in milliseconds across Blocks.

times for complex icons being greater than for simple. Figure 23 illustrates this difference.

However, there was no effect of icon appeal on visual search, F (1,52)=.546, p=.463, η^2=.01. Figure 24 charts the mean response times for Complexity-Appeal groups set forth in Table 27.

The effect of learning on search times across blocks of trials was also significant, F (4, 204)=2.769, p=.028, η^2=.052. Figure 25 illustrates this effect.

Figure 26 reveals the lack of interaction between Complexity and Block. Oddly enough however, tests of within-subjects contrasts revealed a significant joint effect of Block, Complexity, and Appeal between blocks 4 and 5 (F(1,51)=7.108, p=.010, η^2=.122).

5.2.4 Discussion

A key aim of the present experiment was to examine whether or not visual complexity and appeal had an effect on search for icons using a mouse. Previous work employed icon sets which were not representative of icons currently used in mobile

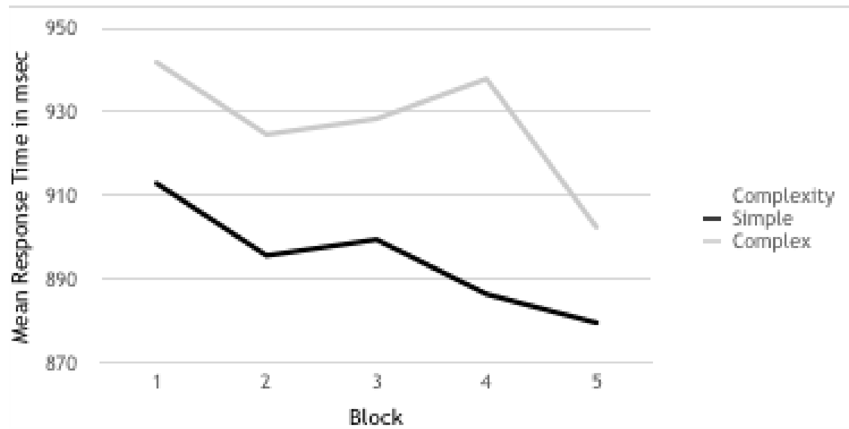


Figure 26: Mean response time in milliseconds for Complexity groups across Blocks.

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 in a search task the same as for previous icon sets? Well, yes and no.

5.2.4.1 Visual Complexity

Yes, the role of icon complexity was the same as in previous research using different icon sets: it took longer for participants to find complex icons than simple icons [56] [66]. The importance of complexity in visual search has been well documented [79] [84]. It is because of the preprocessing done in the preattentive stage of visual processing 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. This was consistent with current findings [56].

5.2.4.2 Aesthetic Appeal

Icon appeal did not appear to affect search times. Importantly, in contrast to earlier findings reported [66], this experiment showed that visual complexity did not act together with icon appeal to enhance visual searching of interfaces. These earlier findings suggests 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 [66]. It is not clear why this disparity between findings has arisen.

5.2.5 Conclusions

5.2.6 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:

(i) icons are simple rather than complex

(ii) 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 [65].

5.3 Post-hoc Analysis of Experiment 4 using ratings collected from an undergraduate student population instead of using ratings from the Mechanical Turk population.

After carrying out search experiment 4, undergraduate student participants were asked to rate the icons on complexity, appeal, familiarity, and concreteness. These new ratings were then used to re-analyze the search data collected in Experiment 4.

The purpose for this post-hoc analysis was two-fold:

1) Examine whether different patterns of findings emerge when aesthetic appeal and visual complexity are manipulated orthogonally using the Diversified Icon Set, but this time with ratings collected from undergraduate students–the same sample population used for the search experiment.

2) Examine whether the effects seen on the first trial change as a result of learning.

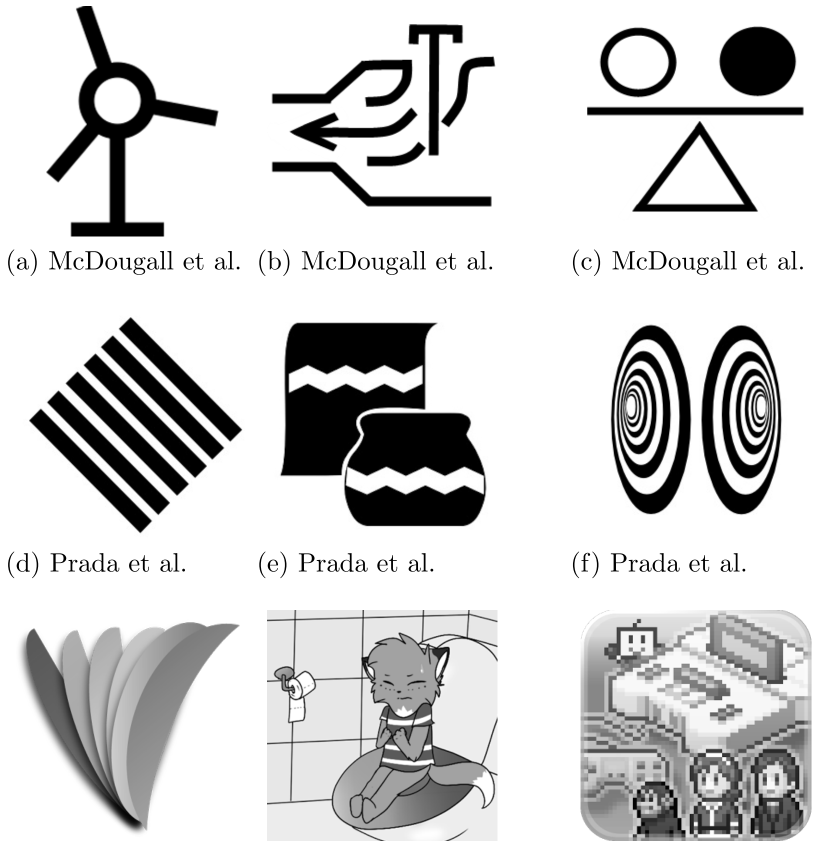
5.3.1 Hypotheses

The hypotheses for the post-hoc analysis remain the same as for Experiment 4. See Experiment 4.

5.3.2 Method

5.3.2.1 Materials

Thirty 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. The raters varied in age but were primarily age 18-24. The raters were also from a variety of majors and all had correct or corrected-to-normal vision. Chapter



(a) McDougall et al. (b) McDougall et al. (c) McDougall et al.

(d) Prada et al. (e) Prada et al. (f) Prada et al.

(g) Mobile App (h) Mobile App (i) Mobile App

Figure 27: Examples of icons from each stimulus set.

4 provides the statistics on how the undergraduate student raters' ratings differed from those provided by Mechanical Turkers. Instructions for rating icons on the four characteristics of interest were the same as for Experiments 3 and 4.

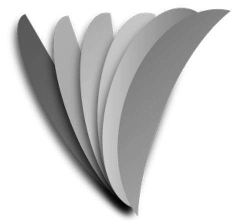
The ratings were then used to select twenty-four of the 56 icons used in the search experiments for re-analysis. Icons were selected for each of the four icon types using the ratings obtained. Figure 28 above includes an example icon from each Complexity-Appeal group. Table 29 includes mean ratings for each Complexity-Appeal group across all four icon characteristic ratings collected.

It was possible to vary icon complexity and appeal while holding familiarity and

(a) Simple Unappealing

(b) Simple Appealing

(c) Complex Unappealing



(d) Complex Unappealing

Figure 28: Examples of icons used. One icon from each Complexity-Appeal group is presented.

concreteness relatively constant (see Table 30). Table 31 provides ANOVA across for all four of the icon characteristics.

5.3.3 Results

Errors accounted for 1.5% of all trials. There were no differences in error rates between any of the conditions (p values>0.05). We used an alpha level of 0.05 for all statistical tests and partial eta-squared as a measure of effect size. Bonferroni corrections were used throughout.

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 (Table 32) revealed that icon complexity significantly affected search times, F (1,20)=4.55, p=.045, η^2=.185, with search times for complex icons being longer than for simple (see Figure 29). However, there was no

Table 29: Means and standard deviations for each Complexity-Appeal group across all four icon characteristics.

Rating Characteristic	Icon Group	N	M	SD
Appeal	Complex Appealing	6	3.94	0.23
	Complex Unappealing	6	3.24	0.18
	Simple Appealing	6	3.72	0.23
	Simple Unappealing	6	3.06	0.21
Complexity	Complex Appealing	6	4.39	0.40
	Complex Unappealing	6	4.07	0.34
	Simple Appealing	6	3.16	0.56
	Simple Unappealing	6	2.97	0.31
Concreteness	Complex Appealing	6	3.58	0.95
	Complex Unappealing	6	3.49	0.73
	Simple Appealing	6	2.89	0.54
	Simple Unappealing	6	2.76	0.24
Familiarity	Complex Appealing	6	2.43	0.51
	Complex Unappealing	6	2.41	0.48
	Simple Appealing	6	2.35	0.59
	Simple Unappealing	6	1.97	0.38

Table 30: Icon characteristic correlations for Experiment 5 Icon Stimulus Set.

	Complexity	Appeal	Concreteness
Complexity	1	.441*	.601**
Appeal	.441*	1	0.186
Concreteness	.601**	0.186	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 31: Means for each icon characteristic across the stimulus set with F values from ANOVA and Newman-Keuls analysis of the four icon type groups.

Characteristic	Icon Group Means				F(3, 23)	Newman-Keuls
	CA	CU	SA	SU		
Appeal	3.94	3.24	3.72	3.06	*21.8	CA, SA>CU, SU
Complexity	4.39	4.07	3.16	2.97	*16.4	CA, CU>SA, SU
Concreteness	3.58	3.49	2.89	2.76	2.31	CA, CU, SA, SU
Familiarity	2.43	2.41	2.35	1.97	1.13	CA, CU, SA, SU

* $p < 0.01$

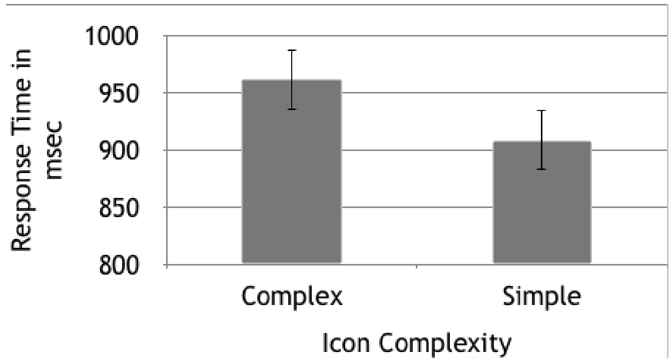


Figure 29: Mean response time in milliseconds for Complexity.

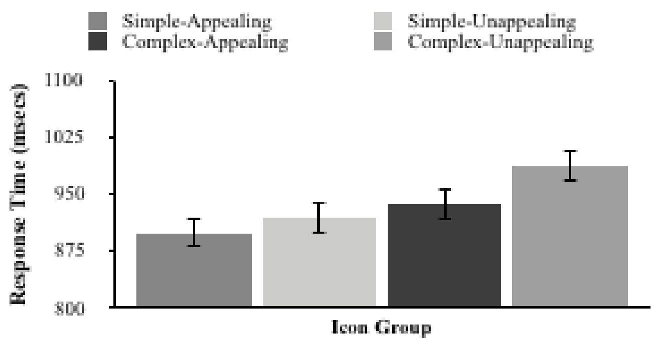


Figure 30: Mean response time in milliseconds for Complexity-Appeal groups.

Table 32: Between-Subjects ANOVA on Icon Characteristics.

Source	df	F	Sig.	Partial Eta Squared
Intercept	1	5710.755	0	0.997
Complexity	1	4.551	0.045	0.185
Appeal	1	1.975	0.175	0.09
Complexity * Appeal	1	0.421	0.524	0.021
Error	20			

a Computed using alpha = .05

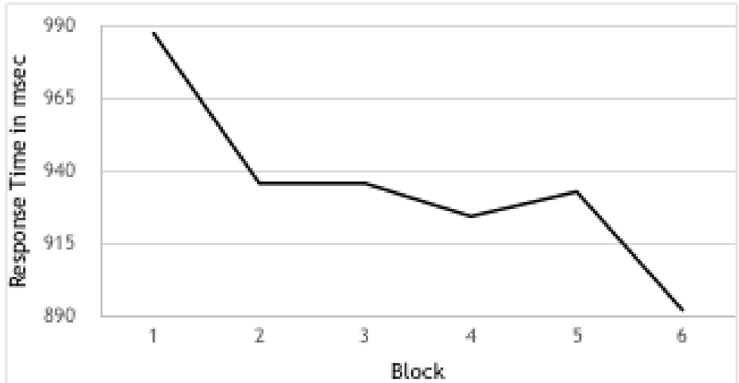


Figure 31: Mean response time in milliseconds across Blocks.

main effect of icon appeal on visual search, F (1,20)=1.98, p=.175, η^2=.090. Neither was there a joint interaction between complexity and appeal on icon search time, F(1,20)=.421, p=.524, η^2=.021. Figure 30 illustrates the lack of interaction between complexity and appeal.

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, η^2=.204. Figure 31 illustrates this learning effect. Tests of within-subjects contrasts revealed a difference in search time between Blocks 1 and 2 (F (1, 20)=4.75, p=.041, η^2=.100) and between Blocks 5 and 6 (F (1, 20)=5.15, p=.034, η^2=.205). There were no other significant effects. Figure 32 reveals the lack of effect between Block and Complexity.

Finally, Figure 33 illustrates the mean response times for Complexity-Appeal groups across six blocks of learning trials.

5.3.4 Discussion

Previous work found that simple icons were found faster than complex ones [56]. In addition, icon appeal and visual complexity have been known to exhibit a joint effect on search performance [65] [66]. Those findings suggested that when the

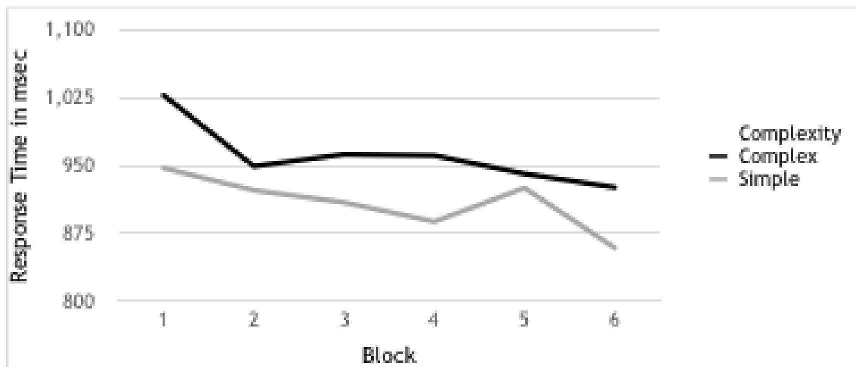


Figure 32: Mean response time in milliseconds for Complexity groups across Blocks.

