An icon recognition study on different simplicity levels

Qing Guo
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An icon recognition study on different simplicity levels

by

Qing Guo

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF FINE ARTS

Major: Graphic Design

Program of Study Committee:
Sunghyun Kang, Major Professor
Alex Braidwood
Suman Lee

Iowa State University
Ames, Iowa
2016

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Current smart phone carriers are sharing the same interface icon style, which is materialized drawing with filtered details. However “complex details can become confusing and may appear muddy at smaller sizes” (iOS human interface design guidelines, 2015). Therefore, The central aim of this study is to examine to what point viewers can recognize or feel lost in recognizing smart phone interface icons, in terms of simplicity levels. Then interface designers can design and produce simplified smart phone interface icons to save space on screens and make icons more clear at small sizes. This study included three survey parts to test the icon recognition of differently simplified icons. There were two phases in this study: in Phase 1, participants were asked to check all icons of five simplicity levels that they can recognize as the meaning of the label in each question’s stem. From the results of Phase 1, the most recognizable simplicity level of icons and simplest level of icons that participants could recognize were selected for Phase 2. Lastly, the researcher compared the icon recognition rates between the icons of these two simplicity levels. The results indicated that the extremely simplified icons had similar correct icon recognition rates as those of the relatively more detailed icons, and participants’ personal backgrounds (age, gender, educational background, first language, and currently used phone brand) affected the icon recognition.
CHAPTER 1. INTRODUCTION

Being a ‘global language’, icons stand for modern society, globalization or even high technology world; but it is never a new thing for human beings. Human ancestors had already begun to use icons to record information before they knew language. So we do not learn to use icons like we learn to read, to use tools or to operate machine, instead, we are born to have the ability of understanding icons. Understanding an icon is based on our visual perception, which is human instinct. Icons can be seen everywhere, no matter offline or online, physical or digital interfaces. They are commonly seen where information is needed to provide visually for viewers to grasp the main content easily and quickly, such as road signs, computer screens and machines’ control panels.

Summing up information visually and graphically, icons enjoy a relatively higher readability than text and even make text unnecessary in some situations (Mertz, 2012), especially for those people who are illiterate to certain language (Horton, 1994). Apart from higher readability, comparing with text, icons save space. What’s more, the less details an icon carries, the less space is needed to display this icon clearly (Torralba, 2009, pp. 123–131). Figure 1.1 illustrates that complex icon is relatively difficult to see all the details and to be recognized when it is at a reduced size comparing with large size. What’s more, “complex details can become confusing and may appear muddy at smaller sizes” (iOS human interface design guidelines, 2015). Otherwise, simplified icon is still recognizable with smaller size. But how simplified? What is the maximum simplify situation to carry enough information for viewers?
As smartphone has been becoming an increasingly indispensable tool not only for work, entertainment, but also for getting connected with the rest of the world, the ones shown on smartphone screens are very frequently used in our daily life. In 2015, more than 90% Americans used mobile phone, among them, more than 70% were smartphones (Anderson, 2015). Time spent on smartphone has been increasing to more than 2.5 hours a day per person; which is 5 times more than that in 2008 (Bosomworth, 2015). As the blooming of smartphone industry, some mobile phone brands gradually occupy the most of the market—Samsung, Apple and Lenovo shared around half of the whole market worldwide. Even though these smart phones were produced by these three different carriers, the existing icons on their interfaces look similar, in terms of design style and icon appearance. Every smartphone brand’s icons seem likely. The current icon situation is that they are sharing the same style—materialized drawing with filtered features, for
example the icons shown in figure 1.2. Apple tends to use flat solid colored geometrics; Samsung and Lenovo are more likely have 3-dimensional elements to be relatively more realistic.

<table>
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<th>Carrier</th>
<th>Camera</th>
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<td><img src="image" alt="Camera Icon" /></td>
<td><img src="image" alt="Browser Icon" /></td>
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</tr>
<tr>
<td>Apple</td>
<td><img src="image" alt="Camera Icon" /></td>
<td><img src="image" alt="Browser Icon" /></td>
<td><img src="image" alt="Email Icon" /></td>
</tr>
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<td>Lenovo</td>
<td><img src="image" alt="Camera Icon" /></td>
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</tr>
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*Figure 1.2: Icon research*

Therefore the purpose of this study is to examine to what point viewers can recognize or feel lost in recognizing smartphone interface icons, in terms of simplicity, in order to assist user interface designers to design and produce maximum simplified smartphone interface icons. In terms of styles, icons can be divided into five categories of how simplified the icons are: Photograph, drawing, Caricature, outline and silhouette.
(Horton, 1994, p138). Photograph is the most detailed and realistic level while silhouette is the maximum simple and abstract. This study will investigate how simplified the icons could be; whether a new guideline can be formed for designers to design more abstract and simplified but still recognizable icons.

Because of the icons’ function is to recall viewers’ memory leading to a direct connection between the icon and brain, through which viewers get the meaning; viewers existing knowledge can vary the way viewers understand the same icon. Viewers at different ages, with unequal educational backgrounds, or from various cultures form their unique existing memory in their mind, as a result, seeing one same objects will recall different memories for each individual viewer. In order to narrow down the differences between individuals, universal and widely familiar objects could be contained in icons. In order to produce effective, acceptable, and recognizable icons for broader viewer groups, designers should have the sense that how viewers decode, react with visual graphics, and how to encode icons appropriately as well. Since designing interfaces icons is for boosting the application’s usability (ISO, 1988).

In order to figure out how viewers see and react with icons, in this study, icons on smartphone interfaces is investigated to examine:

1. What point can viewers recognize icons on smartphone interfaces, in terms of different levels of simplicity?
2. How viewers’ recognition abilities vary, in terms of different age, gender, and educational background?
This study will be an online icon recognition test. Participants will be recruited through email sending to all ISU students, faculty, and stuff members. This study includes two phases: during the first phase, 1/3 of the participants will do 5 multiple selection questions asking participants to check which icons are recognizable to indicate the given meaning of the icons. From this phase, the maximum simplified level that can still be recognizable could be figured out. Icons for phase 2 will be selected based on the response from phase 1. The other 2/3 participants will give short answers to guess the meaning of icons shown to them. The confident level participants indicate with slider and the correct rate of their answers will confirm the results of phase 1. The hypothesis is that smartphone interface icon’s maximum simplified level might be tested out.

**Thesis Organization**

This thesis is presented in 5 chapters. Chapter 1 provides an introduction and objectives of this study, followed by Chapter 2, a review of relative literatures. The literature review part expounds theories mainly from perspectives of visual perception, the process of how human beings see visual element is explored; how icons work; and how to communicate with iconic language. Chapter 3 describes methodology of this study—both within group and between group tests are conducted. Participants are asked to do some multi-choice questions, slider questions and short answer questions aiming to achieve study objectives. Study results and data analysis are shown in Chapter 4, which reveals which simplicity level is the boundary between recognizable and not recognizable.
And how icon recognition differs for people with different backgrounds. The last Chapter concludes this study and indicates the study’s limitations and suggestions.
CHAPTER 2. LITERATURE REVIEW

2.1 Visual Perception

Humans are born to have visual perception and to understand through eyes. Visual perception cannot be fully annotated by languages in some cases, because languages are not innate perception, instead, language is conceptual (Arnheim, 1974, p1). Comparing with verbal language, visual perception has a direct path to contact with reality that existing in the natural world through our visual sensory (Arnheim, 1974, p2). According to Rudolf, it is obvious that the conceptual comes after the perceptual. Seeing is entirely subjective, visual experience depends on our own inner perception and upon the reality (Arnheim, 1974, p6). But what sorts of visual signals we can see? And perceptual mechanisms account for the visual perception?

2.1.1 Balance

How do we see physically? It is the light. Coming from the sun, light rays hit objects and are partly reflected to the lenses of our eyes. As soon as the light formats an image on the retina through the lens, our brain will get the electrochemical messages transferring from the light. When the message comes into our brains, humans need to analyze the visual experiences psychologically.

Inside of our brain, visual perception is not size, distance, angle or waves, these static measurements, but a perception of action psychologically (Arnheim, 1974, pp 16—17). Every aspect of visual perception is the psychological ‘perceptual forces’ that
show the tensions among objects (Arnheim, 1974, p 11). No one certain object is free from the influence of others and the influence of environment that it is located in. All the visual elements work as stimulus to provide the spatial tension, relationship and meaning of what we see (Arnheim, 1974, p 16). In another words, we don’t see things separately. Base on the distances, weights, locations, sizes and angles, there exist pull and push among all objects. For example, in Figure 2.1, when the distance between two objects is decreased, the pull will be weakened and at the same time the push will be stronger. Only in the situation that the forces of pulls equal the strength of pushes in opposite directions respectively, can the visual and psychological balance be achieved (Arnheim, 1974, p 19). Within a balanced composition, the whole system looks stable and standstill as well; the elements inside of it will not have a tendency to move. In a word, seeing is an action perception (Arnheim, 1974, p 16).

![Figure 2.1: The pull and the push.](image)

### 2.1.2 Shape

Seeing means grasping the essentials. By only one glance, you can tell the rectangularity of a building, roundness of a ball, the curve of hair, etc. One of the most outstanding features of visible stimulates is their shapes. We can see two kinds of shapes: one is a physical shape and the other one is a conceptual shape (Arnheim, 1974, p 47).
Physical shape is picked out by the physical boundary—edges, sides, outline; perceptual shape comes from the interaction among objects—shadow, gestalt, etc.

2.1.3 Form

Unlike shape, which pertains to the natural external appearance, form is the visible shape of content (Arnheim, 1974, p96). When we see a tree, first the shapes show the natural appearance of it, then we can tell it is a tree because we know the whole categorical form of trees. Archaeologists can recognize the image of animals by seeing the extremely simple and abstract shapes of ancient cave painting. Shape is always regarded as the form of one kind of object. In another words, form already goes beyond the basic visual quality of roundness or sharpness, strength or frailty, harmony or discord. Instead, forms are making statements about subjects ((Arnheim, 1974, p 97). In terms of that we recognize or fail to recognize an object or one of a category, the different visual conditions make difference.

When we see, our visual area provides a “frame,” retinal orientation, the so-called spatial orientation (Arnheim, 1974, p 99), which may lead to misunderstanding. For instance, by rotating 45 degrees, a square can be seen as a diamond shape. In addition to the retinal field, visual senses also rely on kinesthetic senses. As shown in Figure 2.2, the dynamic difference between these two pins is due to the gravity direction. The left pin is stable physically. But the right one tends to fall down, because the gravity direction is vertically downward and the tip of the right pin cannot support the pushpin balanced to counteract gravity.
After gaining knowledge of the shapes of certain kinds of objects, humans began to produce two-dimensional forms to represent three-dimensional forms. When real objects in nature are translated into their two-dimensional versions, the original axes, proportion, and location will be rearranged based on perspective. Harry Helson claimed that the principles of realism for the two-dimensional representation is not according to absolute physical qualities, but in relation to human’s pre-existing knowledge. The psychological reasons for this way that humans accepting the two-dimensional appearance as real is because in the human mind, recognition is based on correspondence of essential structural features instead of on detailed identity (Arnheim, 1974, p 141), which comes from visual expression and spatial relations. The styles of governing how many details form real nature can be defined as the level of abstraction. Thus can be expressed by stylized, sematic and symbolic. All the expression of visual interpretation can be translated into visual conception through organized abstracts carrying clear perceptual features.
2.1.4 Color

All visible elements in the world have their own brightness and colors (Arnheim, 1974, p 332). Only when the differences of colors or brightness exist, can our eyes distinguish the boundaries between objects or two areas. For example, shown in Figure 2.3, if a black circle is drawn on a black background, it is invisible, because both the square and background sharing the same color and brightness. But when this square is white, or black but with a white outline, it is obvious enough to be seen, since either the filled color or outline color differs from the background color. So it is easy to tell that applying different colors to distinguished shapes will greatly enrich visual discrimination.

![Figure 2.3: Different colors distinguish the boundaries between two areas.](image)

Rorschach discovered that cheerful people are more likely to be attracted by colors while depressed people tend to respond to shapes, which indicates that colors produce emotional experiences, whereas shapes are dealing with intellectual controls (Arnheim, 1974, p 336). Matisse also holds the similar idea that “If drawing is of the spirit and color of the senses, you must draw first, to cultivate the spirit and to be able to lead color into spiritual paths.” The projection of this theory can be found in other fields, for example, the rules of composer coming before lyricist.
How the colors look is determined by at least three dimensions: hue, brightness and saturation (Arnheim, 1974, p 346), but even the same color with exactly the same CMYK or RGB values looks different in two different contexts, because every hue, brightness and saturation in a whole system could be altered by every other piece of visible element added in; a certain color would be brighter when there is another darker color there; A red is redder when standing with green, which indicates that the identity of a color could be effected by the relationships to some degree. The most intensive relation is color contrast. These colors come in pairs or groups, they share extremely different hues, brightness or saturations. Contrast can emphasize the differences between two color areas, in order to make each other stand out. The counter effect, called assimilation, tends to waken the visual distinctness. When a color area is small enough or carrying similar color to others, these stimulates will approach each other instead of highlight each other and finally form an additive mixture (Arnheim, 1974, p 365).