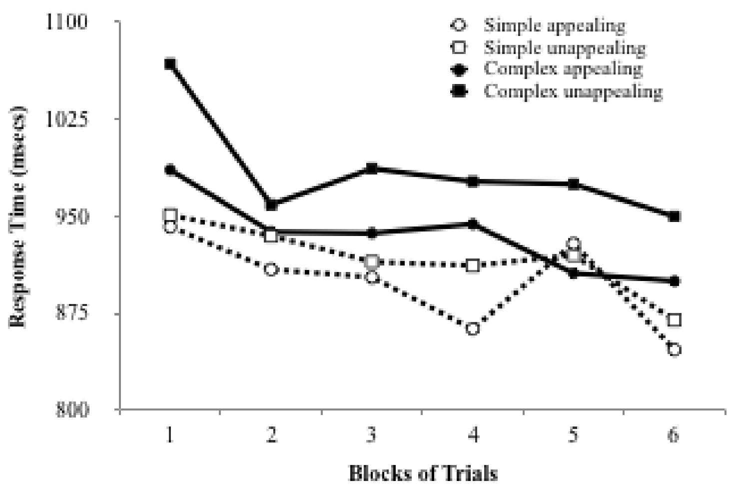


Figure 33: Response times for each type of icon presented in the search task across blocks of trials.

icon was complex, appeal provided a significant time advantage [66]. 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. Using the new icon ratings taken from undergraduate students, the same population that participated in the search experiment, we were able to re-analyze the data to offer a different perspective on icon characteristics.

5.3.4.1 Visual Complexity

It took longer for participants to find complex icons than simple icons [56] [66]. Visual complexity had a consistent affect on icon search time as it did not interact with Block in keeping with previous findings [55].

5.3.4.2 Aesthetic Appeal

Icon appeal did not appear to affect search times. Importantly, in contrast to earlier findings reported [66], 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 [66]. 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 [9]. 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 [47], while previous, relevant work suffered from the confounding variable of familiarity when testing for complexity-appeal search time differences [65]. 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.

CHAPTER 6: DEVELOPMENT OF A MODEL OF ICON SEARCH BASED ON ICON CHARACTERISTICS

A linear model can provide a different level of representation than experimental results when analyzing data from search and icon characteristics. By taking the icon characteristic values and using them in a linear model to predict search time, we can provide another look into how design characteristics may influence an icon's findability.

Experiment 4 was chosen for creating a linear regression model with the icon characteristics used to predict search time. This experiment improved on Experiments 1, 2 and 3 by using a mouse for the search task for more accurate response time measurement.

Given the limited number of icons used in the experiment it was difficult to get a good reading on a possible linear model. The best representations of a model for icon search according to the data used in these experiments was taken from Blocks 2 and 4 of Experiment 4. Table 33 illustrates the importance of these blocks in determining a model as complexity was significantly correlated with search time in these two blocks.

An initial review of the model including all four icon characteristics Table 34 led to the decision to discard all other icon characteristics except for complexity in creating a linear model of icon search. The following tables outline those models–one from each of the blocks mentioned before (Table 35 and Table 36).

Table 33: Pearson correlations across all icon characteristics and blocks.

Correlations

		complexity	appeal	concreteness	familiarity
complexity	Pearson	1	0.245	.650**	0.071
	Sig.		0.069	0.000	0.602
	N	56	56	56	56
appeal	Pearson	0.245	1	0.010	0.105
	Sig.	0.069		0.943	0.439
	N	56	56	56	56
concreteness	Pearson	.650**	0.010	1	.286*
	Sig.	0.000	0.943		0.033
	N	56	56	56	56
familiarity	Pearson	0.071	0.105	.286*	1
	Sig.	0.602	0.439	0.033	
	N	56	56	56	56
block1	Pearson	0.163	0.086	-0.081	-0.148
	Sig.	0.230	0.527	0.554	0.275
	N	56	56	56	56
block2	Pearson	.265*	0.114	0.042	-0.161
	Sig.	0.049	0.404	0.756	0.236
	N	56	56	56	56
block3	Pearson	0.075	0.033	0.101	-0.258
	Sig.	0.582	0.809	0.461	0.055
	N	56	56	56	56
block4	Pearson	.275*	0.178	0.191	0.061
	Sig.	0.040	0.190	0.159	0.657
	N	56	56	56	56
block5	Pearson	0.150	-0.040	0.129	-0.022
	Sig.	0.270	0.771	0.345	0.872
	N	56	56	56	56

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 34: Model coefficients for icon search.

	Unstand. Coeffs		Stand. Coeff's	t	Sig.
	B	Std. Error	Beta		
(Constant)	914.687	73.092		12.514	0
complexity	19.236	9.83	0.364	1.957	0.056
appeal	5.348	18.029	0.042	0.297	0.768
concreteness	-8.762	10.807	-0.153	-0.811	0.421
familiarity	-24.965	23.851	-0.148	-1.047	0.3

a Dependent Variable: block2

Table 35: Model coefficients for icon search. Complexity in Block 2.

	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	862.729	25.146		34.309	0.000
complexity	13.981	6.929	0.265	2.018	0.049

a. Dependent Variable: block2

Table 36: Model coefficients for icon search. Complexity in Block 4.

	Unstandardized		Standardized	t	Sig.
	B	Std. Error	Beta		
(Constant)	860.451	26.291		32.728	0.000
complexity	15.256	7.245	0.275	2.106	0.040

a. Dependent Variable: block4

Interestingly there is another trend found in Block 3 of Experiment 4 where familiarity stands out as a significant predictor of search time ($p < .05$). Given that familiarity was held relatively constant across icon groups, the appearance of significance here does not mean much. But it is here nonetheless. Table 37 details that sort of model.

Although this effect was only found in this one block and familiarity is constant across Student Newman-Keuls groups, familiarity is known to be one of the primary predictors of icon usability, be it search usability or otherwise [65].

Table 37: Model coefficients for icon search. Familiarity.

	Unstand. Coeff's		Stand. Coeff's	t	Sig.
	B	Std. Error	Beta		
(Constant)	971.468	68.56		14.17	0
complexity	-4.181	9.22	-0.085	-0.453	0.652
appeal	10.334	16.911	0.086	0.611	0.544
concreteness	13.383	10.137	0.25	1.32	0.193
familiarity	-52.418	22.372	-0.332	-2.343	0.023

a Dependent Variable: block3

CHAPTER 7: CONCLUSIONS

Revisiting the list of contributions set forth in the introductory chapter enables a thorough discussion of what this dissertation, after completion of the experiments, has to offer. To remind the reader, the contributions listed in the introduction are as follows:

1. Replication and extension of existing psychological experiments with up-to-date icon stimulus sets to provide an ecological perspective [2] [61] .
2. A better understanding of the initial use and learning of icons by observing icon search over repeated use (i.e. blocks of trials).
3. The development of a model of icon search according to their potential primary icon characteristics and their interactions.
4. The creation of a diversified icon stimulus set, consisting of icons from existing, well-known icon stimulus sets as well as modern, mobile application icons. The set is here used in experimentation and serves as potential stimuli for other icon researchers.
5. Informing interface design guidelines to improve usability and user experience.

These contributions provide a road-map for the first portion of this concluding chapter. A Future Work section and then a Final Conclusions section wrap up this dissertation.

Table 38: Main effects identified in 2008 study [66].

Effect	F	P value	Effect size
Complexity	F(1, 14) = 95.05	p <.001	partial eta-squared = .872
Complexity * Appeal	F(1, 14) = 8.05	p <.01	partial eta-squared = .365
Block	F(2, 42) = 8.02	p <.001	partial eta-squared = .364

7.1 Replication and extension of previous findings

Previous research performed using the same icon search paradigm used here found that complexity significantly affected search performance [56] [65] [66] . The first of its kind, McDougall's original study, which compared the effects of icon complexity and concreteness on search time in icon search, found a strong main effect of complexity on search performance, $F(1, 19) = 3.57$, $p < .001$. Concreteness had no main effect. Search time decreased over blocks of trials, $F(10, 190) = 9.09$, $p < .001$, providing evidence that participants gained performance benefits with increasing experience searching for icons. There was no interaction between Complexity and Block over 11 Blocks with complex icons always taking longer to find than simple ones.

Reppa used McDougall's icon set of 239 to select 40 icons varying on complexity and appeal while concreteness and familiarity were held constant across groups. She used this set to test search performance in two different instances. The first study consisted of 5 blocks of trials for the search experiment, whereas the second study analyzed performance over 9 blocks of trials [66] [65]. The results between the two were comparable. Both studies revealed a main effect for complexity and for block, and a joint interaction between complexity and appeal where appealing complex icons were found faster than unappealing complex icons.

The experiments conducted in the interest of this dissertation did not reveal the

Table 39: Main effects identified in 2015 study [65].

Effect	F test	P value	Effect size
Complexity	F(1, 18) = 94.75	p <.001	epsilon squared = .83
Complexity * Appeal	F(1, 18) = 8.50	p <.01	epsilon squared = .28
Block	F(8, 144) = 6.14	p <.001	epsilon squared = .25

Table 40: Main effects identified in Experiment 1.

Effect	F test	P value	Effect size
Complexity	F(1, 56) = 23.783	p = .000	partial eta-squared = .298
Complexity * Appeal	F(1, 56) = 4.747	p = .034	partial eta-squared = .078

same findings all together. While both complexity and block main effects were found in both previous and present studies, a joint interaction between appealing complex and unappealing complex icons was not. Even when icon characteristics were balanced according to Newman-Keuls for complexity and appeal while holding familiarity and concreteness relatively constant, the experiments conducted for this dissertation did not find such a joint interaction.

This dissertation, therefore, validates previous findings concerning the effect of visual complexity on the speed at which an icon is found. Similarly, previous findings on the main effect of learning over blocks was validated here. Furthermore, the absence of an interaction between icon complexity and block was consistent with previous findings which claimed that icon complexity's effect is consistent across blocks [56] [65] [66].

Aesthetic appeal was not by itself did not have a significant effect on search time. Only in the fist experiment did aesthetic appeal and complexity share a joint in-

Table 41: Main effect identified in Experiment 2.

Effect	F test	P value	Effect size
Complexity	F(1, 56) = 14.346	p = .000	partial eta-squared = .204

Table 42: Main effects identified in Experiment 3.

Effect	F test	P value	Effect size
Complexity	$F(1, 20) = 4.551$	$p = .045$	partial eta-squared = .185
Block	$F(4, 100) = 5.13$	$p = .000$	partial eta-squared = .204

teraction on search time. Reasons for the difference in findings on appeal include speculation on how the icon sets themselves differ on appeal, on the proper balancing of characteristics across groups, and on different search performance testing apparatuses.

So to review, the diversified icon stimulus set was created to remedy the first two of these concerns. After working with only mobile application icons in the first preliminary study and after seeing the performance differences between the first two preliminary studies (the second one using only Lisbon Symbol Database icons) [47] [63], it was deemed prudent to create a combined set for further icon search experimentation. The effort to combine icons from three different stimulus sets into a larger set with enough variation among icon characteristics was painstaking.

The effort was successful, however, and a set of 56 icons were selected from icons rated on the four, key icon characteristics. Complexity and appeal were balanced across complexity-appeal groups and it was possible to hold familiarity constant across groups. This first grouping of 56 icons used in Experiments 1 and 2, unfortunately, varied on concreteness across groups but not in a uniform manner.

The final post-hoc analysis outlined in Chapter 5 goes one step further. A subset of the stimulus set used in the first two primary experiments was selected for analysis with new ratings collected from UNCC undergraduates. This set of twenty-four icons with 6 in each of the four complexity-appeal groups was balanced using Student Newman-Keuls to control for both familiarity and concreteness (as in [65] and [66]). Even with these constraints in place, the search performance results did not validate the joint interaction between visual complexity and visual appeal found before [65] [66].

Finally, the apparatus used in the first main study was a touchpad. Touchpad's do not offer the same accuracy in recording response time [74] and McDougall and Reppa both used a mouse device in previous work. For the second and third experiment a mouse was employed for accurate response time recording and for better comparison with previous work. Interestingly, the end results did not differ substantially between the first two experiments. This speaks for the possibility that search experiments such as these can rely on touchpad as well as mouse interaction for proper response time recording. It also takes care of any concerns or speculation that the reason for the differences in findings between this work and previous research is because of the device used for the search task [66] [65].

We can also compare our findings on concreteness and aesthetic appeal to a second study completed by Reppa and McDougall [65]. They found that appeal had a main effect on icon search when the icon stimulus set was balanced on concreteness and appeal with complexity held relatively constant according to Newman-Keuls analysis. Familiarity was not held constant but rather followed the same Newman-Keuls pattern as concreteness, so the results may have been confounded by familiarity, which is known to exert a significant effect on search [55]. Nonetheless, they found an interaction effect between appeal and concreteness, where abstract appealing icons were found faster than abstract unappealing ones. We did not observe the same kind of effect in the experiments conducted. No such advantage was found for concrete icons.

7.2 Understanding the initial use and learning of icons in search

In the preliminary experiments, complexity, appeal, and concreteness were all varied across 8 stimulus set groups. The 8 groups resulted from the combination of complex/simple, appealing/unappealing, and concrete/abstract icons. We aimed to test the main effects and interaction effects of these three icon characteristics in search. Although we continued to put together a combined, diversified icon stimulus set that was balanced across these three characteristics, in the end it was not possible.

Therefore, in the first experiment using undergraduate students concreteness was treated as a co-variate. This analysis revealed there were Block/Concreteness joint interactions for the first three blocks but none thereafter. These findings were in concert with existing findings on how concreteness affects learning in an icon search task. Reppa and McDougall found that when icons were abstract, it took the search performance of abstract icons several blocks to catch up to the search performance of concrete ones [65].

This trend is the opposite of what we and others have found for complexity. Complexity's effect is consistent across blocks and does not diminish after the first several blocks [56].

The difference between how complexity and concreteness each affect icon search is important. In attempting to pinpoint the kind of effects appeal might have on search, complexity and concreteness effect patterns can provide a guide for comparison. For instance if appeal had an interaction with Block in an experiment, then appeal's effect would be seen as similar to concreteness' effect. Likewise, if appeal was found not to have an interaction with Block, then its effect would be viewed as comparable to that of complexity.

7.2.1 Visual Complexity

The attentive processes outlined by Treisman and by Wolfe acknowledge a sort of preattentive stage in which low-level features are perceived by the visual system [79] [83] [84]. Whether features can be considered to belong to this level of processing or to later levels of processing associated with a guided search is typically determined by deciphering whether the feature is processed in parallel to other features or is processed in a sequence of some kind. This dissertation supports the notion of a preattentive feature of visual complexity, especially in icon search where stimuli are spaced evenly and relative size is held constant. Visual complexity of an icon is processed in parallel in our visual system.