Color can carry strong expression, even emotional connection with receptors, while the expression is based on situations and the receptors themselves. Standing for fire or blood, red’s meaning can vary from anger, revolution, and passion, to death, depending on different viewers’ backgrounds.

2.1.5 Dynamics

Dynamic property is inherent in our visual perceptions (Arnheim, 1974, p 365), which can be described by the natural movement and potential motion. Because of the inner kinesthesia sensory, humans can feel the motion and movement even on stable
graphics, where there is nothing physically moving. So the visual dynamics comes from reviewers’ perception, the inner resources. For example, the graphic in Figure 2.4 generates movements when reviewers see it, since the oblique positions, angles, curves and directions on the objects suggest a potential motions, which is similar to the actual motions in real life that reviewers remember in their minds. We know what motion looks like based on existing visual memories.

![Figure 2.4: Visual dynamics](image)

Visual dynamics is caused by directed tension that can lead to a possible motion. In another words, visual dynamics is psychological counterpart of physical motion. The more specific aspects of visual dynamics are direction, speed, and force (Arnheim, 1974, p 386). As shown in Figure 2.5, the dash lines give a clue of the possible physical motion path, which indicates the direction of movement. By seeing this Figure, viewers will have a visual perception to predict the direction. Figure 2.6 indicates that, relatively smaller objects move faster, while the object with a relatively bigger size seems to move slowly. In addition, smaller surroundings make for faster motion. Even though force could refer to a physical tension resource, it is a property inherent in shapes. Take Figure 2.7 as an example, the water ripples can indicate the motion of water.
Figure 2.5: Possible physical motion path

Figure 2.6: Relationship between the size and the speed.

Figure 2.7: Water ripples indicate the motion of water.
2. 2. Semiotics

Robert (1992) claimed that semiotics is a ‘study of signs, signification, and signifying system.’ It can be regarded as representation, signification, meaning, and reference. More specifically, semiotics is the study of meaning, meaning-making, sign processes, and meaningful communication (Oxford English Dictionary, 2003). It can be divided as three sub-branches: Semantics: study of meaning focusing on what meaning do words, phrases, signs, and symbols stand for (Caesar, 1999); Syntactics refers to the rules and principles of the structure of languages (Radford, 1988); and Pragmatics studies how context, time, speaker, receiver, existing knowledge and other effects contribute to meaning (Liu, 2009). Semiotics helps increasing human’s awareness of visual elements through metaphor. Its operations lead to the internal logic of visible signs, images and symbols by defining the meanings through visual elements (Nadin, Zakia, 1995, p115).

As we mentioned before, what signs or symbols show is an objective visual perception, but when it comes into human’s brain, it turns out to be a subjective interpretation.

Semiotics requires directness and clarity—all the elements used to show meanings should be directly and clearly associated with the specific meaning. In terms of existing knowledge, elements should vary when audiences are different, because what they know and can understand are based on their background knowledge. The meaning of a visual element is embedded with the context where it is (Nadin, Zakia, 1995, p127).
2.2.1 Sign, Object, and Interpretant

Peirce’s (Perce, 1931, P58) semiotics model states the relationship between sign, object, and interpretant. Paul Kockelman (2007) has the same understanding: Semiotics is the study of semiotics, a process involving three parts: ‘whatever stands for something else (sign), whatever sign stands for (object), and whatever a sign creates insofar as it stands for an object (interpretant).’ This logic relationship among those three components can be illustrated by Figure 2.8 as that a sign stands for its object (first) and interpretant (second), a sign containing an object can cause its interpretant (third), and the third relation and the first relation are corresponding (Kockelman, 2007). For example, in Figure 2.9, the sign is a commonly seen icon in many kinds of software. The object in this icon is the actual thing that this sign stands for—a hard disk; the interpretant is the meaning that created in viewer’s mind (Anderson, 1992). When a viewer looks at this icon, he or she will know that this icon is for saving his or her files, because what object this sign stands for and what this icon means are corresponding.

Figure 2.8: Relationship among sign, object, and interpretant. (Kockelman, 2007)
Therefore, A sign’s meaning is not self-evident, because a sign gets the meaning by being interpreted by a subsequent thought or reaction (Hoopes, 1991, p7). A sign stands for a certain meaning for a certain viewer through creating an equivalent interpretant in this viewer’s mind. And this equivalent is caused by the object(s) shown in this sign. Thus nothing is a sign until interpreted by an interpretation (Perce, 1931. p58). Peirce claimed that the meaning of a sign is not directly caused by visual perception, but, instead, is coming from the interpretation of the perception. In another word, interpretants predicate the natural relationship between the sign and the objects inside of this sign. Take Peirce’s favorite example, the interpretation of a weathercock, which indicates the wind direction for having a direct relation with wind—the wind determines the weathercock’s direction of pointing and rotation directly. James (1991) concluded that
'The meaning of every thought is established by a triadic relation, an interpretation of the thought as a sign of a determining object.'

2. 3. Icons

Icons are never a product of modern society, instead, they are one of the oldest communications that can be traced back to ancient ages. Before having languages to communicate, our ancestors began to express themselves by facial expression, postures and gestures (Horton, 1994, p1), and even by cave paintings that were found by modern archaeologists. Ancient people have used simple pictorial images standing for objects from nature to record, mark and communicate. For example, they draw abstract cows to record how many cows they owned, or mark ownership. In modern written Chinese language, we can still see the original objects in some characters as shown in Figure 2.10. Another ancestry of icon, Semantography, also known as Blissymbolics, designed by Charles Bliss, is defined as an ideographic writing system including “several hundred basic symbols, each representing a concept, which can be composed together to generate new symbols that represent new and more complex concepts” (http://www.blissymbolics.org/). Chinese can also be a nice example of combining basic symbols to form new complex symbols. It is not difficult to understand what semantography is through Figure 2.11. The first example is combining two basic symbols, “木” (Tree), together to form a new complex symbol, “林” (Forest). The second example is combining two basic symbols, “目” and “月” (Day and night), to form a new complex symbol, “明” (Tomorrow).
<table>
<thead>
<tr>
<th>Character (Basic symbol)</th>
<th>meaning</th>
<th>Character (New complex symbol)</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>木</td>
<td>Tree</td>
<td>林</td>
<td>Forest—many trees</td>
</tr>
<tr>
<td>日，月</td>
<td>Sun, Moon</td>
<td>明</td>
<td>Tomorrow—after one day and one night</td>
</tr>
</tbody>
</table>

**Figure 2.10:** Basic symbols in Chinese Characters

**Figure 2.11:** Combining basic symbols to form a new complex symbol.

So maybe we can imagine that, we are born to have the ability to read icons, which we can refer to visual perception coming before conceptual language.

Currently, icons are widely known because of the universal usage of computers, phones and other digital devices. We all know the small pictorial symbols, working as visual items carry meaning, used on the interfaces of those devices’ screens.
In terms of having icons on interfaces, it improves the effectiveness of sending and receiving information. Users can get the meaning of icons by just one glance without thinking, reading or translating, since visual perception is direct communication between receivers and stimuli. As a result, a well-designed and welled formatted icon can make the interaction between human and interfaces quicker and easier. Studies show that iconic signs can be read at twice the distance and in half the time as reading words (Horton, 1994, p3). Users will recognize it instantly and immediately, because visual perception comes before conceptual language. Additionally, picking out an icon on a crowded screen is less demanding than finding specific text (Figure 2.12), since identifying icons that have the featured and unique graphic shapes is much quicker than reading each of the word labels to find the specific one. It is especially that when the all text are in the same letter size, fonts and weight. Compared to text, which always appear in rectangle text squares containing dozens of letters, an icon only needs a few pixels; an icon sometimes can say more than text occupying same space as shown in Figure2.12 (Horton, 1994, p4). So for interfaces, using icons saves space. Most importantly, by adopting icons, users do not need to read any more. According to the CIA World Factbook, about 775,000,000 people worldwide are illiterate, and 14% of Americans cannot read functionally (http://www.statisticbrain.com). As the uses of smartphone is increasing universally, simply-understandable interfaces with the assistance of icons should be provided for less literate readers. When there is no language limitation and boundary, the product can be global.
Even though icons work so well, icons are not the whole story. Text and icons can get along with each other very well; they are not mutually exclusive. Think about the “STOP” sign that we see on road, text works directly and effectively in this case. An appropriate combination of text and icons could maintain a more widely acceptable interface by taking the cognitive psychology of people into consideration.

2.3.1 How viewers react to icons

But how can iconic graphics make sense as text does? How do people understand and react to icons? For successful icons, users are suppose to be able to decode, recognize, find and interact with them (Horton, 1994, p18).

2.3.1.1 Decoding

Decoding is technically a process of connecting the icon with the existing knowledge, so as to figure out what it is. When a viewer encounters an icon, he or she will try to find out the already existing concepts that are associated with this visual perception. If there is no matched pairs, this icon will be decomposed into simpler
graphics for matching familiar simpler concepts until this viewer can tell the meaning of this icon by combining all the separated subparts’ meanings together. So we can regard decoding as giving to a verbal concept a visual perception. When we look at an icon, what we see comes from our memories instead of from eyes only (Horton, 1994, p22). What we have already seen affects the way we see now and in the future, because we are tend to ‘see’ what we have already known.

To have a better effect, context, working as a catalyst, can be help to awake memories. Context is the situation that icons are located in; all the other visual elements in the same environment can act as context. Context has the ability to contribute different meanings to one single icon. For example the Figure 2.13, when an arrow shown individually, it is an arrow (a); when it stands with another same looking icon, it stands for direction (b); when there is another arrow with bigger size, it might refer to distance or strength (c).

\[ \text{Figure 2.13: Context has the ability to contribute different meanings.} \]
2.3.1.2 Recalling

Once we known the icon’s meaning, all we need to do when seeing it again is to just recognize it and to recall the meaning by wakening the verbal concepts form memories.

2.3.1.3 Finding

To find an icon, first thing is to predict what it probably looks like, which is closely related with our existing knowledge. The more distinguishing and correct visual characters an icon has, the easier viewers can locate it.

After seeing through the users eyes to know how they react to icons, we, designers, should come back and think about how to encode concepts into icons. The concepts of an icon can be communicated to viewers through two parts, one is the message itself, the other one is enablers (Horton, 1994, p30). The message stands for the real specific information that linked with viewers’ inner memories and existing knowledge; while the enable can be the context, design styles, and those kinds of emotional connections that speed the understanding. The only way to test whether the message or enablers are appropriate or not is to test with real users.

2.3.2 How to encode icons

2.3.2.1 Communicate graphically

To communicate, medium is essential. For example, when we talk, language is the medium, and the reason why we can communicate smoothly is because we share the
same signals, we are on the same channel. So when we want to use icons to communicate, the first thing is to share the same concepts between designers and users, which is never an easy task. But every hard problem will be solved in the right way.

Showing real existing natural objects is a shortcut to show an object shared by senders and receivers, because we see the world in a common way. One study run by Rungtai Lin (Lin, 1994) shows that the highly recognized icons always have strong ties with a real existing object. “Skeuomorphism” as a design principle also indicates that: design cues should be taken from the physical world. The design aiming to recall the real existing world makes visual elements more familiar to viewers (Cho, Kwon, Na, Suk, Lee, 2015CHI). Another study found that participants had a tendency to associate physical objects with the meaning of the icon (Sengupta, Chang, Wan, and Chua, 2015 CHI).

Therefore, designers should show the directly respective and commonly seen object related to the message if it is possible, which is the most reliable way to get connection between designers and users. For example, using a shoe icon to refer to the meaning of ‘shoes’. But in our real life, not all concepts can be understood by real referencing objects, at this time, associated object contributes to assist viewers to get the specific message. When we cannot show an idea directly by one single object, we can use the logically related objects to assist viewers to think about the real idea. Logically related objects can be a) the objects causing the activity, like tools; b) representative elements for certain ideas, for example stethoscope stands for doctors; c) results caused by a real idea, the alignment icons in word is a good example right on this point(Horton, 1994, p37).

Besides showing direct or associated objects, as we mentioned earlier, text, like
numbers, letters, words, and symbols, can be also used as elements of icons. Also, spatial, dynamic values and graphical properties contribute to indicate certain activities and ideas.

2.3.2.2 Iconic language

To communicate, language is indispensable, no matter what the language is. It might be spoken language, facial expression or even body language. So for some points, we can consider icon as an iconic language. If the icon is language, vocabulary and grammar work as the two basic elements. For the icon, vocabulary is the collection of simple symbols; while the grammar refers to rules of how to combine each symbol together to have the units of expression (Horton, 1994, p112).