Visual preattentive features are important to capitalize on when designing visualizations [35]. Designers capitalize on paying attention to design elements that correspond to preattentive channels such as form, numerosity, and spatial positioning (shading). In addition to these, this thesis suggests that icon designers should aim to capitalize on managing visual complexity.

7.2.2 Aesthetic Appeal

There are multiple theories on how emotive stimuli can bias perceptual systems. Some state that this effect is limited to faces. Happy faces in a crowd are noticed before other faces [9]. Some theories claim that the intensity of an emotion affects search such as when a stimulus is especially disturbing (i.e., arousal) [29] [44]. Emotion is a multidimensional construct. The assumption is that if aesthetic appeal has anything to do with emotion, then an icon's aesthetic appeal will influence its usability.

But if we are looking solely at how fast a user takes to find an icon, to localize the icon in an interface, does aesthetic appeal of an icon really help? My expectation was that it would not, once balanced sufficiently across characteristics. Although it is already known that aesthetic appeal helps with users' attitudes toward an interface, does appeal really afford the icon an advantage in learning over blocks of icon localization trials [66]? No. Not according to the results herein.

Although arousal or emotion is considered a preattentive feature in experiencing visual stimuli, searching for non-colored (black and white or grayscale) icons among a heterogeneous mixture was not dependent on the icon's rating of aesthetic appeal. When the search task was simply to find a target icon among other icons (all of which were rated low in familiarity, and all lacking a label), appeal had no significant main effect and had no significant interactions with other icon characteristics in affecting search time.

Two different search tasks were employed in the icon characteristic research to date:

1) search -localize

2) search and match -identification

The first was to emulate the generic search of an interface for a specific icon image. The second was to emulate looking for an icon when you have a function in mind but do not have experience with the icons. It is in this second kind of search task that appeal would more likely elicit performance effects since appeal is connected with meaning. The search and match task enables the user to attach meaning to an image.

7.3 A linear model with icon characteristics as predictors of icon search time

Although subjective measures such as ratings of icons on a Likert scale might not translate well to a linear model of icon search time, we can model the interaction using linear regression for some interesting results. Chapter 6 covered the possible linear models that could be responsible for icon search times.

7.4 Diversified Icon Stimulus Set

Refer to chapter 4 for the genesis and evolution of this diversified set of icons used in Experiments 3 and 4. This set is also available for use by other icon researchers. Appendices C, D, and E give the ratings for icons in the Diversified Icon Stimulus Set used in this dissertation. Appendix C lists icons and ratings for the mobile application icon set used in Experiment 1 whereas Appendix D lists them for the subset of the Lisbon set used in Experiment 2. Appendix E lists all icons and ratings for the mixed set that accompanied the icons from Appendix C and D in the final set of 200, the Diversified Icon Stimulus Set.

7.5 Inform interface guidelines

Icon designers that are concerned with creating icons that are easy to find should focus on reducing icon complexity and should also consider whether an abstract or concrete icon fits their needs best, especially since the main strategy in making an icon simple is to make it abstract. Abstract icons typically use metaphor to communicate meaning so as to simplify their design. Although this design method (using metaphor) is only one strategy in creating the best icon for the job, it is an excellent example of how good design can include consideration for simplicity while still creating an easily understood icon.

This research demonstrates that the duration of visual search for icons is likely to be least when:

(i) icons are simple rather than complex

(ii) icons are concrete, using visual metaphors to convey meaning, at least during initial learning

(iii) once icon sets are learned, and when icon sets are likely to be used habitually on an interface, there may be little need to ensure that they are concrete

(iv) icon appeal does not affect search times for icons on a display however other research has shown that it may affect users attitudes towards the display [65].

Icons designed with these characteristics in mind facilitate the visual processing involved in icon menu search.

Icon creators consider aesthetic appeal at different points in their design process. This research supports disregarding thoughts of how aesthetically pleasing an image is at some point in the design process so as to create an icon that will carry with it a certain ease of processing.

7.6 Future Work: Search and match, identification

While the effects observed of icon complexity and concreteness on interface search were very much in agreement with previous research, the effects of icon appeal on visual search appeared to be much more equivocal. Aesthetic appeal can be a tricky characteristic to pin down quantitatively [28] [65]. Future efforts would continue to isolate and examine significant icon characteristic performance predictors in determining a comprehensive and accurate model of icon use that includes appeal or at least an emotional value associated with an icon. This work would include conducting similar experiments but with an identification component. The Lisbon Symbol Database has ratings on arousal and valence that may be used to analyze an individual icon's search and identify performance. Now that we have a model for the search component, we could add to this model to get a better grasp of what is involved in the frequent task of icon identification (i.e. search and match). Identification relies on the completion of search when it comes to the common icon search and match task (i.e. connecting a function name with the appropriate icon).

In addition, we could open up the discussion to how concreteness's cousin, semantic distance, may interact with appeal to affect search identification time and accuracy. The function's name would need to be included in the search experiment. An icon's label and also its semantic distance would be considered in concert with visual complexity, familiarity and appeal in their effects on the icon search and identification stages during learning.

7.7 Conclusions

Given that users' satisfaction levels increases when their interactions are smooth and they experience an interface as easy to use [66], we set out to discover if the ease of processing made possible by low visual complexity was true for mobile application icons, for a modern, standardized set of black and white icons, and then for a mixed set of icons all rated at once together. When aesthetic appeal, also known to affect search time for icons in previous work [65], was varied along with visual complexity and concreteness across experimental groups, results were not clear. We received different results from using different icon sets.

Although Experiment 1 revealed a joint interaction of appeal with complexity, the specific kind of joint interaction was opposite that of the interaction in previous work [66] [65]. These findings may have been due to the icon stimulus set itself, as the initial experiment in this dissertation used only mobile icons in its testing. Still, the fact that appeal had anything to do with influencing icon search time validated the idea that appeal could improve search.

Once all the experiments were completed it was clear that, like in previous work, the main determinant of search was visual complexity. Aesthetic appeal, once properly balanced across experimental groups, and tested using a touchpad and then a mouse, was not found to be a determinant of search time by itself or in concert with visual complexity, except in Experiment 1 where simple-unappealing icons were found faster than simple-appealing ones.

In Experiment 3 and 4, we ran blocks of trials to test if repeated experience with searching for an icon caused visual complexity's effect, found in the first block, continued through to the last block. We ran 5-6 blocks for each participant and found that there was no joint interaction effect between visual complexity and block and that visual complexity's effects did not wane with repeated experience.

Finally, we come to the contribution of the icon set. The mixed icon stimulus set, termed the Diversified Icon Stimulus Set, used in selecting the icons for testing in the latter two experiments, provides icons with their normed characteristic ratings for future research of Human-computer Interaction Scientists and Experimental Psychologists alike. The ratings of this set have already been verified for use in experimentation, having been employed well here in replicating results found across previous studies [55] [65].

Future efforts in exploring the relationship between icon characteristics such as visual complexity and appeal in affecting, not only search, but also the search and identification that happens when searching for an icon when you have a function in mind but have not identified an icon for it yet. Semantic distance, known to have a profound affect during search and identification [49], would replace concreteness as an icon of interest and could be balanced with semantic distance across experimental groups to answer the question whether icon appeal has an impact on icon recognition in search and identify.

7.8 Final Conclusions

An initial, pilot study employing a naturally occurring set of modern, mobile application icons revealed a joint interaction of complexity and appeal. These findings may have been confounded due to the correlation between icon concreteness and icon complexity in the chosen stimulus set (.61) so further experimentation was warranted. To balance the icon characteristics across the stimulus set all follow up studies used subsets of icons that were selected to be as uncorrelated on the three icon characteristics as possible. Unfortunately, efforts in balancing icon characteristics across groups for all three icon characteristics proved challenging, and so visual complexity and appeal were properly varied across four experimental groups.

All experiments, including the initial pilot studies, revealed that visual complexity was the main determinant of icon search time. The studies conducted in prior work found icon appeal to quicken search only when the icon was already difficult to find, such as when the icon was complex [55]; however, Experiment 1 found icon appeal to quicken search for simple icons. By including mobile application icons in the experiments, this dissertation made ecologically valid design recommendations according to design characteristics of visual complexity and aesthetic appeal in modern application icon design.

Lastly, the diversified stimulus set of icons used in the main experiments is included for future researchers interested in icon search. The normed characteristic ratings on the diversified set used in experimentation here provides a starting point for further investigation of icon search and icon usability in general.

REFERENCES

[1] System icons. *Material Design*.

[2] A. Alexander, M. Barnett-Cowan, E. Bartmess, F. Bosco, M. Brandt, J. Carp, J. Chandler, R. Clay, H. Cleary, M. Cohn, and Others. An Open, Large-Scale, Collaborative Effort to Estimate the Reproducibility of Psychological Science. *Perspectives on psychological science*, 7(6):657–660, 2012.

[3] A. L. Alter and D. M. Oppenheimer. Uniting the tribes of fluency to form a metacognitive nation. *Personality and Social Psychology Review*, 13(3):219–235, 2009.

[4] S. A. Alvarez, E. Winner, A. Hawley-Dolan, and L. Snapper. What gaze fixation and pupil dilation can tell us about perceived differences between abstract art by artists versus by children and animals. *Perception*, 2015.

[5] U. Arend, K. P. Muthig, and J. Wandmacher. Evidence for global feature superiority in menu selection by icons. *Behaviour and Information Technology*, 6(4):411–426, 1987.

[6] N. Babich. Icons as part of a great user experience. *Smashing Magazine*, Oct 2016.

[7] G. Bailly, A. Oulasvirta, D. P. Brumby, and A. Howes. Model of visual search and selection time in linear menus. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 3865–3874. ACM, 2014.

[8] D. Becker, U. Anderson, C. Mortensen, S. Neufeld, and R. Neel. The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, 140(4):637–659, 11 2011.

[9] D. V. Becker, U. S. Anderson, C. R. Mortensen, S. L. Neufeld, and R. Neel. The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single and multiple target visual search tasks. *Journal of Experimental Psychology: General*, 140(4), 2011.

[10] I. Biederman. Recognition-by-components: A theory of human image understanding. *Psychological Review*, 94(2):115147, 1987.

[11] G. Birkin. Aesthetic Complexity : Practice and Perception in Art & Design. *October*, (October):327, 2010.

[12] P. Biswas, T. M. Sezgin, and P. Robinson. Perception model for people with visual impairments. In *Visual Information Systems. Web-Based Visual Information Search and Management*, pages 279–290. Springer Berlin Heidelberg, 2008.

[13] E. Blaser, L. Eglington, A. S. Carter, and Z. Kaldy. Pupillometry reveals a mechanism for the Autism Spectrum Disorder (ASD) advantage in visual tasks. *Scientific reports*, 4:4301, 2014.

[14] M. Böcker. A multiple index approach for the evaluation of pictograms and icons. *Comput. Stand. Interfaces*, 18(2):107–115, Mar. 1996.

[15] K. Brennan, D. Kelly, and J. Arguello. The Effect of Cognitive Abilities on Information Search for Tasks of Varying Levels of Complexity. *5th Information Interaction in Context Symposium*, pages 165–174, 2014.

[16] M. Byrne. Using icons to find documents: simplicity is critical. *Human Factors in Computing Systems: Proceedings of INTERCHI'93*, pages 446–453, 1993.

[17] M. D. Byrne and R. W. Pew. A history and primer of human performance modeling. *Reviews of human factors and ergonomics*, 5(1):225–263, 2009.

[18] J. Caldwell. Safety icons and usability: A Peircean reanalysis. *IEEE International Professional Communication Conference*, 2009.

[19] W. CARR. Theories of theory and practice. *Journal of Philosophy of Education*, 20(2):177–186, 1986.

[20] X. Chen, G. Bailly, D. P. Brumby, A. Oulasvirta, and A. Howes. The Emergence of Interactive Behavior: A Model of Rational Menu Search. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 4217–4226. ACM, 2015.

[21] Y. M. Cycowicz, D. Friedman, M. Rothstein, and J. G. Snodgrass. Picture naming by young children: norms for name agreement, familiarity, and visual complexity. *Journal of experimental child psychology*, 65(2):171–237, 1997.

[22] D. Cyr, M. Head, and H. Larios. Colour appeal in website design within and across cultures: A multi-method evaluation. *Int. J. Hum.-Comput. Stud.*, 68(1-2):1–21, Jan. 2010.

[23] D. C. Donderi. Visual Complexity: A Review. *Psychological Bulletin*, 132(1):73–97, 2006.

[24] S. P. Everett and M. D. Byrne. Unintended effects: varying icon spacing changes users' visual search strategy. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '04*, 6(1):695–702, 2004.

[25] M. D. Fleetwood and M. D. Byrne. Modeling the visual search of displays: A revised ACT-R/PM model of icon search based on eye-tracking and experimental data. *Proceedings of the Fifth International Conference on Cognitive Modeling*, pages 87–92, 2003.

[26] A. Forsythe. Visual Complexity: Is That All There Is? In *Engineering psychology and cognitive ergonomics*, pages 158–166. Springer Berlin Heidelberg, 2009.

[27] A. Forsythe, G. Mulhern, and M. Sawey. Confounds in pictorial sets: the role of complexity and familiarity in basic-level picture processing. *Behavior research methods*, 40(1):116–129, 2008.

[28] A. Forsythe, M. Nadal, N. Sheehy, C. J. Cela-Conde, and M. Sawey. Predicting beauty: fractal dimension and visual complexity in art. *British journal of psychology (London, England : 1953)*, 102(1):49–70, 2011.

[29] E. Fox, R. Russo, R. Bowles, and K. Dutton. Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General*, 130(4):681700, 2001.

[30] M. Garca, A. N. Badre, and J. T. Stasko. Development and validation of icons varying in their abstractness. *Interacting with Computers*, 6(2):191–211, 1994.

[31] D. J. Graham, J. D. Friedenberg, D. N. Rockmore, and D. J. Field. Mapping the similarity space of paintings: Image statistics and visual perception. *Visual Cognition*, 18(4):559–573, 2010.

[32] W. D. Gray and D. A. Boehm-Davis. Milliseconds matter: An introduction to microstrategies and to their use in describing and predicting interactive behavior. *Journal of Experimental Psychology: Applied*, 6(4), 2000.

[33] C. M. Hagerhall, T. Purcell, and R. Taylor. Fractal dimension of landscape silhouette outlines as a predictor of landscape preference. *Journal of Environmental Psychology*, 24(2):247255, 2004.

[34] P. Hall and D. Wang. Efficient Visual Search without Top-down or Bottom-up Guidance : A Putative Role for Perceptual Organization. 67(October 2001):239–253, 2015.

[35] C. Healey and J. Enns. Attention and visual memory in visualization and computer graphics. *IEEE Transactions on Visualization and Computer Graphics*, 18(7):1170–1188, July 2012.

[36] J. Heer and M. Bostock. Crowdsourcing graphical perception. *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, 2010.

[37] K.-C. Hou and C.-H. Ho. A Preliminary Study on Aesthetic of Apps Icon Design. *IASDR 2013 5th International Congress of International Association of Societies of Design Research*, pages 1–12, 2013.

[38] P. J. Hsieh, J. T. Colas, and N. Kanwisher. Pop-Out Without Awareness: Unseen Feature Singletons Capture Attention Only When Top-Down Attention Is Available. *Psychological Science*, 2011.

[39] A. Inc. *App Icon - Icons and Images - iOS - Human Interface Guidelines - Apple Developer*.

[40] S. J. Isherwood, S. J. P. McDougall, and M. B. Curry. Icon Identification in Context: The Changing Role of Icon Characteristics With User Experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 49(3):465–476, 2007.

[41] J. H. Kim and K. P. Lee. Cultural difference and mobile phone interface design: Icon recognition according to level of abstraction. In *Proceedings of the 7th international conference on Human computer interaction with mobile devices & services*, pages 307–310. ACM, 2005.

[42] A. J. Lazard and M. S. Mackert. E-Health First Impressions and Visual Evaluations. *Communication Design Quarterly Review*, 3(4):25–34, 2015.

[43] J. Ledoux. The emotional brain: The mysterious underpinnings of emotional life, Mar 1998.

[44] J. E. LeDoux. *The emotional brain.* New York: Simon and Schuster, 1996.

[45] J. P. Lewis and U. Neumann. VisualIDs : Automatic Distinctive Icons for Desktop Interfaces. *ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH 2004*, 1(212):416–423, 2004.

[46] S. Lewis. 6 easy steps to better icon design. *Smashing Magazine*, May 2016.

[47] S. M. and H. M. The effects of icon characteristics on search time. *In: Ahram T., Falco C. (eds) Advances in Usability, User Experience and Assistive Technology. AHFE*, 2018., 2019.

[48] S. McDougall and M. Curry. More than just a picture: Icon interpretation in context. *Proceedings of First International Workshop on Coping with Complexity. University of Bath*, pages 73–80, 2004.

[49] S. McDougall, A. Forsythe, S. Isherwood, A. Petocz, I. Reppa, and C. Stevens. The use of multimodal representation in icon interpretation. In *Engineering Psychology and Cognitive Ergonomics*, pages 62–70. Springer Berlin Heidelberg, 2009.

[50] S. McDougall, A. Forsythe, and L. Stares. Icon use by different language groups: Changes in icon perception in accordance with cue utility. In *Human-Computer Interaction-INTERACT 2005*, pages 1083–1086. Springer Berlin Heidelberg, 2005.

[51] S. McDougall and S. Isherwood. What's in a name? The role of graphics, functions, and their interrelationships in icon identification. *Behavior research methods*, 41(2):325–336, 2009.

[52] S. McDougall and I. Reppa. 2013. *Ease of processing can predict icon appeal. In: HCII 2013*, 21-26, July 2013.

[53] S. McDougall and I. Reppa. Ease of icon processing can predict icon appeal. In *Human-Computer Interaction. Human-Centred Design Approaches, Methods, Tools, and Environments*, pages 575–584. Springer Berlin Heidelberg, 2013.

[54] S. McDougall, V. Tyrer, and S. Folkard. Searching for signs, symbols, and icons: effects of time of day, visual complexity, and grouping. *Journal of experimental psychology. Applied*, 12(2):118–128, 2006.

[55] S. J. McDougall, M. B. Curry, and O. de Bruijn. Measuring symbol and icon characteristics: norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols. *Behavior research methods, instruments, & computers : a journal of the Psychonomic Society, Inc*, 31(3):487–519, 1999.

[56] S. J. McDougall, O. de Bruijn, and M. B. Curry. Exploring the effects of icon characteristics on user performance: the role of icon concreteness, complexity, and distinctiveness. *Journal of experimental psychology. Applied*, 6(4):291–306, 2000.

[57] S. J. P. McDougall and I. Reppa. 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):1257–1261, 2008.

[58] X. Meng and Z. Wang. A pre-attentive model of biological vision. *2009 IEEE International Conference on Intelligent Computing and Intelligent Systems*, 2009.

[59] I. Neath, A. Earle, D. Hallett, and A. M. Surprenant. Response time accuracy in apple macintosh computers, Mar 2011.

[60] M. Ngugi, S. Kimani, R. W. Mwangi, and I. Oteyo. Challenges Encountered by Older Adults while Navigating Mobile Device User Interfaces. (JANUARY 2014):1–9, 2014.

[61] Open Science Collaboration. Estimating the reproducibility of psychological science. *Science*, 349(6251):aac4716–aac4716, 2015.

[62] D. Oyserman, N. Sorensen, R. Reber, and S. X. Chen. Connecting and Separating Mind-Sets: Culture as Situated Cognition. *Journal of Personality and Social Psychology*, 97(2):217–35, 2009.

[63] M. Prada, D. Rodrigues, R. R. Silva, and M. V. Garrido. Lisbon Symbol Database (LSD): Subjective norms for 600 symbols. *Behavior Research Methods*, 2015.

[64] R. Reber, P. Winkielman, and N. Schwarz. Effects of Perceptual Fluency on Affective Judgments. 9(1):45–48, 1998.

[65] I. Reppa and S. McDougall. When the going gets tough the beautiful get going: aesthetic appeal facilitates task performance. *Psychonomic Bulletin & Review*, pages 1–12, 2015.

[66] I. Reppa, D. Playfoot, and S. J. P. McDougall. Visual Aesthetic Appeal Speeds Processing of Complex but not Simple Icons. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 52(18):1155–1159, 2008.

[67] Y. Rogers. Icon design for the user interface. *International Reviews of Ergonomics: 3*, pages 129–155, 1989.

[68] B. Rossion and G. Pourtois. Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition. *Perception*, 33(2):217–236, 2004.

[69] Y. B. Salman and H.-i. Cheng. Senior - Friendly Icon Design for the Mobile Phone. *6th International Conference on Digital Content, Multimedia Technology and its Applications*, pages 103–108, 2010.

[70] S. Schröder and M. Ziefle. Icon design on small screens: Effects of miniaturization on speed and accuracy in visual search. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 50(5):656–660, 2006.

[71] S. Schroeder and M. Ziefle. Effects of icon concreteness and complexity on semantic transparency: Younger vs. Older users. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 5105 LNCS:90–97, 2008.

[72] N. Schwarz and P. Winkielman. Processing Fluency and Aesthetic Pleasure : Is Beauty in the Perceiver ' s Processing Experience ? 8(4):364–382, 2004.

[73] V. Setlur, C. Albrecht-Buehler, A. A. Gooch, S. Rossoff, and B. Gooch. Semanticons: Visual metaphors as file icons. *Computer Graphics Forum*, 24(3):647–656, 2005.

[74] J. M. Shanis and A. Hedge. Comparison of mouse, touchpad and multitouch input technologies. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 47(4):746–750, 2003.

[75] J. M. Silvennoinen and J. P. Jokinen. Aesthetic appeal and visual usability in four icon design eras. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 4390–4400, New York, NY, USA, 2016. ACM.

[76] W. Sluckin, D. J. Hargreaves, and A. M. Colman. Novelty and human aesthetic preferences. pages 1–25, 2009.

[77] D. Smilek, A. Frischen, M. G. Reynolds, C. Gerritsen, and J. D. Eastwood. What influences visual search efficiency? Disentangling contributions of preattentive and postattentive processes. *Perception & psychophysics*, 69(7):1105–1116, 2007.

[78] J. G. Snodgrass and M. Vanderwart. A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning & Memory*, 6(2):174–215, 1980.

[79] A. Treisman. What shall we do with the preattentive processing stage: Use it or lose it? *Journal of Vision*, 3(9):572, 2003.

[80] Y.-C. Tseng and A. Howes. The adaptation of visual search to utility, ecology and design. *International Journal of Human-Computer Studies*, 80:45–55, 2015.

[81] A. W. W. Principles of gestalt psychology. by k. koffka. (london: Kegan paul, trench, trubner co., ltd.1935. pp. xi 720. price 25s.). *Philosophy*, 11(44):502504, 1936.

[82] P.-H. M. Wan, K. T. T. Chang, and R. S. C. Lung. Triadic Relationship of Icon Design for Semi-Literate Communities. *World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering*, 9(5):1114–1122, 2015.

[83] J. M. Wolfe. Guided Search 2 . 0 A revised model of visual search. *Psychnomic Bulletin & Review*, 1(2):202–238, 1994.

[84] J. M. Wolfe. Guided Search 4.0: Current Progress with a Model of Visual Search. *Integrated Models of Cognitive Systems*, pages 99–120, 2012.

[85] K. Yin, L. Wang, and Y. Guo. Fusing Multiple Visual Features for Image Comple. *Proc. PCM*, pages 308–317, 2013.

[86] H. M. Yoshiyuki Takahashi. *Augmented Reality Based Environment Design Support System for Home Renovation*. 2012.

[87] R. B. Zajonc. Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology Monographs*, 9:1–27, 1968.

APPENDIX A: Rating statements for Preliminary Experiments 1 and 2.

Visual Complexity:

Rate the icon's visual complexity, it's level of detail.

1) The icon is very complex.

2) The icon is complex.

3) The icon is neither complex nor simple.

4) The icon is simple.

5) The icon is very simple.

Concreteness:

Rate the concreteness/abstractness of the icon, how realistic it looks.

1) The icon is very concrete.

2) The icon is concrete.

3) The icon is neither abstract nor concrete.

4) The icon is abstract.

5) The icon is very abstract.

Aesthetic Appeal:

Rate the aesthetic value, beauty, attractiveness of the icon.

1) The icon is very attractive.

2) The icon is attractive.

3) The icon is neither attractive nor unattractive.

4) The icon is unattractive.

5) The icon is very unattractive.

Familiarity:

Rate how familiar you are with the icon, or how often you have seen it before.

1) The icon is very familiar.

2) The icon is familiar.

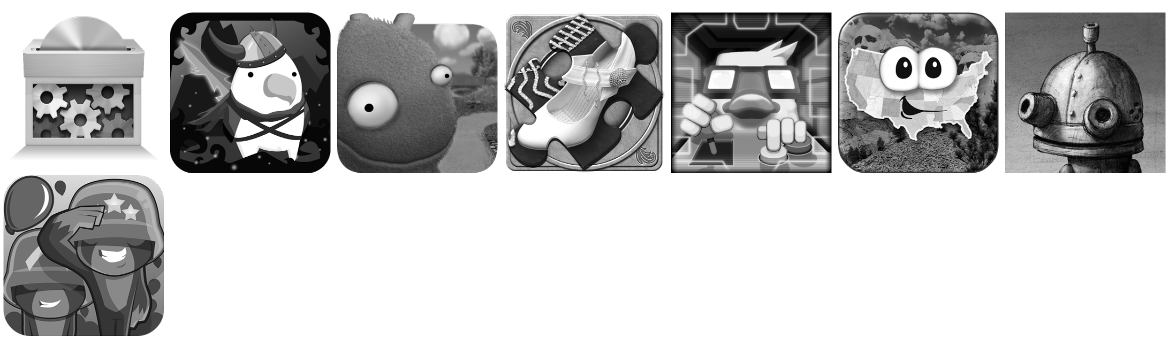
3) The icon is neither familiar nor unfamiliar.

4) The icon is unfamiliar.

5) The icon is very unfamiliar.

APPENDIX B: Pilot study icons from mobile applications.

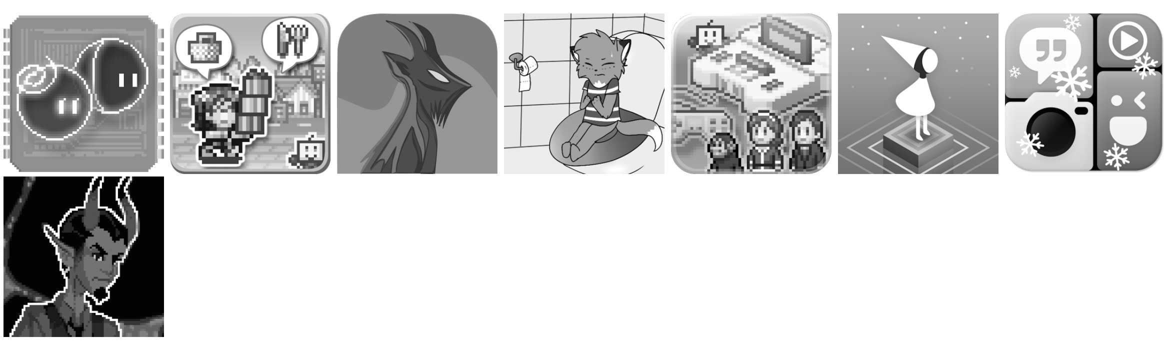
Complex-Attractive-Abstract



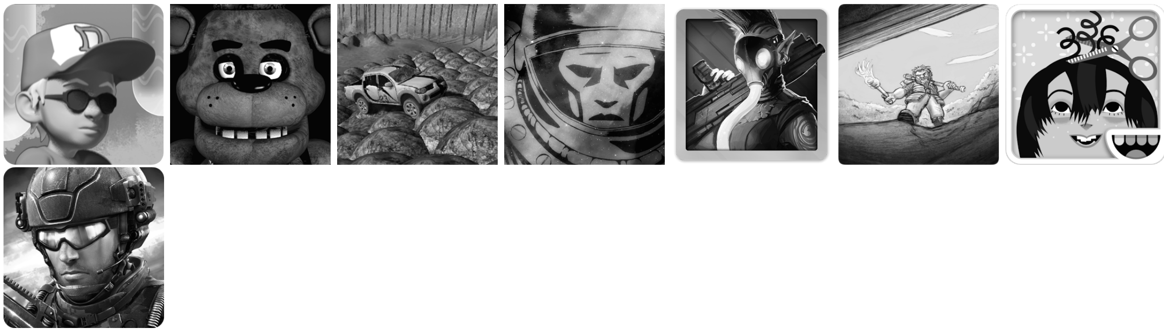
Simple-Unattractive-Concrete

Complex-Attractive-Concrete

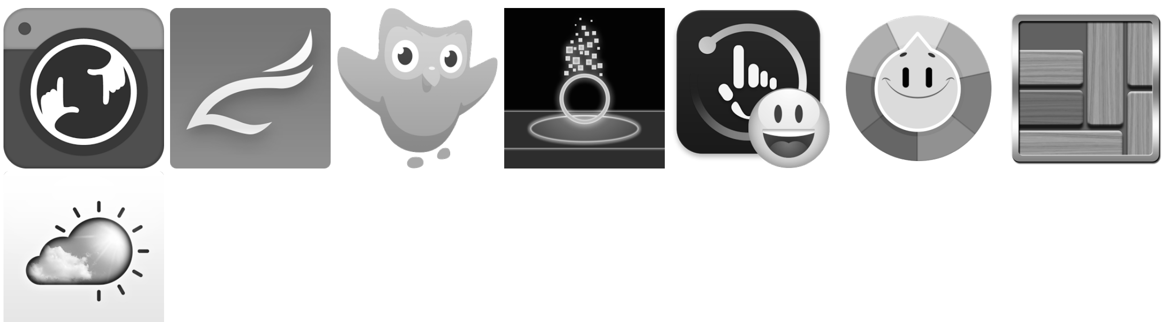
Complex-Unattractive-Abstract



Complex-Unattractive-Concrete



Simple-Attractive-Abstract



Simple-Attractive-Concrete

Simple-Unattractive-Abstract

APPENDIX C: Mobile application icons and ratings for small group of 64 alone as well as the ratings within the larger, diversified set of 200.