What makes meaning different is the law of vocabulary and grammar. a) First of all, vocabularies are what messages need to be presented. And for iconic language, vocabularies are the combination of basic symbols. Since icon is known as clarified, the messages(basic symbols) ought to be minimized and simplified to express the understandable meaning.

b) After having the list of messages, basic visual symbols are the next thing to be created as a collection of vocabulary, which will be combined together to contribute to the icon’s meaning. For each of the simple symbols, they should be easy to combine and rearrange. Like other common languages, English, Chinese, Japanese, etc. Iconic language’s vocabulary also has classification, including nouns, verbs, adverbs, adjectives, etc. In terms of nouns, it refers to object which has already been mentioned before, the direct and associated objects. Since verb means action, movements and dynamics can
indicate actions to work as verbs. According to section 2.1.5, psychologically move comes from perceptual tension caused by inner kinesthesia sensory to a possible motion. To stimulate viewers’ inner senses, graphic elements with different properties, for example dots and lines, could be adopted to indicate possible moving direction, speed and displacement. ‘Adverbs’ and ‘adjectives’ always come along with ‘nouns’ and ‘verbs’ to limit or modify the meaning by using contexts, different graphical elements’ weights, lengths, angles, and patterns.

c) What makes the combination of vocabularies readable and understandable is grammar: the rules for vocabularies working together. Thanks to grammar, all different kinds of combinations of vocabularies are predictable for viewers, which contributes to the more universal and acceptable communication.

This is more like a formula arranging how the elements should be shown and expressed. Designing every icon is like saying one sentence, the first thing that needs to be considered is that what is the most important, required, indispensable element. As soon as having the most essential vocabulary, we need to emphasize it. According to design principles and visual perception, contrast of color and size are two most commonly used methods to make one visual element stand out.

2.3.2.3 Icon design

Once having certain object(s) in mind, we, designers should decide how to design the certain icons. How big it should be? What style should to be adopted? What should it look like? The first thing needs to be considered is the style—how realistic, simplified,
detailed or minimalist? The mission of an icon is to recall viewers’ memory, as the existing knowledge, to assist them understand what this icon actually stands for. Therefore essential details that can recall memory is enough for an icon. But what those appropriate and essential details need to be is explored more in the following content.

Icons can be classified into five levels of realism detailed: photograph, drawing, Caricature, outline and silhouette (Horton, 1994, p138).

a. **Photographic icon**

When the object in an icon can be recognized only with high level of details, photograph can work as an icon. For instance, the landmark icons (photos) used for electronic maps. The common uses of photographic icons are aiming to indicate specific objects. Even though, photographic icons are easy and correctly recognizable for users, it requires a large space to show objects with so many details realistically. According to Antonio Torralba, when a photograph is the size of 64x64 pixels, the correct recognition rate can be higher than 90% (Torralba, 2009), while normal icon only needs 32x32 pixels.

![Figure 2.14: The correct recognition rate can be higher than 90%, when a photograph’s size is bigger than 64 x 64 pixels. (Visual Neuroscience (2009), 26, 123–131. 2009 Cambridge University Press 0952-5238/09)](image-url)
b. Drawings

Drawing is the production of simplified details. Here, the details are not as many as that for photography, but are simplified and filtered as necessary. The drawing icon style contributes to distinguish among objects that share similar profiles (Horton, 1994, p140), when inner features are needed to be distinguishing. Take Obama’s identification icon used in the US presidential election as an example, this icon shows President Obama’s face displaying clear and recognizable facial features through blue and red colors. Almost all human’s faces share the similar round shapes, similar size; we all have two eyes, one nose and one mouth, and hair. What’s more is that their positions are almost the same; so only if giving enough recognizable details, can we recognize Obama’s face from others’.

c. Caricature

Compared with drawing, caricature-style is not only filtering details but also summing up, strengthening, and exaggerating the features (Horton, 1994, p138). For instance, as shown in Figure 2.15 (A stands for realistic and B stands for exaggerated), in Example 1, we enlarge the ‘+’ to make it much bigger than it would be on a real first aid box to emphasis this is for first aid. In Example 2, reduce the number of keys and enlarge the size of each keys on keyboard to make them stand out; Example 3 shows adding movement lines to car to make it more likely to be speedy or exaggerate the curve angle and frequency to emphasis the continuous sharp turn in order to call viewers attention. Caricature-style is often used for objects that are familiar to viewers to accelerate the viewers recognition and draw their attention.
d. Outline

Outline is the second most simplicity level, which can be adopted for those objects with obviously distinguished profiles (Horton, 1994, p138). Outline-style icons show objects only with edges and minimize internal detail lines as necessary, which is indicated in figure 2.16. In this example, both hammer and open book have distinguished profiles.
e. Silhouette

Silhouette is the highest level of simplicity. Like we shaped an eagle shadow on the wall in front of a light using our hands, when we were children, shadow can shape things. Silhouette, which refers to shadow, shapes things filled with one single solid color. The same as outline-style icons, the icons with silhouette-style need to have a distinguished profile. Figure 2.17 shows examples for silhouette.

![Figure 2.17: Silhouette icons.](image)

2.3.3 Icon standards

2.3.3.1 Standards

Everything has standards, and icons are no exception. There are standard parts for icons: border, background, image, label, and size. Because the purpose of this study is to figure out how people recognize icons visually, we will not include labels at this point.

Border and background are important for providing an unmistakable boundary for icons to make the icons stand out from clutters. Additionally border gives all icons a unified solid shape and size that their individual images do not have. In terms of size, the clickable icons on smartphones for finger touching is no smaller than 40*40 pixels (0.5*0.5 in). And Apple’s iPhone Human Interface Guidelines claims a target size of 44*44 pixels is the minimum (iOS human interface design guidelines, 2015).
2.3.3.2 IOS APP icon design guidelines

According to iOS Human Interface Guidelines, there are 12 guidelines to assist graphic designers designing App icons to be beautiful, memorable, and attractive in the App Store and stand out on interfaces. Among them, three guidelines are associated with this study:

a. “Use universal imagery that people will easily recognize.” (iOS Human Interface Design Guidelines, 2015)

iOS App icon design guidelines ask designers to avoid focusing obscure aspect of an element. Instead, universal elements should be used in icons. This point is same as what we mentioned in Section 2.3.2.1: highly recognized icons always have strong ties with a real existing object (Lin, 1994). Showing a universal visual element is the most reliable way to get connection between designers and users, and to make this icon universally acceptable.


This guideline recommends designers to have only one object in one icon and add details cautiously. What’s more, it claims that “complex details can become confusing and may appear muddy at smaller sizes”, which is holding the same opinion as this study.

c. “Create an abstract interpretation of your app’s main idea.” (iOS Human Interface Design Guidelines, 2015)

In this guideline, it claims that using a photograph as an icon rarely works, since the details of a photograph cannot be seen clearly at small sizes. This idea can be supported by the previous literature review: photograph cannot be seen clearly at the size
less than 64 x 64 pixels. Typically, “it’s better to interpret reality in an artistic way” to emphasize the features of an object that can assist viewers to interpret the object in this icon (iOS Human Interface Design Guidelines, 2015).

2.3.3.3 Samsung (Android) APP icon design guidelines

Android App icon design guidelines tend to guide designers to produce icons being three-dimensional with edge effects, gradients and textures:

a. Icons are required to be three-dimensional, front view, and with a slight perspective from above, in order to give viewers a perspective of depth. (Android Developer, 2013)

b. Icons should have a distinct silhouette (shape), instead of simple shapes, like square or circle. (Android Developer, 2013)

c. “Icons should be simple at the macro level but still detailed at the micro level.” For example, having gradients and textures. (Android Developer, 2013)

d. Icons should have drop shadow as their backgrounds. (Android Developer, 2013)

2.4 Simplicity

According to Oxford Dictionary, simplicity the quality of being easy or un-combined to understand or use. But simple never means minimal, in another words, the character is the only thing that exists (Colborne, 2011, p10). If an icon is simple,
viewers can only focus on the most essential characters, therefore, the process of getting information will be quickly and directly. Because there is no unnecessary visual element that will distract viewers encoding this icon. There are several solutions to the problem of simplifying an icon. Next will describe how to simplify an icon.

2.4.1 Remove—Get the rid of all the unnecessaries

Any element that is not necessary or indispensable for viewers to recognize an icon is visual clutter. Removing those visual clutter contributes to filter visual elements and let viewers concentrate on the most essential things. To remove visual clutter, Colborne (2011) suggested that:

a. Limit emphasis, which means don’t using bold or large elements for multiple places. Instead, emphasizing only one or two important elements.

b. Limit levels. Don’t have more than two levels of information. For instance, limiting the diversity of sizes, weights, and numbers.

c. Limits shapes to reduce the variation in shapes of visual elements.

2.4.2 Organize—Arrange all elements

When visual simplicity cannot be achieved by removing, organizing is another great way to make visual elements less demanding to view. Lining things up by the assist of Grid system can lead to a simplified layout that clear and easy to view.
CHAPTER 3. METHODOLOGY

3.1 Methodology Introduction

The object of this study was to examine to what point viewers can recognize or feel lost in recognizing smartphone interface icons, in terms of simplicity. The results can be used in order to assist user interface designers to design and produce maximum simplified smartphone interface icons. The methodology section describes the approach used in this study. Initially three online surveys were conducted to examine how and to what point that viewers can recognize or feel lost in recognizing icons on smartphone interfaces, in terms of icon’s simplicity level. After receiving Institutional Review Board approval, the online surveys were conducted to better comprehend icon recognition at Iowa State University. There were two phases in this study. Phase 1 included Part 1, and Phase 2 included Part 2 and Part 3. All participants were recruited by email sending out to all currently enrolled Iowa State University students. They were randomly and equally divided into three groups. Group 1 only completed Part 1, Group 2 only completed Part 2, and Group 3 only completed Part 3 (See Figure 3.1).

![Diagram](image)

**Figure 3.1:** Introduction of participants for each survey part
Because the main measure was to perceive icons’ simplicity relationship with icon recognition, in Phase 1, for each question, participants were shown five simplicity leveled icons and label in each stem. Participants were asked to check all icons of simplicity levels that they can recognize as the meaning of the label in each question’s stem. From the results of Phase 1 (Part 1), the most recognizable level of icons and simplest level of icons that participants could recognize were selected for Phase 2 (Part 2 and 3). For Phase 2, in both Part 2 and 3, participants were asked to guess the meaning of the icons without seeing label in stem. They wrote down their answers and indicated how did they feel confident with their answers using sliders in each question.

This chapter covers how study materials were created, how participants were recruited, how this study was designed, and the procedure of two phases in this study.

3.2 Study Materials

To conduct this survey, the researcher designed 25 smartphone icons focusing on five smartphone first-depth functions: Phone Call, Message, Email, Camera, and Browser. Each function had five icons at five simplicity levels: Drawing, Caricature, Outline, Silhouette, and Form-reduction. All these 25 icons were used in survey Part 1. Icons of Part 2 and Part 3 were selected from these 25 icons based on Part 1’s results. In part 1, there were five questions including five icons respectively. For each question, participants were asked to check all icons that they thought indicating the meaning shown to them by label in each stem. From Part 1’s results, the most recognizable level’s icons
were selected and used for Part 2, and the simplest recognizable level’s icons were used in Part 3. In Part 2 and Part 3 to exam whether the simplest ones were the maximum simplified ones for viewers to recognize without label. Next, the icon design process will be described.

### 3.2.1 Icon Study

#### 3.2.1.1 The most frequently used icons

According to a study run by Weijie Tang in 2012, the most frequently used first depth functions on smartphone were phone call, camera, message, browser, and email (http://www.ithome.com/html/digi/17719.htm). More specifically, in this study, 99% smartphone users claimed phone call was the most frequently used app on their smartphones, 76% users used camera the most frequently, 72% of them accessed message the most, 38% users regarded browser was the App they used for the longest time, and 34% for email.

#### 3.2.1.2 Top three brands

In 2014 and 2015, the top ten widely used mobile phones brands are indicated in Table 3.1. Among them, in the fourth quarter of 2014, both Samsung and Apple shared 20.1% of the whole smartphone market worldwide; followed by Lenovo holding 6.6% market share. In the first quarter of 2015, Samsung’s sale rose up to 24.3% with 82.8 million units leading position in smartphone segment. Apple was the second largest smartphone carrier in this year with a 17.9% marketing share. Lenovo was still the third
top brand grabbing a 5.5% market share

(\http://www.phonearena.com/news/Top-10-smartphone-makers-in-Q1-2015-Sony-and-Microsoft-drop-out-of-the-picture-Chinese-phone-makers-take-over_id69643). In both these two years, these top three smartphone carriers occupied around half of the entire market share. Being the top three welcomed brands and accepted by half of the smartphone users form different backgrounds in the world, their interfaces were widely and universal accepted by viewers. Therefore, the icons used by these three brands’ smartphones were collected and compared.