animals_result.png

Context Set	Small	Diverse
Familiarity	4.35	3.07
Complexity	6.30	6.57
Concreteness	5.88	6.10
Appeal	4.76	4.60

battery.png

Context Set	Small	Diverse
Familiarity	4.20	4.70
Complexity	4.62	5.67
Concreteness	5.04	6.03
Appeal	5.04	5.17

aquaSlashGL.png

Context Set	Small	Diverse
Familiarity	3.08	2.70
Complexity	4.20	5.67
Concreteness	4.66	5.03
Appeal	3.78	4.73

biker.png

Context Set	Small	Diverse
Familiarity	3.42	3.47
Complexity	4.48	4.57
Concreteness	4.34	5.37
Appeal	3.50	4.17

backflip.png

Context Set	Small	Diverse
Familiarity	3.26	2.50
Complexity	4.62	5.67
Concreteness	5.18	5.73
Appeal	4.48	4.20

bitbitlove_result.png

Context Set	Small	Diverse
Familiarity	3.58	2.20
Complexity	4.48	5.00
Concreteness	3.08	3.97
Appeal	3.92	3.07

bizbuilder.png

Context Set	Small	Diverse
Familiarity	3.11	2.43
Complexity	4.76	5.33
Concreteness	2.94	4.67
Appeal	2.38	2.77

bloons.png

Context Set	Small	Diverse
Familiarity	3.26	2.97
Complexity	4.62	5.50
Concreteness	3.64	5.17
Appeal	5.04	4.80

busyboxpro.png

Context Set	Small	Diverse
Familiarity	2.80	2.60
Complexity	4.76	5.00
Concreteness	4.06	4.67
Appeal	4.62	4.60

camera_result.png

Context Set	Small	Diverse
Familiarity	3.11	2.43
Complexity	3.36	4.50
Concreteness	3.22	3.57
Appeal	4.62	4.87

cardboard.png

Context Set	Small	Diverse
Familiarity	2.94	2.97
Complexity	4.05	3.17
Concreteness	4.35	3.40
Appeal	3.64	3.90

catan.png

Context Set	Small	Diverse
Familiarity	3.74	2.60
Complexity	3.92	4.90
Concreteness	4.48	5.63
Appeal	4.90	4.97

cheetah.png

Context Set	Small	Diverse
Familiarity	2.65	2.10
Complexity	2.66	2.97
Concreteness	3.08	2.30
Appeal	4.76	4.27

clash of clans.png

Context Set	Small	Diverse
Familiarity	4.05	5.30
Complexity	4.62	6.03
Concreteness	4.90	5.63
Appeal	4.20	4.90

datswur_result.png

Context Set	Small	Diverse
Familiarity	3.26	2.10
Complexity	4.48	5.13
Concreteness	3.36	4.43
Appeal	3.78	4.43

defaultdan_result.png

Context Set	Small	Diverse
Familiarity	2.65	2.37
Complexity	5.88	5.97
Concreteness	5.60	5.67
Appeal	3.64	4.40

duoOwl.png

Context Set	Small	Diverse
Familiarity	4.05	4.30
Complexity	3.22	4.67
Concreteness	3.64	4.87
Appeal	4.90	4.50

exchangeByTouch.png

Context Set	Small	Diverse
Familiarity	3.26	2.53
Complexity	4.06	4.97
Concreteness	3.08	4.50
Appeal	3.78	4.33

finnfoxpotty_result.png

Context Set	Small	Diverse
Familiarity	3.26	2.00
Complexity	4.48	5.30
Concreteness	3.92	5.43
Appeal	3.78	3.50

flippix_result.png

Context Set	Small	Diverse
Familiarity	3.74	2.43
Complexity	5.32	6.47
Concreteness	3.92	5.07
Appeal	4.62	4.20

fit_result.png

Context Set	Small	Diverse
Familiarity	2.18	3.93
Complexity	2.80	3.57
Concreteness	2.66	2.40
Appeal	3.92	4.87

framed.png

Context Set	Small	Diverse
Familiarity	3.92	2.33
Complexity	3.89	4.27
Concreteness	5.60	5.17
Appeal	3.64	3.47

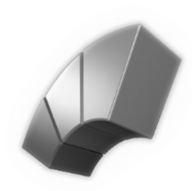
flighttracker.png

Context Set	Small	Diverse
Familiarity	4.05	3.87
Complexity	3.64	5.00
Concreteness	4.62	5.33
Appeal	4.48	4.67

freddys.png

Context Set	Small	Diverse
Familiarity	2.49	4.60
Complexity	5.32	6.13
Concreteness	4.90	5.47
Appeal	3.78	4.13

freeon_result.png



Context Set	Small	Diverse
Familiarity	2.49	2.10
Complexity	3.22	4.47
Concreteness	2.66	3.30
Appeal	3.92	3.93

gamedev.png

Context Set	Small	Diverse
Familiarity	3.42	2.80
Complexity	4.48	5.20
Concreteness	2.94	4.57
Appeal	2.94	2.77

gunbrick_result.png

Context Set	Small	Diverse
Familiarity	2.95	2.40
Complexity	5.46	6.07
Concreteness	3.50	5.17
Appeal	5.04	5.00

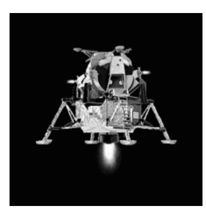
handprint_result.png

Context Set	Small	Diverse
Familiarity	4.05	3.23
Complexity	3.36	4.20
Concreteness	4.76	4.87
Appeal	4.34	3.70

libraryWrench.png

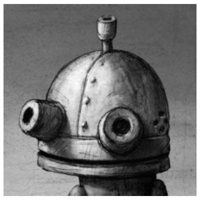
Context Set	Small	Diverse
Familiarity	3.64	3.70
Complexity	4.35	4.53
Concreteness	4.35	4.40
Appeal	3.78	3.97

lunarmodule_result.png



Context Set	Small	Diverse
Familiarity	4.05	2.40
Complexity	6.16	6.30
Concreteness	5.60	5.87
Appeal	4.62	4.57

machinarium.png



Context Set	Small	Diverse
Familiarity	3.26	2.90
Complexity	5.04	6.20
Concreteness	4.06	5.00
Appeal	4.34	4.57

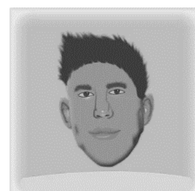
monumentValley.png

Context Set	Small	Diverse
Familiarity	2.80	2.40
Complexity	4.48	4.77
Concreteness	3.08	4.40
Appeal	3.92	4.40

manualCamera.png

Context Set	Small	Diverse
Familiarity	3.11	2.97
Complexity	2.52	3.40
Concreteness	3.08	4.07
Appeal	3.64	3.47

mynameisjeff_result.png

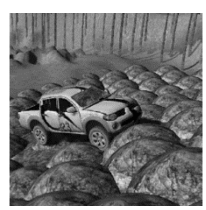


Context Set	Small	Diverse
Familiarity	2.65	1.87
Complexity	4.48	5.07
Concreteness	4.76	5.67
Appeal	3.36	2.73

monstersscoks_result.png

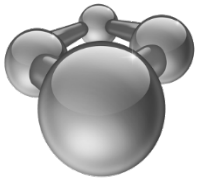
Context Set	Small	Diverse
Familiarity	2.65	2.63
Complexity	5.18	6.07
Concreteness	3.78	4.97
Appeal	5.04	4.17

offroadtrip_result.png



Context Set	Small	Diverse
Familiarity	3.26	2.60
Complexity	5.60	6.43
Concreteness	6.16	5.80
Appeal	3.92	4.13

openGL.png



Context Set	Small	Diverse
Familiarity	2.94	2.53
Complexity	4.20	5.03
Concreteness	4.35	3.30
Appeal	3.64	4.70

over.png

Context Set	Small	Diverse
Familiarity	3.42	2.80
Complexity	2.24	2.03
Concreteness	2.94	2.73
Appeal	3.78	3.57

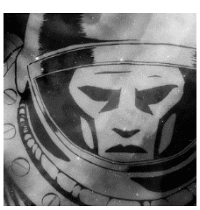
orbits_result.png

Context Set	Small	Diverse
Familiarity	3.58	2.90
Complexity	3.92	5.30
Concreteness	4.90	5.30
Appeal	5.60	4.73

photo editor.png

Context Set	Small	Diverse
Familiarity	3.26	3.67
Complexity	5.18	5.73
Concreteness	5.74	5.63
Appeal	4.90	5.23

outThere.png



Context Set	Small	Diverse
Familiarity	3.58	2.63
Complexity	5.88	5.90
Concreteness	4.20	5.20
Appeal	3.92	4.87

photoedit.png

Context Set	Small	Diverse
Familiarity	3.42	2.90
Complexity	4.76	5.30
Concreteness	3.36	3.83
Appeal	3.64	3.63

pocketCasts.png

Context Set	Small	Diverse
Familiarity	2.95	2.43
Complexity	2.66	3.30
Concreteness	2.66	2.47
Appeal	3.78	3.73

raisinghell_result.png

Context Set	Small	Diverse
Familiarity	3.42	2.57
Complexity	4.90	5.17
Concreteness	3.78	5.17
Appeal	3.22	2.93

printerShare.png

Context Set	Small	Diverse
Familiarity	3.42	2.67
Complexity	4.06	4.77
Concreteness	4.06	5.07
Appeal	3.78	4.27

remoteforTV.png

Context Set	Small	Diverse
Familiarity	4.05	2.90
Complexity	5.88	6.27
Concreteness	6.02	5.90
Appeal	4.48	4.53

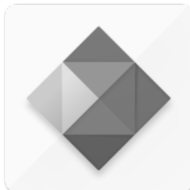
prisonEscape.png

Context Set	Small	Diverse
Familiarity	3.11	2.40
Complexity	3.36	4.60
Concreteness	3.08	4.87
Appeal	3.36	3.30

shadowrun.png

Context Set	Small	Diverse
Familiarity	3.11	2.83
Complexity	5.88	6.67
Concreteness	4.76	5.73
Appeal	3.64	4.67

shopping.png



Context Set	Small	Diverse
Familiarity	3.42	2.53
Complexity	3.64	4.13
Concreteness	2.80	2.67
Appeal	3.78	4.03

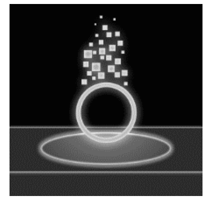
sixaxis controller.png

Context Set	Small	Diverse
Familiarity	3.74	5.67
Complexity	4.06	5.83
Concreteness	5.60	5.40
Appeal	4.90	5.07

sniper.png

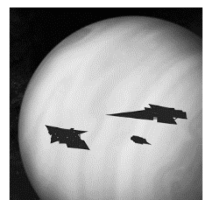
Context Set	Small	Diverse
Familiarity	3.11	3.53
Complexity	6.02	6.30
Concreteness	6.02	5.87
Appeal	4.90	4.83

soccertron_result.png



Context Set	Small	Diverse
Familiarity	2.65	1.97
Complexity	4.06	4.87
Concreteness	3.08	2.33
Appeal	4.90	4.40

solvictus_result.png



Context Set	Small	Diverse
Familiarity	3.58	2.57
Complexity	4.06	5.07
Concreteness	4.34	4.83
Appeal	3.78	3.40

stacktheStates.png

Context Set	Small	Diverse
Familiarity	3.42	2.77
Complexity	5.46	6.13
Concreteness	3.92	5.20
Appeal	4.48	4.00

sweep.png

Context Set	Small	Diverse
Familiarity	4.05	4.83
Complexity	3.64	5.10
Concreteness	5.46	6.07
Appeal	4.34	4.57

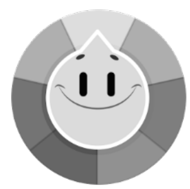
touchPalEmoji.png

Context Set	Small	Diverse
Familiarity	3.58	2.50
Complexity	4.06	4.83
Concreteness	3.64	4.40
Appeal	4.62	4.63

textdungeon_result.png

Context Set	Small	Diverse
Familiarity	3.11	2.20
Complexity	5.18	6.17
Concreteness	5.32	5.87
Appeal	4.06	4.70

trivia.png



Context Set	Small	Diverse
Familiarity	2.95	3.37
Complexity	2.80	4.53
Concreteness	3.22	3.93
Appeal	4.48	4.53

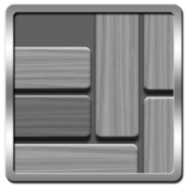
tocahairsalon.png

Context Set	Small	Diverse
Familiarity	3.11	2.50
Complexity	5.18	5.77
Concreteness	4.76	5.47
Appeal	3.92	3.97

umi_result.png

Context Set	Small	Diverse
Familiarity	3.74	2.40
Complexity	5.32	6.03
Concreteness	4.06	5.23
Appeal	4.62	4.93

unblockMegam.png



Context Set	Small	Diverse
Familiarity	3.89	3.30
Complexity	3.50	4.90
Concreteness	2.94	3.57
Appeal	4.48	4.63

wheels_result.png

Context Set	Small	Diverse
Familiarity	3.11	2.57
Complexity	4.48	5.13
Concreteness	5.32	4.97
Appeal	5.18	4.43

warofnations.png

Context Set	Small	Diverse
Familiarity	4.35	3.53
Complexity	6.30	6.57
Concreteness	6.58	6.33
Appeal	4.06	5.33

weatherLive.png

Context Set	Small	Diverse
Familiarity	4.05	3.07
Complexity	3.08	4.67
Concreteness	3.78	4.90
Appeal	4.62	4.00

APPENDIX D: Lisbon Symbol Database icons and ratings from original Lisbon set of 600 as well as ratings within the diversified set of 200.

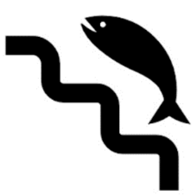
S001.png

Context Set	Small	Diverse
Familiarity	3.27	2.17
Complexity	4.08	2.37
Concreteness	3.89	2.93
Appeal	2.92	2.73

S065.png

Context Set	Small	Diverse
Familiarity	2.69	3.07
Complexity	1.69	1.03
Concreteness	2.00	2.47
Appeal	2.38	2.03

S105.png



Context Set	Small	Diverse
Familiarity	2.80	2.33
Complexity	3.40	2.23
Concreteness	4.63	4.10
Appeal	5.03	3.23

S112.png

Context Set	Small	Diverse
Familiarity	2.47	1.77
Complexity	3.20	2.17
Concreteness	3.73	3.10
Appeal	4.73	3.40

S142.png

Context Set	Small	Diverse
Familiarity	3.23	2.33
Complexity	3.67	3.67
Concreteness	4.77	4.33
Appeal	2.77	3.17

S149.png

Context Set	Small	Diverse
Familiarity	3.29	2.30
Complexity	3.18	1.93
Concreteness	3.32	2.53
Appeal	3.84	3.40

S160.png

Context Set	Small	Diverse
Familiarity	2.82	2.13
Complexity	4.33	3.70
Concreteness	5.18	4.60
Appeal	3.73	2.67

S169.png

Context Set	Small	Diverse
Familiarity	3.19	2.33
Complexity	3.32	3.00
Concreteness	4.58	4.67
Appeal	3.90	3.07

S170.png

Context Set	Small	Diverse
Familiarity	3.45	2.43
Complexity	4.36	3.87
Concreteness	5.36	5.47
Appeal	4.36	3.47

S176

Context Set	Small	Diverse
Familiarity	3.00	2.77
Complexity	4.28	2.67
Concreteness	3.34	3.73
Appeal	3.41	3.33

S182.png

Context Set	Small	Diverse
Familiarity	3.41	2.57
Complexity	3.81	3.73
Concreteness	5.22	4.40
Appeal	3.81	2.90

S188

Context Set	Small	Diverse
Familiarity	2.81	2.87
Complexity	3.59	3.27
Concreteness	4.22	4.70
Appeal	2.97	3.07

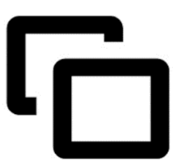
S191.png

Context Set	Small	Diverse
Familiarity	3.43	4.47
Complexity	3.06	1.83
Concreteness	3.57	3.13
Appeal	3.34	3.23

S193.png

Context Set	Small	Diverse
Familiarity	2.68	2.90
Complexity	4.82	3.47
Concreteness	4.90	5.00
Appeal	2.92	3.03

S226.png



Context Set	Small	Diverse
Familiarity	2.63	2.60
Complexity	2.97	1.53
Concreteness	2.43	2.60
Appeal	3.70	2.43

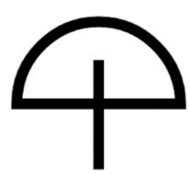
S281.png

Context Set	Small	Diverse
Familiarity	2.43	2.03
Complexity	3.87	1.97
Concreteness	3.57	2.93
Appeal	3.57	2.57

S293

Context Set	Small	Diverse
Familiarity	2.72	2.83
Complexity	2.69	1.67
Concreteness	2.56	2.47
Appeal	4.25	2.60

S300.png



Context Set	Small	Diverse
Familiarity	3.33	2.83
Complexity	2.12	1.23
Concreteness	3.79	2.80
Appeal	4.03	2.10

S302.png

Context Set	Small	Diverse
Familiarity	2.68	2.20
Complexity	2.42	1.27
Concreteness	3.00	2.13
Appeal	3.13	2.27

S305.png

Context Set	Small	Diverse
Familiarity	2.81	2.40
Complexity	2.68	1.27
Concreteness	2.94	2.60
Appeal	3.26	2.37

S307

Context Set	Small	Diverse
Familiarity	2.81	2.43
Complexity	2.72	1.37
Concreteness	2.81	2.50
Appeal	4.00	2.30

S308.png

Context Set	Small	Diverse
Familiarity	2.79	2.23
Complexity	3.09	1.50
Concreteness	2.97	2.50
Appeal	3.79	2.37

S317.png

Context Set	Small	Diverse
Familiarity	2.46	3.10
Complexity	2.49	1.47
Concreteness	3.55	3.87
Appeal	3.52	2.70

S331.png

Context Set	Small	Diverse
Familiarity	3.42	2.53
Complexity	2.27	1.17
Concreteness	3.52	2.43
Appeal	3.97	2.17

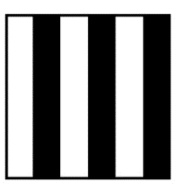
S333

Context Set	Small	Diverse
Familiarity	3.17	2.13
Complexity	1.46	1.20
Concreteness	3.34	2.27
Appeal	3.54	2.23

S342.png

Context Set	Small	Diverse
Familiarity	3.00	2.67
Complexity	3.38	1.97
Concreteness	3.53	3.30
Appeal	3.16	2.57

S349.png



Context Set	Small	Diverse
Familiarity	2.88	2.27
Complexity	2.30	1.50
Concreteness	2.76	2.27
Appeal	3.27	2.27

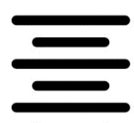
S358.png

Context Set	Small	Diverse
Familiarity	2.70	2.40
Complexity	2.42	1.10
Concreteness	2.12	2.43
Appeal	3.12	2.33

S365.png

Context Set	Small	Diverse
Familiarity	2.68	2.17
Complexity	3.42	2.23
Concreteness	2.45	2.47
Appeal	3.26	2.80

S382.png

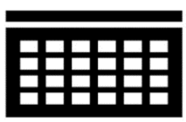


Context Set	Small	Diverse
Familiarity	2.75	2.63
Complexity	2.91	1.63
Concreteness	2.63	2.17
Appeal	3.31	2.97

S433.png

Context Set	Small	Diverse
Familiarity	2.73	1.97
Complexity	4.90	3.23
Concreteness	3.57	2.83
Appeal	3.70	3.10

S441.png



Context Set	Small	Diverse
Familiarity	3.38	2.03
Complexity	3.75	2.00
Concreteness	3.66	3.40
Appeal	3.25	2.43

S447.png

Context Set	Small	Diverse
Familiarity	2.97	2.50
Complexity	2.49	1.50
Concreteness	3.82	2.90
Appeal	3.21	2.20

S449.png

Context Set	Small	Diverse
Familiarity	3.41	2.07
Complexity	2.47	1.37
Concreteness	4.09	3.03
Appeal	3.85	2.77

S450.png

Context Set	Small	Diverse
Familiarity	3.09	2.23
Complexity	2.74	1.27
Concreteness	3.59	2.63
Appeal	3.94	2.50

S453

Context Set	Small	Diverse
Familiarity	2.31	2.33
Complexity	3.66	2.03
Concreteness	3.03	2.73
Appeal	3.41	2.63

S454.png

Context Set	Small	Diverse
Familiarity	3.36	2.07
Complexity	5.03	3.33
Concreteness	4.36	4.20
Appeal	4.24	3.70

S476.png

Context Set	Small	Diverse
Familiarity	2.84	2.00
Complexity	4.34	3.20
Concreteness	3.72	3.03
Appeal	3.22	2.43

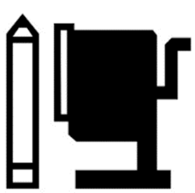
S469.png

Context Set	Small	Diverse
Familiarity	2.49	1.80
Complexity	5.24	3.40
Concreteness	3.42	2.67
Appeal	2.97	2.70

S487.png

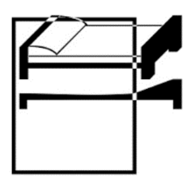
Context Set	Small	Diverse
Familiarity	2.46	1.70
Complexity	3.54	2.63
Concreteness	3.57	4.20
Appeal	4.26	3.43

S473



Context Set	Small	Diverse
Familiarity	3.34	2.53
Complexity	4.53	2.73
Concreteness	4.72	4.17
Appeal	3.22	2.67

S494



Context Set	Small	Diverse
Familiarity	3.13	1.87
Complexity	4.26	3.17
Concreteness	3.77	3.73
Appeal	2.94	2.27

S518.png

Context Set	Small	Diverse
Familiarity	2.73	1.80
Complexity	4.52	3.07
Concreteness	3.27	3.10
Appeal	3.09	2.83

S523.png

Context Set	Small	Diverse
Familiarity	2.97	2.20
Complexity	4.23	2.03
Concreteness	3.45	2.67
Appeal	3.32	2.33

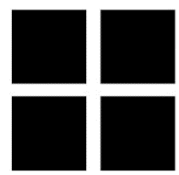
S524.png

Context Set	Small	Diverse
Familiarity	3.47	2.10
Complexity	3.53	3.47
Concreteness	5.00	4.77
Appeal	5.07	3.00

S529.png

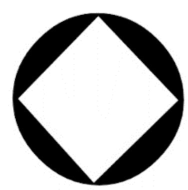
Context Set	Small	Diverse
Familiarity	2.94	2.77
Complexity	2.58	1.77
Concreteness	3.18	3.97
Appeal	3.33	2.77

S531.png



Context Set	Small	Diverse
Familiarity	3.58	3.47
Complexity	2.71	1.37
Concreteness	3.52	3.00
Appeal	2.84	2.87

S535.png



Context Set	Small	Diverse
Familiarity	2.85	2.70
Complexity	2.36	1.47
Concreteness	2.46	2.43
Appeal	3.55	2.63

S544.png

Context Set	Small	Diverse
Familiarity	2.88	2.23
Complexity	2.64	1.50
Concreteness	2.52	2.47
Appeal	3.91	3.17

S547.png

Context Set	Small	Diverse
Familiarity	2.84	2.53
Complexity	2.97	1.47
Concreteness	3.14	2.57
Appeal	4.43	3.73

S552.png

Context Set	Small	Diverse
Familiarity	2.55	2.13
Complexity	5.07	3.53
Concreteness	2.48	2.20
Appeal	3.26	2.63

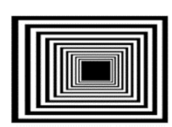
S553.png

Context Set	Small	Diverse
Familiarity	3.00	2.43
Complexity	4.91	3.23
Concreteness	2.14	2.00
Appeal	4.71	3.40

S556.png

Context Set	Small	Diverse
Familiarity	2.53	1.77
Complexity	4.72	3.13
Concreteness	2.59	1.97
Appeal	3.88	3.47

S559.png



Context Set	Small	Diverse
Familiarity	2.53	2.30
Complexity	4.75	3.23
Concreteness	2.09	2.03
Appeal	3.94	3.33

S568.png

Context Set	Small	Diverse
Familiarity	2.84	2.80
Complexity	4.75	2.47
Concreteness	2.81	2.73
Appeal	2.78	3.10

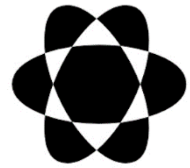
S574.png

Context Set	Small	Diverse
Familiarity	2.84	2.33
Complexity	3.29	2.27
Concreteness	4.00	3.00
Appeal	2.97	2.83

S575.png

Context Set	Small	Diverse
Familiarity	3.03	2.27
Complexity	3.38	2.37
Concreteness	3.85	3.37
Appeal	2.59	3.37

S578.png



Context Set	Small	Diverse
Familiarity	2.82	3.00
Complexity	4.35	3.03
Concreteness	2.68	2.07
Appeal	4.71	3.77

S582.png

Context Set	Small	Diverse
Familiarity	3.18	2.43
Complexity	5.15	4.67
Concreteness	2.85	2.83
Appeal	5.35	4.30

S583.png

Context Set	Small	Diverse
Familiarity	2.78	2.17
Complexity	4.95	4.33
Concreteness	2.73	2.30
Appeal	4.92	4.03

S584

Context Set	Small	Diverse
Familiarity	2.58	1.77
Complexity	5.73	4.63
Concreteness	2.30	2.40
Appeal	5.06	4.33

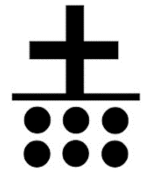
S585.png

Context Set	Small	Diverse
Familiarity	3.20	2.53
Complexity	5.63	4.77
Concreteness	2.80	2.77
Appeal	5.23	4.23

S591.png

Context Set	Small	Diverse
Familiarity	2.69	1.80
Complexity	5.09	2.47
Concreteness	2.75	2.27
Appeal	3.41	3.07

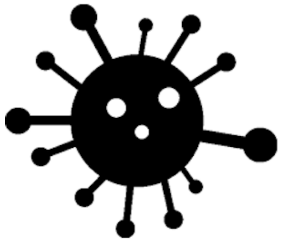
S597.png



Context Set	Small	Diverse
Familiarity	3.19	2.00
Complexity	3.69	2.07
Concreteness	3.91	2.63
Appeal	2.53	2.40

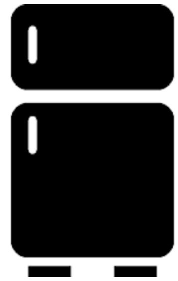
APPENDIX E: Remaining 72 icons from mobile, Lisbon, and McDougall sets with ratings procured within the diversified set of 200.