**Table 3.1 Top 10 smart phones brands in 2014 and 2015**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Manufacturer</th>
<th>Units</th>
<th>Market share Q1 2015</th>
<th>Market share Q4 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 (1)</td>
<td>Samsung</td>
<td>82.8</td>
<td>24.3%</td>
<td>20.10%</td>
</tr>
<tr>
<td>#2 (2)</td>
<td>Apple</td>
<td>61.6</td>
<td>17.9%</td>
<td>20.10%</td>
</tr>
<tr>
<td>#3 (3T)</td>
<td>Lenovo</td>
<td>18.7</td>
<td>5.5%</td>
<td>6.60%</td>
</tr>
<tr>
<td>#4 (3T)</td>
<td>Huawei</td>
<td>17.5</td>
<td>5.1%</td>
<td>6.60%</td>
</tr>
<tr>
<td>#5 (7)</td>
<td>LG</td>
<td>15.4</td>
<td>4.5%</td>
<td>4.20%</td>
</tr>
<tr>
<td>#6 (5)</td>
<td>Xiaomi</td>
<td>15</td>
<td>4.4%</td>
<td>4.60%</td>
</tr>
<tr>
<td>#7 (9)</td>
<td>ZTE</td>
<td>12.5</td>
<td>3.5%</td>
<td>3.60%</td>
</tr>
<tr>
<td>#8 (8)</td>
<td>Coolpad/Yulong</td>
<td>11.5</td>
<td>3.4%</td>
<td>4%</td>
</tr>
<tr>
<td>#9 (6)</td>
<td>TCL/Alcatel</td>
<td>9.7</td>
<td>2.8%</td>
<td>4.50%</td>
</tr>
<tr>
<td>#10 (-)</td>
<td>Vivo</td>
<td>9.3</td>
<td>2.7%</td>
<td>3.10%</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>97.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>340.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Five most commonly used App’s icons of three brands are listed in Table 3.2. The first impression by a quick glance is that Apple and Samsung icons’ shapes were square with round corners, but Lenovo’s icons shapes were prefect round. Additionally, It is
obvious that generally, all the icons were designed as materialized drawing with filtered features. Among these three brands, Samsung and Lenovo, these two Asian smartphone brands, tended to adopt gradient colors, lighting effects to create a relative more realistic styled drawing; Apple mainly used flat and solid colored geometrics to build the icons. The phone call icon and message icon for Apple were extremely simple, which could be regarded as ‘Silhouette’ according to previous literature review. But the other three icons, camera, browser, and email still tended to be closer to drawing.

As Peirce stated that the interpretation of an icon is corresponding with the objects that shown in this icon, objects in all icons were compared and analyzed. In terms of objects, all three brands shared the same objects to indicate ‘phone call’ and ‘camera’. They all chose the side view of real phone receiver’s and front view of camera’s as their objects that displayed in their icons. For message, Samsung used real existing envelope and notes paper as the objects; both Apple and Lenovo designed the message icons with showing chat bubble that appears on screen when people chatting on smartphone. Browser is very worth mentioning because Apple’s object, a compass, was distinguished different from the other two brands who used earth to express the internet is everywhere around the world. The last one was email. All these three brands had envelope as their object, but what worth mentioning is that both Lenovo and Samsung also included a ‘@’ sign, which is the indispensable and most distinctive part of an email address.
Table 3.2: Five most commonly used smartphone functions of each of the three top phone brands

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Phone call</th>
<th>Camera</th>
<th>message</th>
<th>Browser</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
</tr>
<tr>
<td>Apple</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
</tr>
<tr>
<td>Lenovo</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
<td>[Icon]</td>
</tr>
</tbody>
</table>

3.2.2 Icon design

To exam icon recognition of five most frequently used first depth functions on smartphone, researcher designed icons indicating these five functions at different simplicity levels. There were five simplicity levels for each function’s icons to exam to what point participants recognize or feel lost in recognizing icons at different simplicity levels. Hence 25 icons were designed in total — five icons for each function. This section describes how these icons were designed.
3.2.2.1 Standard parts

Firstly, According to previous literature review, border and background work for providing an unmistakable boundary for icon and making icon more out standing form clutters and giving all icons a unified solid shape and size that their individual images do not have (Horton, 1994). Researcher adopted border and background for all icons that designed for this study, in order to reduce the affects on recognition that might be caused by different shapes or sizes of icons.

Second, for the size of icons, researcher designed the icons with size of 44 x 44 pixels, since Apple’s iPhone Human Interface Guidelines claims target size of 44*44 pixels is the minimum. (https://developer.apple.com). But the icons’ actual size appearing in surveys was 88 x 88 pixels (twice as big as the standard icon size). Because a study run by Ankrum, D.R. (1999) showed that the comfortable eye-to-computer distance is at least 25 inches, which is twice as far as the eye-to-phone distance (12 inches).

3.2.2.2 Objects

James Hoopes (1991, p7) said that a sign’s meaning is not self-evident, because a sign gets the “meaning by being interpreted by a subsequent thought or reaction”. A sign stands for a certain meaning for a certain viewer through creating an equivalent interpretant in this viewer’s mind. And this equivalent is caused by the object(s) shown in this sign. Also, William Horton (Horton, 1994, p22) claimed that decoding icon is technically a process of connecting the icon with the existing knowledge. When a viewer is encountered an icon, he or she will try to find out the already existed concepts that
associated with the visual objects in this icon. In reference with literature review, for each function, the five simplicity levels’ icons shared one same object. Thus, different simplicity levels were the only one independent variable that affected participants’ recognition. In another word, the results could be more reliable to exam how simplicity levels affect icon recognition.

According to William, there are two main principles to choose appropriate objects to stimulate viewers’ interpretation. One is showing direct associate object; the other one is showing logical related objects: a) the objects causing the activity; b) representative elements for certain ideas; c) results caused by this real idea (Horton, 1994).

(1) Phone Call’s representative object was a smartphone with sound waves. This icon’s object was the direct object, phone, and the result caused by this idea was the sound waves. (2) Message — chart bubble and keyboard. Chart bubble was the directly related object; keyboard was the tool causing this activity. (3) Email — envelope. Envelope was representative element for email, because we do not really use envelope to mail email. (4) Camera — front view of a camera, the direct related object. (5) Browser — worldwide net. The worldwide net is the object that makes browser work. Every icon was designed using its own object(s). (See Figure 3.2)
3.2.2.3 Style

Icons can be classified into five degrees of realism: Photograph, drawing, Caricature, outline and silhouette (Horton, 1994, p138).

According to literature review, Photograph is the style that directly showing a photo of real objects, and requires no less than 64 x 64 pixels to display (Torralba, 2009).
Photograph icons are too obvious and detailed, and their minimum space requirement is significantly bigger than the touchable icon standard size (44 x 44 pixels) (https://developer.apple.com 2015). And According to iOS App design guideline “It rarely works well to use a photo or screenshot in an app icon because photographic details can be very hard to see at small sizes. Typically, it’s better to interpret reality in an artistic way, because doing so lets you emphasize the aspects of the subject that you want users to notice.” (https://developer.apple.com 2015) Therefore photography icons were not included in this study.

Additionally, since the purpose of this study was to exam the recognizable maximum simplicity level of icons, and in order to exam how far we can go, researcher added an extremely simplicity level: form reduction. The form reduction is a style that reflects the definition of simplicity in Oxford Dictionary: the quality of being easy or un-combined to understand or use and there is no unnecessary visual elements.

a. Drawing

Drawing is materialized expression with filtered and necessary details and features. In this simplicity level, researcher designed icons using the objects with filtered features (See Figure 3.3). (1) For phone call, the object, smartphone was drawn with filtered details, like screen, home button, light sensor, and sounds wave, etc. (2) In message’s icon, keys in keyboard, and ellipsis inside of chat bubble were shown to indicate the process of typing text in message application on smart phone. (3) In terms of email, the decoration patterns around the envelope made it easy for viewers to recognize it as an
envelope. Putting this envelope in front of two computers with arrows indicating in and out also indicated the process of sending and receiving email. (4) The camera icon was drawn to show its details including lens, flash, and shutter. (5) Browser was expressed by displaying an earth surrounded by a sphere net and computers to indicate the meaning of using browser.

![Figure 3.3: Five drawing-style icons](image)

**b. Caricature**

Caricature is a style that not only filtering details but also summing up, strengthening, and exaggerating the features (See Figure 3.4). In this level, researcher exaggerated sound of phone call; the process of using keyboard to type; the speed of sending and receiving email; size of the lens of camera; and the worldwide net of internet. At the same time, some unnecessary details were removed. For example, the detailed structures of phone, the computers used for sending and receiving email, shutter of camera, and the computers connected by Internet.

![Figure 3.4: Five caricature-style icons](image)
c. Outline

In Figure 3.5, outline-style icons showed objects only with edges, profile, and minimize internal detail lines as necessary. In this simplicity level, all objects were shown with only profile and the most necessary inner features to make them being distinguished from the objects with same profiles or shapes.

![Figure 3.5: Five outline-style icons](image)

d. Silhouette

Silhouette, which refers to shadow, shaped things filled with one single solid color. All icons with silhouette-style had a solid color filling their profile shapes and without specifying inner details. (See Figure 3.6)

![Figure 3.6: Five silhouette-style icons](image)
e. Form-reduction

Form-reduction-style is the simple style with uncombined element to show the most distinguish and necessary element (See Figure 3.7). Because simple means no combined elements, being the most simplified style, every icon had only one visual element in this icon. With the aiming to make the icons being extremely simplified, all profiles of the objects were removed in icons, and only the most distinguished visual elements were kept. All visual elements were displayed by basic graphic property — lines.

![Form-reduction-style icons](image)

**Figure 3.7: Five form-reduction-style icons**

3.2.2.4 Modified icons for Part 3

As shown in Figure 3.8, (a) were the original designs of form-reduction-style icons used in Part 1, Figure 3.8 (b) were the modified ones that used for Part 3. For “Phone call” icon, neatly arranged small dots indicating speaker were added beside the sound waves to give viewers more clues. For “Message” icon, researcher added upward curve angles to the both sides of the straight lines’ edges in order to make the lines have an upward trend that could assist viewers to form the whole shape of chart bubble in their mind. “Email” icon was modified by changing the sharp corner into a round corner to make the icon look more natural. To make the “Camera” icon more recognizable, a little round cornered
rectangle indicating flash was added at the right top corner of the circle. In the modified “Browser” icon, researcher still showed a part of the net, but instead of the original one, a new view-point was used to show the right top part of the sphere net, in order to give viewers a better perspective of the whole sphere.

![Images of modified icons](image)

Figure 3.8: Modified form-reduction-style icons for survey Part 3

3.3 Study Participants

To conduct this survey, mass email list of all currently enrolled students in Iowa State University student was requested from the Registrar’s Office in advance. Since this survey needed three groups of participants to answer the three parts of this survey separately and independently, the mass email list was randomly and equally divided into three parts by the Registrar’s Office and labeled as ‘List 1’, ‘List 2’, and ‘List 3’. One
student could be assigned only to one group, in another words, there was no overlapping between each two groups. Group 1 received recruiting email for part 1, group 2 received recruiting email for part 2, and group 3 received recruiting email for part 3.

The recruiting emails containing invitations, introductions of survey Part 1, Part 2, and Part 3 were sent to “List 1”, “List 2”, and “List 3” by Iowa State University Solution Center before each phase. In each email, there was a link bring participants to the survey. Thus students in “List 1” got the link bringing them to survey Part1, students in “List 2” got the link of survey Part 2, and students in “List 3” had the link to survey Part3. As a result, 556 students participated in part 1 and 528 of them completed the entire part 1. 462 students participated in part 2 and 415 of them completed the entire part 2. 426 students participated in part 3 and 394 of them completed the entire part 3. All of the participants were 18 years old or older when this study was conducted.

3.3.1 Entrance survey

At the beginning of each survey part, the participants were asked provide personal information, which included questions about gender, age, educational background level, first language, and current used phone brand.

The following questions were asked to gather data in order to examine how icon recognition varied between people with different backgrounds:

1. Please indicate you age at:

2. What's your gender?

3. What's your educational background?
4. What's your first language?

5. What's the brand of the phone you are using now?

3.4 Study Design

Because of the objective of this study was to examine to what point viewers can recognize or feel lost in recognizing smartphone interface icons, in terms of simplicity. Icons at different simplicity levels were designed to test how participants recognize them. There were two phases in this study. Phase 1 included part 1 (See APPENDIX D), and phase 2 included part 2 (See APPENDIX E) and part 3 (See APPENDIX F). Group 1 only completed part 1, group 2 only completed part 2, and group 3 only completed part 3. From the results of phase 1 (part 1), the most recognizable icons and the simplest recognizable icons were selected for phase 2 (part 2 and 3). In the stems of all questions in both two phases, participants were told that the icons were shown on smartphone interfaces to assist them recognize icons. Because the meaning of a visual element is embedded with the context where it is (Semiotic-advertising, pp127).

3.4.1 Phase 1

In Phase 1, participants in Group 1 completed survey Part 1 (APPENDIX D). There were five multiple choices questions. Each question focused on one smartphone function. That means that Part 1 had questions about five smartphone functions including phone call, message, email, browser, and camera. As shown in Figure 3.9, participants could choose as many as they would like to have. All of these five questions had the same stem
to ask participants questions. Each question focused on one of the five smartphone functions, and the label of any specific function was shown in the stem. For example, one of these five questions was: “Select icon(s) that indicate(s) 'Phone call'. Please check all that applied. (Multiple Answer)”. Below each stem, five different simplicity-leveled icons were displayed. Each of the five icons stood for five different simplicity levels: Drawing, Caricature, outline, silhouette, and form-reduction based on previous research. Drawing was the most detailed level, and the form-reduction was the simplest level. In each question, five icons were randomly arranged instead of arranging in order to avoid that some participants would probably guess the hypothesis or the purpose of this study. In addition, one webpage only displayed one question, as a result, participants could only see the current question that he or she were working on without being interrupted or affected by the stems or icons from other questions. After answering one question, the participants could click one the “Next” button to bring them to the next question. (Figure 3.10)

3.4.2 Phase 2

In Phase 2, Part 2 and Part 3 were two parallel surveys. They were conducted at the same time. Participants in Group 2 completed the survey Part 2 (APPENDIX E) and participants in Group 3 completed survey Part 3 (APPENDIX F), respectively and independently. Part 2 and Part 3 shared the same stem, but the icons used for each part were different. All the icons tested in Phase 2, both Part 2 and Part 3, were selected from Phase 1, Part 1, based on the results of Part 1.
Figure 3.9: Survey Part 1 questions
According to Part 1 results, the outline-style icons were the most recognizable for participants. And because the study purpose was to find out the breaking point that make viewers recognize or feel lost in recognizing icons, in terms of simplicity. Researcher wanted to test how simplified the icons could be for viewers to recognize. The data of silhouette and form-reduction styles were compared, which showed that silhouette-style icons did not really indicate the correct meaning of the icons in three questions. And the form-reduction-style icons were more recognizable than silhouette-style icons in three question. Therefore, outline-style and form-reduction-style icons were selected for Part2 and Part3 to compare the icons recognition of these two simplicity levels in order to figure out how simplified icons could be.