_0011_Virus.png



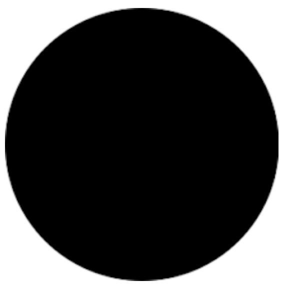
Complexity	3.00
Concreteness	2.37
Appeal	3.40

_0041_Refridgerator.png



Complexity	2.40
Concreteness	3.23
Appeal	2.73

_0021_Record.png

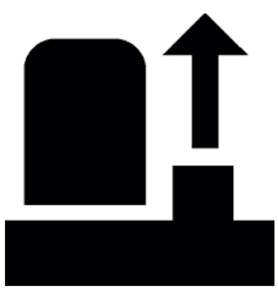


Complexity	1.03
Concreteness	2.93
Appeal	2.20

_0058_Briefcase.png

Complexity	2.20
Concreteness	4.23
Appeal	2.63

_0026_Submersible.png

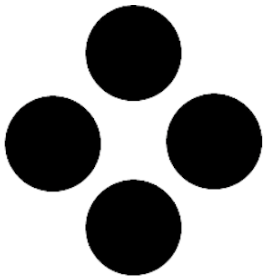


Complexity	2.20
Concreteness	2.67
Appeal	2.40

_0070_Cabin.png

Complexity	1.43
Concreteness	2.90
Appeal	1.77

airconditioning.png

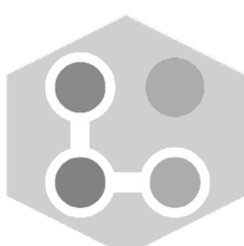


Complexity	1.17
Concreteness	2.57
Appeal	2.53

butterfly_result.png

Complexity	5.83
Concreteness	6.23
Appeal	5.17

catalyst_result.png

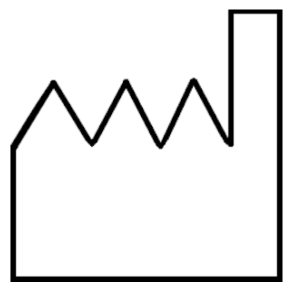


Complexity	2.93
Concreteness	2.27
Appeal	3.07

City.png

Complexity	1.37
Concreteness	2.90
Appeal	2.13

dateofmanufactue.png

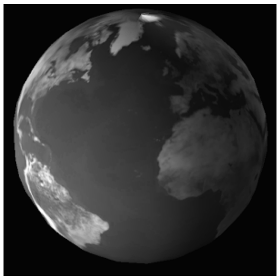


Complexity	1.37
Concreteness	3.07
Appeal	2.13

dragonstorm_result.png

Complexity	4.97
Concreteness	4.90
Appeal	3.07

earth_result.png



Complexity	5.53
Concreteness	6.40
Appeal	4.43

essentialoils_result.png

Complexity	3.40
Concreteness	4.03
Appeal	3.77

face_result.png

Complexity	2.43
Concreteness	3.30
Appeal	3.23

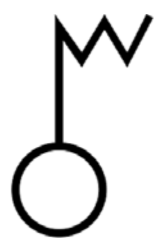
facetune.png

Complexity	4.53
Concreteness	3.67
Appeal	4.70

filmblackening.png

Complexity	1.13
Concreteness	2.57
Appeal	2.13

Fixing.png

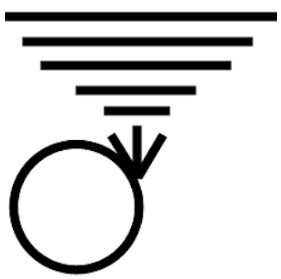


Complexity	1.53
Concreteness	2.13
Appeal	2.20

geardrive.png

Complexity	2.03
Concreteness	2.57
Appeal	2.53

halfwidthwinding.png



Complexity	2.67
Concreteness	2.07
Appeal	2.03

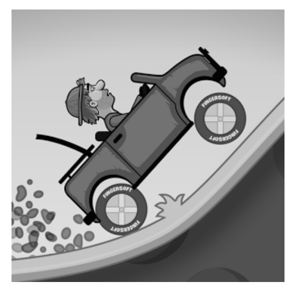
hauntedhallow_result.png

Complexity	6.67
Concreteness	6.27
Appeal	5.70

hauntedhous_result.png

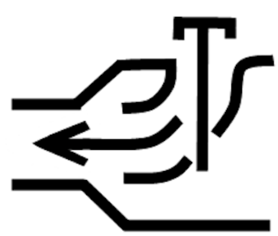
Complexity	6.33
Concreteness	5.60
Appeal	4.27

hill.png



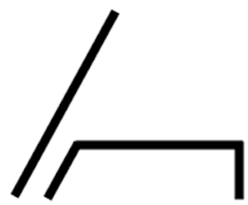
Complexity	5.70
Concreteness	5.77
Appeal	4.23

Injectreactingresin1.png



Complexity	2.60
Concreteness	2.17
Appeal	2.13

inspectiontable.png



Complexity	1.17
Concreteness	2.07
Appeal	1.73

kungfupet_result.png

Complexity	6.40
Concreteness	5.30
Appeal	5.23

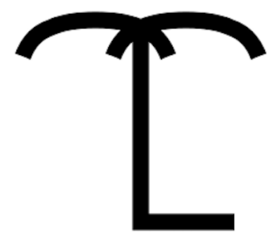
lightflow.png

Complexity	4.37
Concreteness	2.60
Appeal	4.03

modernSniper.png

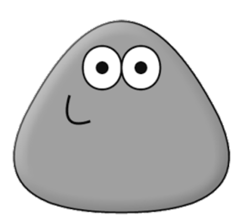
Complexity	6.63
Concreteness	6.43
Appeal	5.20

PalmTrees.png



Complexity	1.73
Concreteness	2.37
Appeal	2.20

pou.png



Complexity	3.37
Concreteness	4.27
Appeal	3.77

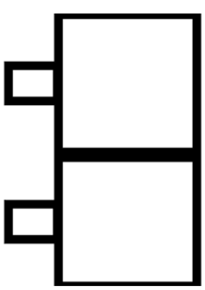
PrioritySeating.png

Complexity	3.17
Concreteness	5.23
Appeal	2.90

removematerial.png

Complexity	1.77
Concreteness	2.17
Appeal	2.13

rollerends.png

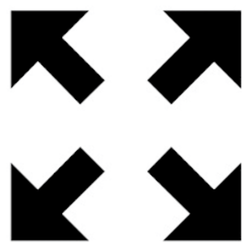


Complexity	1.63
Concreteness	2.50
Appeal	2.10

S172

Complexity	3.47
Concreteness	3.83
Appeal	3.30

S245



Complexity	1.90
Concreteness	2.40
Appeal	3.20

S299

Complexity	1.60
Concreteness	1.83
Appeal	2.00

S315

Complexity 1.23

Concreteness 2.10

Appeal 2.43

S335

Complexity 1.30

Concreteness 2.30

Appeal 2.87

S337

Complexity 2.33

Concreteness 2.47

Appeal 3.90

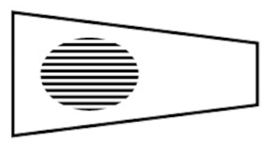
S338

Complexity 3.90

Concreteness 3.13

Appeal 4.37

S367



Complexity 2.40

Concreteness 2.50

Appeal 2.50

S434

Complexity 2.03

Concreteness 2.60

Appeal 3.33

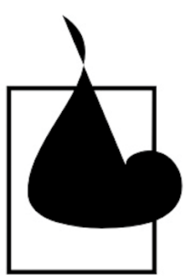
S439

Complexity	1.40
Concreteness	3.87
Appeal	3.43

S489

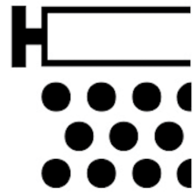
Complexity	3.27
Concreteness	1.93
Appeal	2.20

S512



Complexity	2.63
Concreteness	2.43
Appeal	2.47

S513



Complexity	2.37
Concreteness	2.57
Appeal	2.60

S533

Complexity	2.77
Concreteness	3.10
Appeal	3.77

S538

Complexity	2.67
Concreteness	2.33
Appeal	3.47

S539

Complexity	2.73
Concreteness	2.07
Appeal	3.73

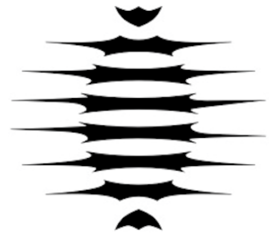
S554

Complexity	3.63
Concreteness	2.03
Appeal	3.50

S558

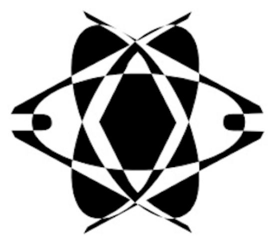
Complexity	2.80
Concreteness	2.23
Appeal	3.33

S561



Complexity	3.50
Concreteness	1.93
Appeal	3.83

S576



Complexity	4.47
Concreteness	1.93
Appeal	3.43

S577

Complexity	2.13
Concreteness	2.87
Appeal	3.03

S586

Complexity 2.77

Concreteness 2.73

Appeal 2.83

S587

Complexity 2.47

Concreteness 2.90

Appeal 2.60

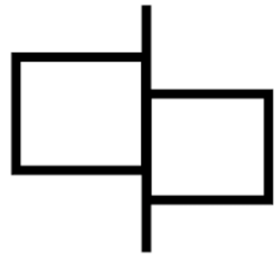
S592

Complexity 3.03

Concreteness 2.03

Appeal 2.70

safelyoverloaddevice1.png



Complexity 1.40

Concreteness 2.40

Appeal 2.03

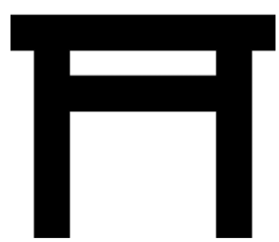
scannerRadio.png

Complexity 4.30

Concreteness 4.40

Appeal 3.80

Shrine.png



Complexity 1.40

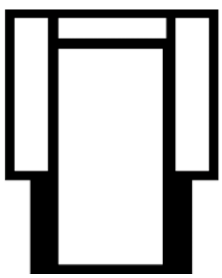
Concreteness 3.10

Appeal 2.40

skyGambers.png

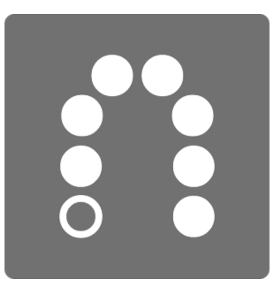
Complexity	6.67
Concreteness	6.10
Appeal	4.40

slide.png



Complexity	2.03
Concreteness	2.37
Appeal	2.40

slingplayer.png



Complexity	2.30
Concreteness	2.20
Appeal	3.10

sumotori.png

Complexity	5.87
Concreteness	4.97
Appeal	3.53

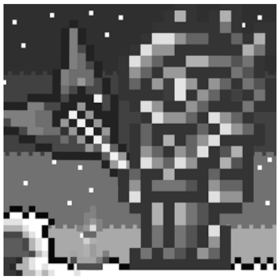
tasker.png

Complexity	4.17
Concreteness	3.70
Appeal	4.17

teamspeak.png

Complexity	4.87
Concreteness	4.00
Appeal	5.07

terraria.png



Complexity	5.10
Concreteness	3.73
Appeal	2.13

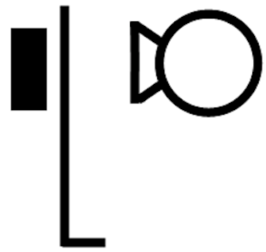
tiger.png

Complexity	6.60
Concreteness	5.90
Appeal	4.83

trafficRacer.png

Complexity	6.30
Concreteness	6.27
Appeal	4.60

Verticalradiographicstand.png

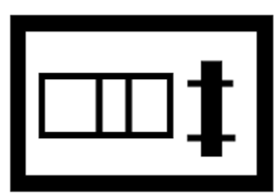


Complexity	2.27
Concreteness	2.17
Appeal	2.17

Windmill.png

Complexity	1.50
Concreteness	2.70
Appeal	2.57

zoom11.png



Complexity	2.30
Concreteness	2.20
Appeal	2.00

APPENDIX F: Javascript code for search task experiments.

```


//  Html/js code by Mick Smythwood 2014
//
//  CALLS ON THE CHANCE FUNCTION FROM VICTOR QUINN CODE 2013
//  Chance.js 0.5.5
//  http://chancejs.com
//  (c) 2013 Victor Quinn
//  Chance may be freely distributed or modified under the MIT
    license.



//beginning of my own code --Mick


function afterWelcome () {
  document.getElementById("welcomeDiv").style.display = "none";
  document.getElementById("instructions").style.display = "block";
  document.getElementById("submitButton").style.display = "none";
}

var i = 0,
finalArray = [],
counter = [];
answers = [];
```

```
function afterIntro () {

  cacpre = ["http://webpages.uncc.edu/~ksmythwo/icons/sniper.png",
      "http://webpages.uncc.edu/~ksmythwo/icons/remoteforTV.png",
      "http://webpages.uncc.edu/~ksmythwo/appleIcons/animals_result.png",
      "http://webpages.uncc.edu/~ksmythwo/icons/photoeditor.png",
      "http://webpages.uncc.edu/~ksmythwo/appleIcons/lunarmodule_result.png",
      "http://webpages.uncc.edu/~ksmythwo/appleIcons/wheels_result.png",
      "http://webpages.uncc.edu/~ksmythwo/icons/backflip.png",
      "http://webpages.uncc.edu/~ksmythwo/icons/battery.png"];
      caapre = [ "http://webpages.uncc.edu/~ksmythwo/icons/machinarium.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/flippix_result.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/stacktheStates.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/monstersscoks_result.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/gunbrick_result.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/bloons.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/busyboxpro.png",
```

```
    "http://webpages.uncc.edu/~ksmythwo/appleIcons/umi_result.png"];
    cucpre = [
        "http://webpages.uncc.edu/~ksmythwo/icons/warofnations.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/offroadtrip_result.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/outThere.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/textdungeon_result.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/freddys.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/shadowrun.png",
        "http://webpages.uncc.edu/~ksmythwo/appleIcons/defaultdan.png",
        "http://webpages.uncc.edu/~ksmythwo/icons/tocahairsalon.png"];
        cuapre = [   "http://webpages.uncc.edu/~ksmythwo/icons/monumentValley.png",
            "http://webpages.uncc.edu/~ksmythwo/appleIcons/bitbitlove_result.png",
            "http://webpages.uncc.edu/~ksmythwo/appleIcons/finnfoxpotty_result.png",
            "http://webpages.uncc.edu/~ksmythwo/appleIcons/datswur_result.png",
            "http://webpages.uncc.edu/~ksmythwo/icons/photoedit.png",
```

```
                "http://webpages.uncc.edu/~ksmythwo/appleIcons/
raisinghell_result.png",
                "http://webpages.uncc.edu/~ksmythwo/icons/gamedev.
png",
                "http://webpages.uncc.edu/~ksmythwo/icons/bizbuilder
.png"];
                sacpre = [  "http://webpages.uncc.edu/~ksmythwo/
icons/sixaxis controller.png",
                  "http://webpages.uncc.edu/~ksmythwo/appleIcons/
orbits_result.png",
                  "http://webpages.uncc.edu/~ksmythwo/icons/sweep.
png",
                  "http://webpages.uncc.edu/~ksmythwo/icons/
solitaire.png",
                  "http://webpages.uncc.edu/~ksmythwo/appleIcons/
handprint_result.png",
                  "http://webpages.uncc.edu/~ksmythwo/icons/catan.
png",
                  "http://webpages.uncc.edu/~ksmythwo/icons/doc
scanner.png",
                  "http://webpages.uncc.edu/~ksmythwo/icons/calorie
counter.png"];
                  saapre = [ "http://webpages.uncc.edu/~ksmythwo/
icons/duoOwl.png",
                      "http://webpages.uncc.edu/~ksmythwo/appleIcons
/soccertron_result.png",
                      "http://webpages.uncc.edu/~ksmythwo/icons/
```

```
cheetah.png",
                    "http://webpages.uncc.edu/~ksmythwo/icons/
weatherLive.png",
                    "http://webpages.uncc.edu/~ksmythwo/icons/
touchPalEmoji.png",
                    "http://webpages.uncc.edu/~ksmythwo/appleIcons
/camera_result.png",
                    "http://webpages.uncc.edu/~ksmythwo/icons/
unblockMegam.png",
                    "http://webpages.uncc.edu/~ksmythwo/icons/
trivia.png",];
                    sucpre = [  "http://webpages.uncc.edu/~
ksmythwo/icons/clash of clans.png",
                        "http://webpages.uncc.edu/~ksmythwo/icons/
biker.png",
                        "http://webpages.uncc.edu/~ksmythwo/
appleIcons/mynameisjeff_result.png",
                        "http://webpages.uncc.edu/~ksmythwo/icons/
flighttracker.png",
                        "http://webpages.uncc.edu/~ksmythwo/
appleIcons/solvictus_result.png",
                        "http://webpages.uncc.edu/~ksmythwo/
appleIcons/snipersquirrel_result.png",
                        "http://webpages.uncc.edu/~ksmythwo/icons/
playstation.png",
                        "http://webpages.uncc.edu/~ksmythwo/icons/
printerShare.png"];
```

```
                        suapre = [  "http://webpages.uncc.edu/~ksmythwo/appleIcons/freeon_result.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/exchangeByTouch.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/pocketCasts.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/prisonEscape.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/manualCamera.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/over.png",
                          "http://webpages.uncc.edu/~ksmythwo/icons/shopping.png",
                          "http://webpages.uncc.edu/~ksmythwo/appleIcons/flipmin_result.png"];

                          cac = chance.shuffle(cacpre);
                          caa = chance.shuffle(caapre);
                          cuc = chance.shuffle(cucpre);
                          cua = chance.shuffle(cuapre);
                          sac = chance.shuffle(sacpre);
                          saa = chance.shuffle(saapre);
                          suc = chance.shuffle(sucpre);
                          sua = chance.shuffle(suapre);


```

```
                                  cacArray = [["cac", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
                                      ["cac", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
                                      ["cac", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
                                      ["cac", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
                                      ["cac", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
                                      ["cac", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], suc[2]],
                                      ["cac", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], sua[1]],
                                      ["cac", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], sua[0]]
                                      ];

                                      caaArray = [["caa", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
                                          ["caa", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
                                          ["caa", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
                                          ["caa", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
                                          ["caa", cac[4], caa[4] , cuc[4],
```

```
 cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
                                        ["caa", cac[5], caa[5] , cuc[5],
 cua[5], sac[5], saa[5], suc[5], sua[5], sua[2]],
                                        ["caa", cac[6], caa[6] , cuc[6],
 cua[6], sac[6], saa[6], suc[6], sua[6], suc[1]],
                                        ["caa", cac[7], caa[7] , cuc[7],
 cua[7], sac[7], saa[7], suc[7], sua[7], suc[0]]
                                        ];

                                        cucArray = [["cuc", cac[0], caa
[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
                                            ["cuc", cac[1], caa[1] , cuc
[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
                                            ["cuc", cac[2], caa[2] , cuc
[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
                                            ["cuc", cac[3], caa[3] , cuc
[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
                                            ["cuc", cac[4], caa[4] , cuc
[4], cua[4], sac[4], saa[4], suc[4], sua[4], sua[3]],
                                            ["cuc", cac[5], caa[5] , cuc
[5], cua[5], sac[5], saa[5], suc[5], sua[5], suc[2]],
                                            ["cuc", cac[6], caa[6] , cuc
[6], cua[6], sac[6], saa[6], suc[6], sua[6], saa[1]],
                                            ["cuc", cac[7], caa[7] , cuc
[7], cua[7], sac[7], saa[7], suc[7], sua[7], saa[0]]
                                            ];
```

```
cuaArray = [["cua", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
            ["cua", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
            ["cua", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
            ["cua", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
            ["cua", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
            ["cua", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], sua[2]],
            ["cua", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], suc[1]],
            ["cua", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], suc[0]]
            ];

sacArray = [["sac", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
            ["sac", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
            ["sac", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], suc[5]],
            ["sac", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
```

```
                                              ["sac", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
                                              ["sac", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], sua[2]],
                                              ["sac", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], cua[1]],
                                              ["sac", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], cua[0]]
                                              ];

                                              saaArray = [["saa", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
                                                  ["saa", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], sua[6]],
                                                  ["saa", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
                                                  ["saa", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
                                                  ["saa", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
                                                  ["saa", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], suc[2]],
                                                  ["saa", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], cuc[1]],
                                                  ["saa", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], cuc[0]]
```

```
];

sucArray = [["suc", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], sua[7]],
["suc", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
["suc", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
["suc", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
["suc", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
["suc", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], suc[2]],
["suc", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], caa[1]],
["suc", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], caa[0]]
];
```

```
suaArray = [["sua", cac[0], caa[0] , cuc[0], cua[0], sac[0], saa[0], suc[0], sua[0], caa[7]],
["sua", cac[1], caa[1] , cuc[1], cua[1], sac[1], saa[1], suc[1], sua[1], cuc[6]],
["sua", cac[2], caa[2] , cuc[2], cua[2], sac[2], saa[2], suc[2], sua[2], cua[5]],
["sua", cac[3], caa[3] , cuc[3], cua[3], sac[3], saa[3], suc[3], sua[3], sac[4]],
["sua", cac[4], caa[4] , cuc[4], cua[4], sac[4], saa[4], suc[4], sua[4], saa[3]],
["sua", cac[5], caa[5] , cuc[5], cua[5], sac[5], saa[5], suc[5], sua[5], suc[2]],
["sua", cac[6], caa[6] , cuc[6], cua[6], sac[6], saa[6], suc[6], sua[6], cac[1]],
["sua", cac[7], caa[7] , cuc[7], cua[7], sac[7], saa[7], suc[7], sua[7], cac[0]]
];
```

```
var
totalIconArray = [];

totalIconArray[0] = cacArray[0];
totalIconArray[1] = cacArray[1];
totalIconArray[2] = cacArray[2];
totalIconArray[3] = cacArray[3];
totalIconArray[4] = cacArray[4];
totalIconArray[5] = cacArray[5];
totalIconArray[6] = cacArray[6];
totalIconArray[7] = cacArray[7];
totalIconArray[8] = caaArray[0];
totalIconArray[9] = caaArray[1];
```

```
totalIconArray[10] = caaArray[2];
totalIconArray[11] = caaArray[3];
totalIconArray[12] = caaArray[4];
totalIconArray[13] = caaArray[5];
totalIconArray[14] = caaArray[6];
totalIconArray[15] = caaArray[7];
totalIconArray[16] = cucArray[0];
totalIconArray[17] = cucArray[1];
totalIconArray[18] = cucArray[2];
totalIconArray[19] = cucArray[3];
totalIconArray[20] = cucArray[4];
totalIconArray[21] = cucArray[5];
totalIconArray[22] = cucArray[6];
totalIconArray[23] = cucArray[7];
```

```
    totalIconArray[24] = cuaArray[0];
    totalIconArray[25] = cuaArray[1];
    totalIconArray[26] = cuaArray[2];
    totalIconArray[27] = cuaArray[3];
    totalIconArray[28] = cuaArray[4];
    totalIconArray[29] = cuaArray[5];
    totalIconArray[30] = cuaArray[6];
    totalIconArray[31] = cuaArray[7];
    totalIconArray[32] = sacArray[0];
    totalIconArray[33] = sacArray[1];
    totalIconArray[34] = sacArray[2];
    totalIconArray[35] = sacArray[3];
    totalIconArray[36] = sacArray[4];
```

```
totalIconArray[37] = sacArray[5];
totalIconArray[38] = sacArray[6];
totalIconArray[39] = sacArray[7];
totalIconArray[40] = saaArray[0];
totalIconArray[41] = saaArray[1];
totalIconArray[42] = saaArray[2];
totalIconArray[43] = saaArray[3];
totalIconArray[44] = saaArray[4];
totalIconArray[45] = saaArray[5];
totalIconArray[46] = saaArray[6];
totalIconArray[47] = saaArray[7];
totalIconArray[48] = sucArray[0];
totalIconArray[49] = sucArray[1];
totalIconArray[50] = sucArray[2];
```

```
    totalIconArray[51] = sucArray[3];
    totalIconArray[52] = sucArray[4];
    totalIconArray[53] = sucArray[5];
    totalIconArray[54] = sucArray[6];
    totalIconArray[55] = sucArray[7];
    totalIconArray[56] = suaArray[0];
    totalIconArray[57] = suaArray[1];
    totalIconArray[58] = suaArray[2];
    totalIconArray[59] = suaArray[3];
    totalIconArray[60] = suaArray[4];
    totalIconArray[61] = suaArray[5];
    totalIconArray[62] = suaArray[6];
    totalIconArray[63] = suaArray[7];
```

```
    finalArray = chance.shuffle(totalIconArray);


                                                                             document
    .getElementById("submitButton").style.display = "none";
                                                                             document
    .getElementById("answer1").disabled = false;


    showTarget("instructions", "icon1.0");


}






function newfunc (questionNum, answer){

  //var i = questionNum;
  var imageHtml = "";

  switch(finalArray[i][0]) {
    case "cac":   imageHtml = finalArray[i][1];
```

```
    break;
    case "caa":   imageHtml = finalArray[i][2];
    break;
    case "cuc":   imageHtml = finalArray[i][3];
    break;
    case "cua":  imageHtml= finalArray[i][4];
    break;
    case "sac":   imageHtml =  finalArray[i][5];
    break;
    case "saa":   imageHtml = finalArray[i][6];
    break;
    case "suc":  imageHtml = finalArray[i][7];
    break;
    case "sua":   imageHtml = finalArray[i][8];
    break;
  }


  var timeStr = "answertime" + (questionNum + 1);
  getNextTime(timeStr);

  var imageStr = "img" + questionNum + "." + answer;
  document.getElementById(imageStr).style.border = "thick solid
   #000000";

  var source = document.getElementById(imageStr).src,
  answerStr = "answer" + (questionNum + 1),
```

```
correct = "correctAnswer" + (questionNum + 1);


document.getElementById(answerStr).value = source;

document.getElementById(correct).value = imageHtml;


var answerid = "answer" + (questionNum + 1) + ".1";
document.getElementById(answerid).disabled = false;

var imageStr1 = "img" + questionNum + ".1",
imageStr2 = "img" + questionNum + ".2",
imageStr3 = "img" + questionNum + ".3",
imageStr4 = "img" + questionNum + ".4",
imageStr5 = "img" + questionNum + ".5",
imageStr6 = "img" + questionNum + ".6",
imageStr7 = "img" + questionNum + ".7",
imageStr8 = "img" + questionNum + ".8",
imageStr9 = "img" + questionNum + ".9";

setTimeout(function() {

   document.getElementById(imageStr1).onclick = "";
   document.getElementById(imageStr2).onclick = "";
   document.getElementById(imageStr3).onclick = "";
   document.getElementById(imageStr4).onclick = "";
```

```
        document.getElementById(imageStr5).onclick = "";
        document.getElementById(imageStr6).onclick = "";
        document.getElementById(imageStr7).onclick = "";
        document.getElementById(imageStr8).onclick = "";
        document.getElementById(imageStr9).onclick = "";

        }, 300);

        i++;
}

function newFilledArray(length, val) {
  var array = [];
  for (var i = 0; i < length; i++) {
    array[i] = val;
  }
  return array;
}


function afterOverall (){
  document.getElementById("overall").style.display = "none";
  document.getElementById("debriefing").style.display = "block";
  document.getElementById("submitButton").style.display = "block";
}


```

```
function showTarget(id1, id2) {
  document.getElementById(id1).style.display = "none";
  document.getElementById(id2).style.display = "block";

  var imgStr = "img" + i + ".0";




  switch(finalArray[i][0]) {
    case "cac":  document.getElementById(imgStr).src = finalArray[i][1];
    break;
    case "caa":  document.getElementById(imgStr).src = finalArray[i][2];
    break;
    case "cuc":  document.getElementById(imgStr).src = finalArray[i][3];
    break;
    case "cua":  document.getElementById(imgStr).src = finalArray[i][4];
    break;
    case "sac":  document.getElementById(imgStr).src = finalArray[i][5];
    break;
    case "saa":  document.getElementById(imgStr).src = finalArray[i][6];
```

```
    break;
    case "suc":   document.getElementById(imgStr).src = finalArray[i
   ][7];
    break;
    case "sua":   document.getElementById(imgStr).src = finalArray[i
   ][8];
    break;
  }

  setTimeout(function() {
     document.getElementById(imgStr).style.display = "none";
     }, 2000);

}

function showDiv(id1, id2, t1) {

  // i is question number

  var imageStr1 = "img" + (i) + ".1",
  imageStr2 = "img" + (i) + ".2"
  imageStr3 = "img" + (i) + ".3"
  imageStr4 = "img" + (i) + ".4"
  imageStr5 = "img" + (i) + ".5"
  imageStr6 = "img" + (i) + ".6"
  imageStr7 = "img" + (i) + ".7"
  imageStr8 = "img" + (i) + ".8"
```

```
imageStr9 = "img" + (i) + ".9";

var iconOrderArray = [1, 2, 3, 4, 5, 6, 7, 8, 9];

var newOrderArray = chance.shuffle(iconOrderArray);


if (i < 64) {
  document.getElementById(imageStr1).src = finalArray[i][
 newOrderArray[0]];
  document.getElementById(imageStr2).src = finalArray[i][
 newOrderArray[1]];
  document.getElementById(imageStr3).src = finalArray[i][
 newOrderArray[2]];
  document.getElementById(imageStr4).src = finalArray[i][
 newOrderArray[3]];
  document.getElementById(imageStr5).src = finalArray[i][
 newOrderArray[4]];
  document.getElementById(imageStr6).src = finalArray[i][
 newOrderArray[5]];
  document.getElementById(imageStr7).src = finalArray[i][
 newOrderArray[6]];
  document.getElementById(imageStr8).src = finalArray[i][
 newOrderArray[7]];
  document.getElementById(imageStr9).src = finalArray[i][
 newOrderArray[8]];

```

```

    //var answerid = "answer" + (i+1);
    //document.getElementById(answerid).disabled = true;
  }

  //i++;

  getNextTime(t1);

  var answerid = "answer" + (i+1) + ".1";
  document.getElementById(answerid).disabled = true;


  document.getElementById(id1).style.display = "none";
  document.getElementById(id2).style.display = "block";

}


function getNextTime (t1) {

  var d = new Date();
  var x = document.getElementById(t1);

  x.value=d.getTime();
}
```