In Part 2, five outline-style icons of five functions were adopted, since the
statistically relative higher recognition rate of this level. In Part 3, form-reduction icons were selected, because in Part 1, form-reduction icons were still recognizable for many participants even though they were simplicity by removing profiles.

As shown in Figure 3.11 (a, b, c, d, e), Part 2 contained five short-answer and slider questions each showing one icon. Each question represented one of the five smartphone functions: phone call, message, email, browser, and camera. Each function was displayed in one question. Each question contained one outline-style icon, resulting in five unique questions. The order of these questions was randomly assigned by the researcher. Without showing the label of each icon in stems, each question asked participants to guess the meaning of each icon, write down the answer in blank, and indicate how confident did they felt with their answers. It is worth mentioning that, there was no word limitation for each short answer question, therefore participants could type down what they thought was correct to answer this question. By doing so, we didn’t limit participants’ answers. In terms of the layout of Part 2, it was still the same as that for Part 1. One webpage only displayed one question in order to reduce the impact from other questions. After answering one question, the participants could click one the “Next” button to bring them to the next question.

Part 3’s stems and layouts were exactly the same as that for Part 2. But the icons tested in Part 3 were at a different simplicity level. Icons used in Part 3 were the form-reduction-style icons selected from Part 1’s results. In order to make form-reduction-style icons more recognizable for viewers, all five icons at this simplicity level were modified before conducting Part 3.
1/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

2/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:
3/5. What function does this icon stand for, if you see it on a **smartphone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

4/5. What function does this icon stand for, if you see it on a **smartphone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:
3.5 Study Tool

This online survey was made and conducted on Qualtrics, which is a website for creating surveys for study. Expect creating surveys, Qualtrics can also record all participants’ information and process for further data analysis. SPSS was used to calculate and analyze data.

3.6 Study Procedure

At the very beginning of all three survey parts, all participants were asked to read the informed consent (See APPENDIX B), participants could decide whether they would continue doing this survey or not. If they agreed, they were brought to the survey
questions; otherwise, they excited this survey automatically. By reading this informed consent, all participants were aware that their involvement were entirely voluntary and they could quit this survey at any time if they felt uncomfortable to answer the questions. The informed consent also introduced the purpose, benefits, risks, and confidentiality of this study. All participants were asked to answer a demographic entrance survey about personal background information, including gender, age, educational background, first language and the brand of the phone that currently used. This researcher notified all respondents that their data was protected on researcher’s personal computer with password.

As shown in Figure 3.12, during Phase 1: Participants of group 1 did survey Part 1 containing five multiple choices questions, asking participants to select all icon(s) that can indicate the given meaning (label) of the icons. Each of the questions has 5 choices, which stand for 5 levels of simplicity that from most detailed drawing to the simplest form-reduction style. These 5 choices of each question were randomly arranged, in order to avoid misleading, influencing subjects’ responses, and avoid some participants guessing the study hypothesis. After collecting data, all these 5 choices for each question were encoded using number 1 to 5 for data analysis in SPSS: 1 was minimum simplicity level and 5 was the maximum level.

Phase 2: After having all Part 1 data been collected and analyzed, we got the maximum simplify level that viewers can recognize and the most recognizable level. Then most recognizable level icons were used for survey Part 2, and the maximum simplified icons for each function were used for survey Part 3. In both Part 2 and Party3,
each question asked participants to guess and write down the meaning of the icon that they saw in the stem, and did slider questions to indicate how confident did they feel with their answers.

At last, data of part 2 and part3 was analyzed and compared in SPSS, so that the accepted maximum simplicity level of icon was figured out.

*Figure 3.12: Study Procedure*
CHAPTER 4. DATA ANALYSIS AND RESULTS

This chapter presents the results of the data analysis that answered the two research questions of this study:

1. To what point can viewers recognize icons on smartphone interfaces, in terms of different levels of simplicity?
2. How viewers’ recognition abilities vary, in terms of different age, gender, and educational background?

Before answering each research question, data were prepared for analyses.

4.1 Preparing Data

The data consisted of all information for both Phase 1 (Part 1) and Phase 2 (Part 2 and Part 3). The data were downloaded from Qualtrics into IBM Statistical Package for the Social Sciences (SPSS). All data were analyzed in SPSS. One-way analysis of variance (ANOVA) tests were conducted to examine significant effects. A significance level of $p \leq .05$ was used for all ANOVA analyses.

4.2 Data Analysis

In Phase 1, in order to examine to what point viewers recognize or feel lost in recognizing icons, in terms of different simplicity levels, icon recognition tests were investigated. If differences between each simplicity level’s icon recognition were found,
then those icons of the most recognizable level and simplest recognizable level would be selected for Phase 2. In Phase 2, icon recognition of these two levels would be compared. If significance level(s) were shown, gender, age, educational background, first language, and currently used phone brand’s significant effects on icon recognition would be revealed.

### 4.2.1 Phase 1 (Part 1)

#### 4.2.1.1 Part 1 data cleaning

In Phase 1, 528 participants of Group 1 completed survey Part 1. Among all participants of this part, 15 of them did not answer any question in this survey, two participants only answered demographic questions, and one quit during question three. In order to have valid character values, the researcher deleted these 18 participants’ data from SPSS. As a result, 510 participants’ data were analyzed.

#### 4.2.1.2 Part 1 participants’ demographic

As shown in Figure 4.1, Group 1 was composed of 279 female (54.7%) and 231 male (45.3%) students. The age distribution of the participants ranged from 18 to 64 years old (Figure 4.2). 74.7% of participants were from 18 to 24 years old, 22% — 25 to 34 years old, and 4% — older than 35 years old. In terms of educational backgrounds (Figure 4.3), 180 participants (35.3%) reported graduate educational background, 316 (62%) — undergraduate background, and 14 (2.5%) — high school or lower educational background. Of the 510 participants, 451 (88.4 %) were native speakers of English and
58 (11.6%) were not native speakers (Figure 4.4). One hundred and fifty-seven (30.8%) participants used Samsung phones, 251 (49.2%) — Apple, and 102 (20%) — other brands’ phones (Figure 4.5).

Figure 4.1: Part1 Gender Distribution

Figure 4.2: Part1 Age Distribution
Figure 4.3: Part 1 Educational background Distribution

Figure 4.4: Part 1 First Language Distribution

Figure 4.5: Part 1 Current Phone Brand Distribution
4.2.1.3 Part 1 results

There were five questions in Part 1. Each question focused on one smartphone function, and every question included five simplicity-leveled icons.

a. Survey Question 1

Figure 4.6 indicates recognition rate of each of the icons in Question 1. In the survey Question 1, all five icons were designed to stand for “Phone call”. For participants, outline-style icons were the most recognizable (53%), which means 53% of the participants recognized it as a “Phone call” icon on a smartphone interface. For Level 1 as seen in Figure 4.6, drawing-style, and Level 4, silhouette-style, had a similar recognition rate at 46% and 49%. The simplest one, form-reduction-style could be recognized by only 22% of participants, which was the lowest recognition rate, according to the statistical results of Question 1.

![Figure 4.6: Part 1 Question 1 Recognition Rate](image)
b. **Survey Question 2**

In terms of the results of Question 2 (See Figure 4.7), it is obvious that the Level 3, outline-style was the most recognizable with the recognition rate at 86%, followed by Level 4, Silhouette (72%). But Level 2, Caricature had only 34% of participant recognition, even though it had the same profile as that of Level 3 and 4. Half of the participants could recognize the drawing-style “Message” icon. And for Level 5, the form-reduction-style icons, approximately 1/3 of the participants could recognize it, even though it was extremely simplified.

*Figure 4.7: Part 1 Question 2 Recognition Rate*
c. Survey Question 3

As shown in Figure 4.8, in Question 3, Level 3, the outline-style “Email” icons were highly recognized by participants, with a recognition rate of 88%. It is worth mentioning that Level 4, Silhouette-style icons did not indicate “Email” for nearly all the participants. Only 7% of the participants checked it as recognizable. One interesting finding according to this question’s results was that the simpler level, form-reduction-style (37%), was more recognizable than the most detailed style, drawing-style (32%).

![Email Recognition Rate Chart](chart)

*Figure 4.8: Part 1 Question 3 Recognition Rate*
d. Survey Question 4

For the results of Question 4, generally, the simpler the icon style was, the lower recognition rate participants had (See Figure 4.9). For example, Level 1, the most detailed drawing-style was recognizable for as many as 89% participants. However, there was an exception that, Level 4, silhouette (9%) was less recognizable than Level 5, form-reduction (13%).

![Camera Recognition Rate](image)

*Figure 4.9: Part 1 Question 4 Recognition Rate*
e. Survey Question 5

As displayed in Figure 4.10, the two higher simplicity levels, silhouette- and form-reduction-style “Browser” icons were practically unrecognizable for participants, especially the silhouette, which had a very low recognition rate at 1%. Level 3, outline-style icons still had the highest recognition rate at 80%.

![Browser Recognition Rate](image)

*Figure 4.10: Part 1 Question 5 Recognition Rate*

f. Phase 1 Part 1 Results Conclusion

As shown in Figure 4.11, in four of the total five questions in Phase 1, Part1, outline-style icons were relatively more recognizable for participants than other styles icons. Especially in Question 2 (Message), Question 3 (Email), and Question 5 (Browser), more than 80% of the participants could recognize those outline-style icons. In Question
4 (Camera), even though the most recognizable style was drawing, the recognition rate of outline-style icon was still more than 50%. Therefore, we can infer that outline-style icons in these five questions were the most recognizable.

Additionally, it is worth mentioning that Level 4, silhouette-style icons always had lower recognition rates than that of other levels. Especially in Question 3, 4, and 5—less than 10% participants recognized those icons. There were only 1% participants that thought the silhouette of a sphere indicated browser in Question 5.

Lastly, even though Level 5, form-reduction-style icons were extremely simplified icons, they were still recognizable according to the results. In Question 1, form-reduction-style “Phone call” icon were recognizable for 22% participants, in Question 2, form-reduction-style “Message” icon’s recognition rate was 29%, and in Question 3, as many as 37% participants recognized the form-reduction-style “Email” icon. In Question 4 and 5, for the form-reduction-style icons, “Camera” and “Browser”, the recognition rates were 13% and 8% respectively. Even though the recognition rates of form-reduction-style icons in Question 4 and 5 were not as high as that of previous three questions, the recognition rates were still higher than that of the silhouette-style icons in these two questions.
Figure 4.11: Part 1 Results Conclusion
4.2.1.4 Icon selection for Phase 2

According to the Part 1’s results, outline-style icons had the highest recognition rates in four of the five questions. Because of the study was to find out how simplified the icons could be, the styles that more simple than outline-style were compared: The silhouette-style icons were recognizable for less than 10% participants in three of the five questions; but the form-reduction-style icons’ recognition rates that lower than 10% were only happened in one of the five questions. In order to figure out the simplest style that icons could be for viewers to recognize, outline and form-reduction-style icons were selected for Part 2 and Part 3 in Phase 2.

4.2.2 Phase 2 results (Part 2 and Part3)

4.2.2.1 Part 2 Data cleaning

There were six participants who did not answer any question in this survey part. In order to have valid character values, the researcher cleared these six participants’ data from the whole data set. Therefore, 409 participants’ data were analyzed in SPSS.

4.2.2.2 Part 2 Participants’ demographic

According to demographic data results, Group 2 (409 participants) was composed of 56% female and 44% male students (See Figure 4.12). As indicated in Figure 4.13, the age distribution of the subjects ranged from 18 to 54 years. 91% of them were from 18 to 24 years old, 7% participants were from 25 to 34 years old, and the percentages of both 35 to 44 years old and 45 to 54 years old were 1%. In terms of the research participants’
educational backgrounds, it was found that 9% of them had graduate backgrounds, 86% had undergraduate backgrounds, and 5% participants were with high school or lower educational backgrounds (Figure 4.14). Of the 409 participants shown in Figure 4.15, 95% were native speakers of English and 5% were not native speakers. According to Figure 4.16, 28% participants used Samsung phone, 57% used Apple, and 16% participants were using other brands’ phones.

Figure 4.12: Part2 Gender Distribution

Figure 4.13: Part2 Age Distribution
Figure 4.14: Part2 Educational background Distribution

Figure 4.15: Part2 First Language Distribution
4.2.2.3 Part 2 Results

Part 2 contained five short-answer and slider questions each showing one icon. Each question represented one of the five smartphone functions: phone call, message, email, camera, and browser. Participants guessed the meaning of icons in each question and indicated how confident they felt. The short-answer questions results of Part 2 are illustrated in Figure 4.17. It is obvious that the “Phone Call” icon shown in Question 1 had the lowest correct recognition rate at only 15.4%. However, an interesting phenomenon was that most participants thought that this icon stood for speaker, voice, volume, and so on, because they saw sound waves beside the phone. (See Figure 4.18) Except Question 1, the other four icons in each question were recognizable for most of the participants. Among them, more than 97% participants wrote down the correct answer of “Message” in Question 2 (Figure 4.19), and as many as 98% participants recognized the icon as “Camera” in Question 4 (Figure 4.20). The recognition rates of both Question 3 (Email) and Question 5 (Browser) were around 90%.
**Figure 4.17**: Part 2 Short-answer Questions Correct Rate Results

<table>
<thead>
<tr>
<th>Phone is ringing</th>
<th>Hotspot</th>
<th>Talking</th>
<th>sound on</th>
</tr>
</thead>
<tbody>
<tr>
<td>phone call</td>
<td>Speaker</td>
<td>Phone is on speaker</td>
<td>Volume</td>
</tr>
<tr>
<td>call</td>
<td>Sound</td>
<td>Wifi</td>
<td>SPEAKER</td>
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<td>Signal Strength</td>
<td>speaker phone</td>
<td>Speaker on</td>
</tr>
<tr>
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<td>Wifi</td>
<td>WIFI</td>
<td>speaker</td>
</tr>
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<td>WiFi</td>
<td>Speaker</td>
<td>wifi</td>
</tr>
<tr>
<td>Speaker</td>
<td>Wi-fi</td>
<td>Volume</td>
<td>speaker</td>
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<td>Speaker</td>
<td>NFC</td>
<td>Wifi</td>
</tr>
<tr>
<td>Speakers</td>
<td>sound</td>
<td>volume</td>
<td>Speaker</td>
</tr>
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<td>Wifi reception</td>
<td>WIFI enabled</td>
<td>Speakerphone</td>
</tr>
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<td>Speaker phone</td>
<td>Connecting</td>
<td>Bump</td>
<td>speaker</td>
</tr>
<tr>
<td>Speakerphone</td>
<td>Hotspot</td>
<td>Speaker</td>
<td>Audio</td>
</tr>
<tr>
<td>Speaker</td>
<td>speaker phone</td>
<td>sound</td>
<td>Ringer</td>
</tr>
</tbody>
</table>

**Figure 4.18**: Selected examples of Part 2 Participants’ Text Responses of “Phone Call” icon.
<table>
<thead>
<tr>
<th>Message</th>
<th>Text</th>
<th>messaging</th>
<th>text box/bubble</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text messaging</td>
<td>Message</td>
<td>Messaging</td>
<td>Text Message</td>
</tr>
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<td>Message</td>
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<td>message</td>
<td>text</td>
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<td>Text message</td>
<td>speech bubble</td>
<td>Text or call</td>
</tr>
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<td>Messaging</td>
<td>Message</td>
</tr>
<tr>
<td>message</td>
<td>Message</td>
<td>Chat</td>
<td>Messaging</td>
</tr>
<tr>
<td>Message</td>
<td>message/chat</td>
<td>Text</td>
<td>Text message</td>
</tr>
</tbody>
</table>

**Figure 4.19:** Selected examples of responses of “Message” icon in Part 2

<table>
<thead>
<tr>
<th>camera</th>
<th>Camera</th>
<th>camera</th>
<th>camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>camera</td>
<td>Camera</td>
<td>money</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>camera</td>
<td>Camera</td>
<td>camera</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>camera</td>
<td>camera</td>
<td>Camera</td>
<td>Money</td>
</tr>
<tr>
<td>Camera</td>
<td>camera</td>
<td>Camera</td>
<td>camera</td>
</tr>
<tr>
<td>camera</td>
<td>camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>camera</td>
<td>camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>camera</td>
<td>Camera</td>
<td>A rip off</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
</tbody>
</table>

**Figure 4.20:** Selected examples of responses of “Camera” icon in Part 2
It is worth mentioning that generally, the higher participants’ icon recognition rates were, the more confident the participants felt according to their self-reported confident level (See Table 4.1). Among all these five questions in Part 2, Question 1, “Phone Call” icon recognition, had a lowest correct recognition rate at 15.4%. And the mean value of participants’ confident levels was -0.1057, which means that participants tended to be somewhat not confident with their answers when they guessed the meaning of “Phone Call” icon in Part 2. “Browser” icon’s correct recognition rate was under 90%, and the mean value of participants confident level was at around 1.5. It indicates that when participants guessed the meaning of “Browser” icon, participants’ confident level was between somewhat confident and confident. For “Message”, “Email”, and “Camera” icons, all the correct recognition rate were higher than 90%, and participants’ confident level mean values were all around 2, which stands for feeling confident. What’s more, “Camera” icon enjoyed the highest correct recognition rate (98%), and according to the mean value of participants’ confident level (2.1275) for this question, participants had a tendency to report their confident level as between confident and strongly confident.

**Table 4.1:** Means of Part 2 Participants Self-reported results of how did they feel confident with their answers (-3—Strongly NOT confident, -2—NOT confident, -1—Somewhat NOT confident, 1—Somewhat confident, 2—Confident, 3—Strongly confident)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone</td>
<td>-0.1057</td>
</tr>
<tr>
<td>Browser</td>
<td>1.6201</td>
</tr>
<tr>
<td>Message</td>
<td>1.8382</td>
</tr>
<tr>
<td>Email</td>
<td>2.1275</td>
</tr>
<tr>
<td>Camera</td>
<td>1.4755</td>
</tr>
</tbody>
</table>
4.2.2.4 Part 3 Data cleaning

There were two participants that did not use sliders to indicate how confident they feel with their answers in this survey part. Two participants misunderstood the questions: They typed numbers in short-answer questions’ blank areas to indicate confident levels instead of writing down the meaning of the icons, and 4 participants didn’t answer any question. In order to have valid character values, the researcher cleared these eight participants’ data from the whole data set. Therefore, 386 participants’ data were analyzed in SPSS.

4.2.2.5 Part 3 Participants’ demographic

As shown in Figure 4.21, Group 3 was composed of 203 female (52.6%) and 183 male (47.4%) students. The age distribution of the participants ranged from 18 to 74 years old (Figure 4.22). 90.7% of participants were from 18 to 24 years old, 7.5% were 25 to 34 years old, and less than 2% were older than 35 years old. In terms of educational backgrounds (Figure 4.23), 46 participants (11.9%) reported graduate educational background, 334 (86.5%) — undergraduate background. Of the 386 participants, 359 (93 %) were native speakers of English and they others were not native speakers (Figure 4.24). 26.4% participants used Samsung phone, 57.5% — Apple, and 16% — other brands’ phones (Figure 4.25).
Figure 4.21: Part I Gender Distribution

Figure 4.22: Part I Age Distribution

Figure 4.23: Part I Educational background Distribution
Figure 4.24: Part 1 First Language Distribution

Figure 4.25: Part 1 Current Used Phone Brands Distribution

4.2.2.6 Part 3 Results

The question layout and the stem of Part 3 were exactly the same as that of Part 2. Part 3 also included 5 icons (Form-reduction-style icons indicating phone call, message, email, camera, and browser) for participants. In each question, participants were shown one icon and guessed its meaning, as well as indicated how confident did they feel with their answers using sliders. The results of short-answer questions are displayed in Figure
4.26, which were similar as Part 2 results: Question 1 (Phone Call) had the lowest correct rate, and Question 2, 3, 4, 5 had obviously higher correct rates. “Phone Call” icon in Part 3 was still not recognizable enough: only 6.2% participants wrote down the correct answer. Instead of the correct answer, there were some commonly seen wrong answers among participants (Figure 4.27): 32.3% participants had “Wifi” as their answer, even though this icon had a different direction of the commonly seen “Wifi” icon in our daily life; and 26.7% participants wrote down “Voice” because of seeing the sound waves. “Message” icon was recognizable for the most of the participants (96.6%), followed by “Browser” icon with a correct recognition rate at 88.9%. Both “Email” and “Camera” icons had correct recognition rates at about 81%.

Figure 4.26: Selected examples 2 Short-answer Questions Correct Rate Results
In terms of how confident participants felt in Part 3, we can see the mean values of confident levels for each question in Table 4.2. The most notable thing is that all mean values of participants’ confident levels were bigger than 1, which stood for somewhat confident. In Question 2, when participants saw the “Message Icon” and guessed the meaning of this icon, they had a highest confident level at 2.0440 (Confident), and at the same time, this icon had the highest correct recognition rate as we mentioned before. For the other four questions, all confident level means were between 1 and 1.5, which indicates that participants’ confident levels were between somewhat confident and confident. Among them, although “Phone Call” icon had a very low recognition rate at 6.2%, participants still felt confident with their answers.
Table 4.2: Means of Part 3 Participants Self-reported results of how did they feel confident with their answers (-3—Strongly NOT confident, -2—NOT confident, -1—Somewhat NOT confident, 1—Somewhat confident, 2—Confident, 3—Strongly confident)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>1.3187</td>
</tr>
<tr>
<td>Chat</td>
<td>2.0440</td>
</tr>
<tr>
<td>Clock</td>
<td>1.2617</td>
</tr>
<tr>
<td>Wifi</td>
<td>1.3010</td>
</tr>
<tr>
<td>Volume</td>
<td>1.3005</td>
</tr>
</tbody>
</table>

4.2.2.7 Comparison of Part 2 and Part 3

In Phase 2, participants in Group 2 completed survey Part 2 and participants in Group 3 completed survey Part 3. Part 2 included five questions containing five outline-style icons, and Part 3 included five questions containing five form-reduction-style icons.

Figure 4. 28 illustrates the results of Part 2 and Part 3 were similar: “Phone Call” icons had the lowest recognition rate in both Part 2 and Part 3, especially in Part 3, the recognition rate dropped down to 6.2% from 15.4%. The low correct recognition rates could be explained by the theory created by Rungtai Lin: Icon recognition confusion falls into three types: (1) “Visual similarity (shape feature)”. (2) “Conceptual similarity (image feature)”. (3) “Visual and conceptual similarity (function feature)”. For the outline-style “Phone Call” icon, the low recognition could be caused by the visual and conceptual similarity, since “voice,” “speaker,” versus “phone call” “yielded the same image at first glance”, and they all shared the similar functions. For the form-reduction-style “Phone Call” icon, its shape feature had visual similarity with “Wifi” or “Volume” icons (Lin, 1994).
But for the other four icons, “Message”, “Email”, “Camera”, and “Bowser”, their recognition rates were all higher than 80% in both two parts. It is worth mentioning that “Message” and “Browser” icons’ recognition rates in Part 2 and Part 3 changed very slightly: compared with Part 2, “Message” icon’s recognition rate in Part 3 only decreased by 0.05%, and the recognition rates in these two parts were around 97%.

Unlike the other icons, “Browser” icon’s recognition rate claimed lightly from 86.8% to 88.9% in Part 3, even though the icon in Part 3 was more simplified than that in Part 2. The effect of simplifying icon on correct recognition rate was the most dramatic for “Camera” icon: when the “Camera” icon was simplified in Part 3, its correct recognition rate declined from 98% (Part 2) to 81.1% (Part 3).

![Figure 4.28: Comparison of Part 2(Blue) and Part 3(Red) Short-answer Questions Correct Rates](image)
4.3 One-Way ANOVA Tests

The one-way ANOVA test is used for examining whether there are any significant differences between the means of two or more independent groups (Howell, 2002, pp. 324–325). In order to examine the study question: how different personal backgrounds influenced icon recognition, One-way between-groups ANOVA tests were conducted using data of Part 2 and Part 3 in SPSS.

4.3.1 How personal backgrounds influence icon recognition correctness

In order to examine the relationship between age and correctness of icon recognition, one-way between-groups ANOVA tests were conducted with the correctness of icon recognition as dependent variable, and age as independent variable. Results were interpreted using a significance level of $p \leq .05$ to test the effects. By checking the option, Means Plots, in SPSS when conducted ANOVA test, we could also see the comparison of means between different groups.

4.3.1.1 Age

Means Plots shows that younger participants had higher correct icon recognition rates than those of the older participants, in terms of six icons (outline-style “Message,” “Camera,” and “Browser” icons; as well as form-reduction-style “Email,” “Camera,” and “Browser” icons).

The statistical results calculated by SPSS displayed in Table 4.3 showing that in Part2, there was a significant relationship ($p=0.001 \leq .05$) between icon recognition
correctness and age, in terms of “Browser” icon recognition. More specifically, when seeing this icon, younger participants had a higher mean of icon recognition correctness (0: wrong, 1: correct) at around 0.9, while elder participants had a mean of icon recognition correctness at less than 0.7, which indicates that this outline-style “Browser” icon assisted younger participants to recognize it as a browser better than that for elder participants. (See Figure 4.29)

Table 4.3: Part 2 Results of a One-way between-groups ANOVA test with age as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.363</td>
</tr>
<tr>
<td>Message</td>
<td>.102</td>
</tr>
<tr>
<td>Email</td>
<td>.319</td>
</tr>
<tr>
<td>Camera</td>
<td>.444</td>
</tr>
<tr>
<td>Browser</td>
<td>.001*</td>
</tr>
</tbody>
</table>

*Significant at .05 level
Figure 4.29 Comparison of the mean values of icon recognition correctness between 2 different age groups, in terms of the “Browser” icon in Part 2. (0: wrong, 1: correct)

Also in Part 3, as shown in Table 4.4, different age ranges significantly effected icon recognition of “Camera” icon with a $p = 0.000 \leq 0.05$. Figure 4.30 illustrates that younger participants also maintained a higher ability (mean $\approx 0.9$) to recognize this icon correctly than elder participants (mean $\approx 0.7$).
Table 4.4: Part 3 Results of a One-way between-groups ANOVA test with age as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th></th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.000*</td>
</tr>
<tr>
<td>Message</td>
<td>1.000</td>
</tr>
<tr>
<td>Email</td>
<td>.362</td>
</tr>
<tr>
<td>Camera</td>
<td>.881</td>
</tr>
<tr>
<td>Browser</td>
<td>.078</td>
</tr>
</tbody>
</table>

*Significant at .05 level

Figure 4.30: Comparison of the mean values of icon recognition correctness between 2 different age groups, in terms of the “Camera” icon in Part 3. (0: wrong, 1: correct)
4.3.1.2 Gender

Gender differences had influences on icon recognition, which could be reflected by “Phone Call” icons, “Email” icons, and “Browser” icons. Females tended to have higher correct recognition rates when they saw outline-style icons: they performed better than males, in terms of three of the five outline-style icons (“Phone Call”, “Email”, “Browser”). However males tended to have higher recognition rates when they saw form-reduction-style icons (Form-reduction-style “Phone Call,” “Email,” “Browser”).

There were statistically significant differences in both survey parts. For Part 2, the result of “Email” icon was $p = .038$ (Table 4.5), and for Part 3, the result of “Message” icon was $p = .029$ (Table 4.6). Therefore female participants were significantly more likely to recognize these two icons correctly than males did. (Mean plots shown in Figure 4.31 and Figure 4.32)

*Table 4.5: Part 2 Results of a One-way between-groups ANOVA test with gender as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)*

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.080</td>
</tr>
<tr>
<td>Message</td>
<td>.385</td>
</tr>
<tr>
<td>Email</td>
<td>.038*</td>
</tr>
<tr>
<td>Camera</td>
<td>.426</td>
</tr>
<tr>
<td>Browser</td>
<td>.452</td>
</tr>
</tbody>
</table>

*Significant at .05 level
Figure 4.31: Comparison of the mean values of icon recognition correctness between males and females, in terms of the “Email” icon in Part 2. (0: wrong, 1: correct)

Table 4.6: Part 3 Results of a One-way between-groups ANOVA test with gender as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.503</td>
</tr>
<tr>
<td>Message</td>
<td>.029*</td>
</tr>
<tr>
<td>Email</td>
<td>.120</td>
</tr>
<tr>
<td>Camera</td>
<td>.315</td>
</tr>
<tr>
<td>Browser</td>
<td>.681</td>
</tr>
</tbody>
</table>

*Significant at .05 level
Figure 4.32: Comparison of the mean values of icon recognition correctness between males and females, in terms of the “Message” icon in Part 3. (0: wrong, 1: correct)

4.3.1.3 Educational background

Educational background’s effects on icon recognition were consistent with the effects of age differences. Undergraduate participants had higher correct icon recognition rates than those of graduate participants, in terms of six icons (both outline-style and form-reduction-style “Message,” “Camera,” and “Browser” icons).

Educational background did not show significant effects on icon recognition for Part 2 questions. But according to the ANOVA results indicated in Table 4.7, in Part 3, educational background influenced icon recognition significantly when participants guessed the meaning of the outline-style “Camera” icon, because the p value was 0.000,
which is smaller than the significant level at 0.05. Undergraduate participants’ correctness mean was about twice as high as that of graduate participants (Figure 4.33). Thus we can infer that undergraduate participants generally had a higher correct icon recognition rate than graduate participants. These results were consistent with the relationship between icon recognition correctness and age as we mentioned before, since undergraduate participants were generally younger than graduate participants, and younger participants were more likely to recognize outline-style “Camera” icon correctly.

**Table 4.7:** Part 3 Results of a One-way between-groups ANOVA test with educational background as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.000*</td>
</tr>
<tr>
<td>Message</td>
<td>.669</td>
</tr>
<tr>
<td>Email</td>
<td>.892</td>
</tr>
<tr>
<td>Camera</td>
<td>.145</td>
</tr>
<tr>
<td>Browser</td>
<td>.616</td>
</tr>
</tbody>
</table>

*Significant at .05 level
Figure 4.33: Comparison of the mean values of icon recognition correctness between undergraduate and graduate participants, in terms of the “Camera” icon in Part 3.

(0: wrong, 1: correct)

4.3.1.4 First Language

As for first language, native English speaking participants had higher correct icon recognition rates than those of nonnative speakers, in terms of seven icons (outline-style “Phone Call,” “Message,” and “Camera” icons; as well as form-reduction-style “Camera,” “Phone Call,” “Email,” and “Browser” icons).

As shown in Table 4.8 and Table 4.9, different first languages affected icon recognition significantly for “Message” icon in Part 2 (p=0.000), and “Browser” (p=0.000) and “Camera” (p=0.011) icons in Part 3. Native participants always had higher mean values of icon recognition correctness than nonnative participants. Therefore, it is obvious that when participants were asked to answer these three icon recognition
questions, native participants were more likely to answer these questions correctly.

(Figure 4.34 and Figure 4.35)

**Table 4.8:** Part 2 Results of a One-way between-groups ANOVA test with first language as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.545</td>
</tr>
<tr>
<td>Message</td>
<td>.000*</td>
</tr>
<tr>
<td>Email</td>
<td>.172</td>
</tr>
<tr>
<td>Camera</td>
<td>.224</td>
</tr>
<tr>
<td>Browser</td>
<td>.764</td>
</tr>
</tbody>
</table>

*Significant at .05 level

**Figure 4.34:** Comparison of the mean values of icon recognition correctness between native English speaking and nonnative participants, in terms of the “Email” icon in Part 2. (0: wrong, 1: correct)
**Table 4.9**: Part 3 Results of a One-way between-groups ANOVA test with first language as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th></th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.000*</td>
</tr>
<tr>
<td>Message</td>
<td>.316</td>
</tr>
<tr>
<td>Email</td>
<td>.576</td>
</tr>
<tr>
<td>Camera</td>
<td>.053</td>
</tr>
<tr>
<td>Browser</td>
<td>.011*</td>
</tr>
</tbody>
</table>

*Significant at .05 level

**Figure 4.35**: Comparison of the mean values of icon recognition correctness between native English speaking and nonnative participants, in terms of the “Browser” and “Camera” icon in Part 3. (0: wrong, 1: correct)
4.3.1.5 Currently used phone brand

There was a notable phenomenon that icon recognition correctness of both “Email” icons in Part 2 and Part 3 had a significant relationship with participants’ currently used phone brand. Since according to the ANOVA results indicated in Table 4.10 and Table 4.11, the p values of these two “Email” icons in two survey parts were 0.000 and 0.020, which were all smaller than the significant level, 0.05. Furthermore, Samsung users kept had the lowest mean values in both of the two survey parts: Samsung users were significantly less likely to guess the meaning of “Email” icons correctly in both of the two survey parts than other brands users did. (See Figure 4.36 and Figure 4.37)

Table 4.10: Part 2 Results of a One-way between-groups ANOVA test with currently used phone brand as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th></th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.563</td>
</tr>
<tr>
<td>Message</td>
<td>.061</td>
</tr>
<tr>
<td>Email</td>
<td>.000*</td>
</tr>
<tr>
<td>Camera</td>
<td>.683</td>
</tr>
<tr>
<td>Browser</td>
<td>.333</td>
</tr>
</tbody>
</table>

*Significant at .05 level
Figure 4.36: Comparison of the mean values of icon recognition correctness between different phone brands’ users, in terms of the “Email” icon in Part 2. (0: wrong, 1: correct)

Table 4.11: Part 3 Results of a One-way between-groups ANOVA test with currently used phone brand as independent variable and icon recognition correctness as dependent variable. (Significant at .05 level)

<table>
<thead>
<tr>
<th>Icon</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone Call</td>
<td>.510</td>
</tr>
<tr>
<td>Message</td>
<td>.699</td>
</tr>
<tr>
<td>Email</td>
<td>.812</td>
</tr>
<tr>
<td>Camera</td>
<td>.020*</td>
</tr>
<tr>
<td>Browser</td>
<td>.659</td>
</tr>
</tbody>
</table>

*Significant at .05 level
4.3.2 How confidence levels are different between recognizing an icon correctly or wrongly

In Table 4.12, the icon recognition correctness had a significant relationship with how confident participants felt with their answers in most of the questions in both Part 2 and Part 3. In Part 2, participants’ confident levels were significantly related with whether they recognized the icon correctly or wrongly, in term of “Email” icon (p=0.31), “Camera” icon (p=0.000), and “Browser” icon (p=0.000). In Part 3, except “Phone Call” icon, the other four icons’ recognition correctness had significant relationships with participants’ confident levels: all the p values of these four icons were 0.000.
In terms of the relationship between icon recognition correctness and confident level, when participants recognized an icon correctly, they tended to be more confident than when they did it wrongly. (Figure 4.38) But for the “Phone Call” icons in two parts, the correlation was opposite: the participants felt relatively less confident when they wrote down the correct answer, because the icons were more likely to be interpreted as another icon that participants feel more familiar with. The form-reduction-style “Phone Call” icon looks like a horizontal “Wifi” icon that we can see on every smartphone interface. Therefore many participants thought it was a “Wifi” icon. Additionally, as shown in Figure 4.38, except “Phone Call” icons in two survey parts, the means of confident level of the other eight icons in both Part 2 and Part 3 were all around 2 (2: Confident), when participants recognized the icons correctly.

4.4 Summary

This chapter presented the results of several analyses in order to determine how participants recognized icons at different simplicity levels, and how icon recognition varied between people with different backgrounds.
Table 4.12: Comparison how confident levels were related with icon recognition correctness in Part 2 and Part 3 (Significant at .05 level)

<table>
<thead>
<tr>
<th>Phone Call</th>
<th>Sig.</th>
<th>Message</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Phone Icon" /></td>
<td>.358</td>
<td><img src="image" alt="Message Icon" /></td>
<td>.213</td>
</tr>
<tr>
<td><img src="image" alt="Phone Icon" /></td>
<td>.111</td>
<td><img src="image" alt="Message Icon" /></td>
<td>.000*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Email</th>
<th>Sig.</th>
<th>Camera</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Email Icon" /></td>
<td>.031*</td>
<td><img src="image" alt="Camera Icon" /></td>
<td>.000*</td>
</tr>
<tr>
<td><img src="image" alt="Email Icon" /></td>
<td>.000*</td>
<td><img src="image" alt="Camera Icon" /></td>
<td>.000*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Browser</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Browser Icon" /></td>
<td>.000*</td>
</tr>
<tr>
<td><img src="image" alt="Browser Icon" /></td>
<td>.000*</td>
</tr>
</tbody>
</table>

*Significant at .05 level
To answer the first research question, the data of Group 1 participants who completed survey Phase 1 was analyzed. The results showed that among all five simplicity level icons, outline-style icons were the most recognizable for most of the participants. However, the silhouette-style icons generally had the lowest recognition rate among participants, because the objects shown in those icons did not have distinct silhouettes (shapes) for participants to interpret them as the correct meanings. Finally the form-reduction-style icons were still recognizable for participants, even though the visual
elements in those icons were extremely simplified by removing the profile and showing only one feature of each object.

Then in Phase 2, outline-style icons and form-reduction-style icons were selected for Part 2 and Part 3, in order to conduct further icon recognition tests. The results indicated that the extremely simplified form-reduction-style icons had similar correct icon recognition rates as that of the more detailed outline-style icons.

To answer the second research question, one-way between-groups ANOVA tests were conducted. The results revealed that: Out of ten questions in Phase 2,

- Younger participants had higher correct icon recognition rates than those of older participants, in terms of six icons (outline-style “Message,” “Camera,” and “Browser” icons; as well as form-reduction-style “Email,” “Camera,” and “Browser” icons). Age differences effected icon recognition significantly for outline-style “Browser” and form-reduction-style “Camera” icons.

- Gender differences had influences on icon recognition, which could be reflected by “Phone Call” icons, “Email” icons, and “Browser” icons. Females tended to have higher correct recognition rates when they saw outline-style icons: they performed better than males, in terms of three of the five outline-style icons (“Phone Call”, “Email, “Browser”). However males tended to have higher recognition rates when they saw form-reduction-style icons (Form-reduction-style “Phone Call”, “Email”, “Browser”). In addition, Females had significantly higher correct icon recognition rates for the
outline-style “Email” icon and the form-reduction-style “Message” icon.

- Educational background’s effects on icon recognition were consistent with the effects of age differences. Undergraduate participants had higher correct icon recognition rates than those of graduate participants, in terms of six icons (both outline-style and form-reduction-style “Message”, “Camera”, and “Browser” icons). The effect was significant in one survey question that contained the form-reduction-style “Camera” icon.

- Native speaking participants had higher correct icon recognition rates than those of nonnative speakers, in terms of seven icons (outline-style “Phone Call”, “Message”, and “Camera” icons; as well as form-reduction-style “Camera”, “Phone Call”, “Email”, and “Browser” icons). Native speakers had significantly higher correct icon recognition rates than nonnative speakers for outline-style “Message” icon, and form-reduction-style “Camera” and “Browser” icon.

- The currently used phone brand differences affected the icon recognition significantly, in terms of “Email” icons in both of the two survey parts: Samsung users had the lowest correct icon recognition rates when they saw “Email” icons of both outline-style and form-reduction-style.

Lastly, the researcher also conducted ANOVA tests to examine how participants’ confidences related with the icon recognition correctness. According to the results, when participants recognized an icon correctly, they felt more confident than when they recognized it wrongly.
CHAPTER 5. CONCLUSIONS

According to previous research, materialized drawing with filtered features works as an icon style that shared by different phone carriers. But complex details can become confusing and may appear muddy at smaller sizes (iOS Human Interface Design Guidelines, 2015); and icons with uncombined or simple visual elements are easy to be recognized, since no unnecessary visual element will distract viewers (Colborne, 2011). Therefore, the purpose of this study is to examine to what point viewers can recognize or feel lost in recognizing smartphone interface icons, in terms of simplicity. The results will assist user interface designers to design and produce simplified smartphone interface icons. According to this purpose, an icon recognition survey was conducted. There were two research questions: 1) To what point viewers can recognize or feel lost in recognizing smartphone interface icons, in terms of simplicity. 2) How viewers’ recognition abilities vary, in terms of different age, gender, and educational background. To conduct this survey, the researcher designed 25 smartphone icons focusing on five smartphone first-depth functions: Phone Call, Message, Email, Camera, and Browser. Each function had five icons at five simplicity levels: Drawing, Caricature, Outline, Silhouette, and Form-reduction.

The results of survey Phase 1 answered the first study question: outline-style icons were the most recognizable for a majority of the participants, in terms of the five smartphone function icons created for this study. However, the silhouette-style icons generally had the lowest recognition rate among participants, because the objects shown in those icons did not have distinct silhouettes (shapes) for participants to interpret them
as the correct meanings. The form-reduction-style icons were still recognizable for participants, even though the visual elements in those icons were extremely simplified by removing the profile and showing only one feature of each object.

Additionally, the results of the Phase 2 were that each form-reduction-style icon’s correct answers rate was similar as that of its corresponding outline-style icon. According to Peirce’s semiotics model, it is the object that shown in an icon that causes viewers’ interpretent (Peirce, 1931, p58), therefore, simplifying the objects in icons did not decrease icon recognition rate dramatically.

The results of Phase 2 also answered the second study question: age, gender, educational background, first language, and currently used phone brand had significant effects on icon recognition, in terms of part of the icons tested in this study. The results supported William’s statement: When we look at an icon, what we see comes from our existing knowledge instead of from eyes only (Horton, 1994, p22). Different people have different existing knowledge, that is why different people recognize one icon differently.

**Practical contributions**

The results of this study suggests several practical applications for interface icon design:

1. Use silhouette as the style of an icon, only if the object shown in this icon has a distinguished profile shape. Since the results of this survey part were consistent and supported the previous literature review that icons with silhouette-style need to have a
distinguished profile (Horton, 1994, p138). For the five icons with silhouette-style created for this study, except “Message” icon had a distinguished shape as a round cornered rectangle with a little cusp, “Phone Call” icon had sound waves; the other three icons shapes were not distinguished enough. “Email,” and “Camera” icons’ shapes were all a simple rectangle, and “Brower” icon’s shape was a simple circle. Because both rectangle and circle are simple shapes that shared by many objects in nature world, viewers might create many meanings caused by seeing those basic shapes.

2. Try to have commonly acceptable and real existing object in an icon to cause interpretent created in viewers’ minds. If the object shown in an icon is not familiar for viewers, even though the object is shown with enough details, the correct icon recognition rate is still not satisfactory. For example, the “Phone Call” icons’ object in both Part 2 and Part 3 was a modern smartphone instead of the speaker of a vintage telephone, which was not commonly used object for phone call icons, viewers would interpret them as other meanings instead of phone call.

3. When design an icon, take target audience’s different backgrounds into consideration. Test icon recognition with people having different personal backgrounds, in order to make this icon to be widely acceptable. Because when viewers see an icon, the decoding process is to connect their existing concepts with this icon to figure out the meaning of this icon, and everyone has different existing inner knowledge; different people’s icon recognition ability vary.
Limitations

This study had some limitations. The first limitation was the absence of participants with more diverse backgrounds. The researcher only recruited currently enrolled students of Iowa State University. Since students in one university cannot represent the students at other universities, and students cannot represent people at different age ranges, the results cannot be used for a wider population. The second limitation was that in this study, icons’ colors were not taken into consideration. The third limitation was that this study did not investigate whether the participants preferred the simplified icons to the detailed ones or not.

Future Directions

The results and limitations of this study suggested several directions for future research. Most immediately, future research should take participants’ emotional reacts into consideration. For example, future research could examine for people with different personal backgrounds, how their preferences different, in terms of icon styles, including color, simplicity, and other design elements. In addition, in future study, the participants could be recruited from a wider population.
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APPENDIX A. INSTITUTIONAL REVIEW BOARD APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Iowa State University
Office for Responsible Research
Office of the President
111 W. 18th Street
Ames, IA 50011-2497
515-294-7300
FAX 515-294-1275

Date: 1/6/2016
To: Qing Guo
3224 Memorial Union
From: Office for Responsible Research
Title: Icon Recognition
IRB ID: 15-751

To: Dr. Sungyoon Kang
CC: 282 Design

Study Review Date: 1/6/2016

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects’ responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:
- You do not need to submit an application for annual continuing review.
- You must carry out the research as described in the IRB application. Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.
- Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then the Application for Approval of Research Involving Human Subjects Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. Only the IRB or designee may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

Please be aware that approval from other entities may also be needed. For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.

Please don’t hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.
APPENDIX B. INFORMED CONSENT

Informed Consent:

Title of Study: Icon Recognition Online Survey
Participants: Faculty Supervisor: Sunghyun Kang, BFA, MA, MFA
Principal Investigator: Qing Guo

Introduction
You are invited to take part in an icon recognition online survey. All participants should be older than 18 years old. If you are under 18 years old, please skip this survey. The purpose of this survey is to find out how people understand the icons on interfaces.

Most people can finish this in about 5 minutes. Your responses will be confidential and you are free to skip any question or quit the survey when you do not feel comfortable answering. Your responses will be of great use in furthering my research and in improving our understanding of the icon recognition. Thank you in advance for your time and participation.

Benefits
There is no direct benefit to the participant. But, I hope to find out how people recognize icons on interfaces. The results of this study will be used for scholarly purposes only.

Risks
There are no foreseeable risks in this study. However, you may leave the study at any time without penalty.

Participant Rights
Your participation in this study is completely voluntary and you may skip or quit the survey at any time. If you decide to not participate in the survey, it will not result in any penalty or loss of benefits to which you are otherwise entitled. During the testing, if you feel uncomfortable at any time you can quit.
Confidentiality
All participants’ data will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your data for quality assurance and data analysis. These data may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken.
Only the researcher will have access to the data. The data will be entered and kept in a password-protected computer located on the researcher’s computer. Once the study has been concluded, all data files may be retained for future use pertaining to this research (process).

Questions or Problems
For further information about the study contact Qing Guo, Principal Investigator, qingg@iastate.edu.

If you have any questions about the rights of research subjects or research-related injury, please contact IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, Office for Responsible Research, (515) 294-3115, 1138 Pearson Hall, Ames, IA 50011.

Agree         Disagree
APPENDIX C. SURVEY RECRUITING EMAIL

**Introduction script for part 1:**

**Icon recognition online survey**

Hello,
You are invited to take part in an icon recognition online survey. The purpose of this survey is to find out how people understand the icons on interfaces.

The survey, which contains 5 questions with multiple answers, will be completed through online and will take approximately 5 minutes to finish. As a participant, you will be asked to answer the questions.

If you would like to have any additional details about this research study, please contact Qing Guo via email: qingg@iastate.edu

You may start the survey at any time:
https://iastate.qualtrics.com/SE/?SID=SV_da6Un94zCvu0Uap

If you are under 18 years old, please skip this survey.

Thank you so much.
We look forward to having you join the study.

Qing Guo
MFA Graphic Design candidate
Iowa State University
qingg@iastate.edu
Introduction script for part 2:
Icon recognition online survey

Hello,
You are invited to take part in an icon recognition online survey. The purpose of this survey is to find out how people understand the icons on interfaces.

The survey, which contains 5 questions with multiple answers, will be completed through online and will take approximately 5 minutes to finish. As a participant, you will be asked to answer the questions.

If you would like to have any additional details about this research study, please contact Qing Guo via email: qinggg@iastate.edu

You may start the survey at any time:
https://iastate.qualtrics.com/SE/?SID=SV_d3UIYEQb6KxABDL

If you are under 18 years old, please skip this survey.

Thank you so much.
We look forward to having you join the study.

Qing Guo
MFA Graphic Design candidate
Iowa State University
qinggg@iastate.edu
Introduction script for part 3:
Icon recognition online survey

Hello,
You are invited to take part in an icon recognition online survey. The purpose of this survey is to find out how people understand the icons on interfaces.

The survey, which contains 5 questions with multiple answers, will be completed through online and will take approximately 5 minutes to finish. As a participant, you will be asked to answer the questions.

If you would like to have any additional details about this research study, please contact Qing Guo via email: qingg@iastate.edu

You may start the survey at any time:
https://iastate.qualtrics.com/SE/?SID=SV_cYK6ItFQiAPrQhTv

If you are under 18 years old, please skip this survey.

Thank you so much.
We look forward to having you join the study.

Qing Guo
MFA Graphic Design candidate
Iowa State University
qingg@iastate.edu
1. Please indicate you age at:
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - 65 - 74
   - 75 - 84
   - 85 or older

3. What's your gender?
   - Male
   - Female
   - I don't want to indicate.
4. What's your education background?
   - Graduate
   - Undergraduate
   - High school or lower

5. What's your first language?
   - English
   - Other. Please specify language: [ ]

6. What's the brand of the phone you are using now?
   - Samsung
   - Apple
   - Other. Please specify brand: [ ]

1/5. Select icon(s) that indicate(s) 'Phone call'. Please check all that applied. (Multiple Answer)
2/5. Select icon(s) that indicate(s) 'Message'. Please check all that applied. (Multiple Answer)

3/5. Select icon(s) that indicate(s) 'Email'. Please check all that applied. (Multiple Answer)
4/5. Select icon(s) that indicate(s) 'Camera'. Please check all that applied. (Multiple Answer)

5/5. Select icon(s) that indicate(s) 'Browser'. Please check all that applied. (Multiple Answer)
APPENDIX E. SURVEY QUESTIONS (PART 2)

1. Please indicate your age at:
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - 65 - 74
   - 75 - 84
   - 85 or older

3. What’s your gender?
   - Male
   - Female
   - I don’t want to indicate.
4. What's your education background?
   - Graduate
   - Undergraduate
   - High school or lower

5. What's your first language?
   - English
   - Other: Please specify language: 

6. What's the brand of the phone you are using now?
   - Samsung
   - Apple
   - Other: Please specify brand: 
1/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

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<tr>
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<th>Somewhat NOT confident</th>
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Please indicate how confident do you feel with your answer
3/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:
2/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:
4/5. What function does this icon stand for, if you see it on a smartphone interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:
5/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

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And please indicate how confident do you feel with your answer using the slider below:

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Click to write Choice 1
APPENDIX F. SURVEY QUESTIONS (PART 3)

1. Please indicate you age at:
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - 65 - 74
   - 75 - 84
   - 85 or older

3. What's your gender?
   - Male
   - Female
   - I don't want to indicate.
4. What's your education background?
- Graduate
- Undergraduate
- High school or lower

5. What's your first language?
- English
- Other: Please specify language: 

6. What's the brand of the phone you are using now?
- Samsung
- Apple
- Other: Please specify brand: 

1/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

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Please indicate how confident do you feel with your answer
2/6. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below: 

And please indicate how confident do you feel with your answer using the slider below:
3/5. What function does this icon stand for, if you see it on a **smart phone** interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

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Please indicate how confident do you feel with your answer
4/5. What function does this icon stand for, if you see it on a smart phone interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below:

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</tbody>
</table>

Please indicate how confident do you feel with your answer
5/6. What function does this icon stand for, if you see it on a *smart phone* interface? Please write down your answer below:

And please indicate how confident do you feel with your answer using the slider below: