

**Comprehension problems in icon design for
mobile devices: Analysis and prototype design**

by

Fei Yang

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:

Lisa Fontaine

Sunghyun Kang

Frederic Malven

Iowa State University

Ames, Iowa

2015

Copyright © Fei Yang, 2015. All rights reserved.

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	viii
ABSTRACT	ix
INTRODUCTION	1
CHAPTER 1: LITERATURE REVIEW.....	3
1.1 Icon Design	4
1.2 Semiotics.....	10
1.3 Evaluation Criteria.....	15
1.3.1. Recognizability	15
1.3.2. Relevance.....	17
1.3.3. Uniqueness.....	18
1.4 Comprehension Test of the Icons.....	19
CHAPTER 2: COMPREHENSION TEST METHODOLOGY	25
2.1 Objective.....	25
2.2 Comprehension Study Subjects	26
2.3 Comprehension Study Procedure.....	27
2.3.1. Survey structure	29
2.3.2. Styles and colors.....	31
2.3.3. Questions wording	33
2.3.4. Selection of meaningful options.	41
CHAPTER 3: COMPREHENSION TEST ANALYSIS.....	42
3.1 Clean the Data	42
3.2 Analysis of the Results	47
3.2.1 Make a payment.....	47
3.2.2 Discover.....	49
3.2.3 Baby journal.....	50
3.2.4 Social activity.....	51
3.2.5 Birth and baby club.....	52

CHAPTER 4: PROTOTYPE DESIGN METHODOLOGY	55
4.1 Objective.....	55
4.2 Methodology in Prototype Design	55
4.3 Concept Ideation	58
4.3.1 Make a payment.....	61
4.3.2 Discover	63
4.3.3 Baby journals	63
4.3.4 Social activity	64
4.3.5 Birth and baby club.....	65
4.4 Concept Refinement	67
4.4.1 Make a payment.....	67
4.4.2 Discover	68
4.4.3 Baby journal	69
4.4.4 Social activity	69
4.4.5 Birth and baby club.....	70
4.5 Final Prototype	71
4.5.1 Make a payment.....	71
4.5.2 Discover	72
4.5.3 Baby journal	73
4.5.4 Social activity	74
4.4.5 Birth and baby club.....	75
CHAPTER 5: COMPREHENSION TEST OF THE PROTOTYPE ICONS	79
5.1 Analysis of Test Results of the Prototype Icons	82
5.1.1 Make a payment.....	82
5.1.2 Discover	84
5.1.3 Baby journal	86
5.1.4 Social activity	87
5.1.5 Birth and baby club.....	89
CHAPTER 6: LIMITATIONS AND FURTHER STUDY	91
CHAPTER 7: CONCLUSION	95
APPENDIX A – IRB FORM	100
APPENDIX B – COMPREHENSION TEST MATERIALS	102
APPENDIX C – COMPREHENSION TEST RESULTS	105

APPENDIX D – REDESIGNED ICON SKETCHES107

APPENDIX E – REDESIGNED ICONS COMPREHENSION TEST114

APPENDIX F – REDESIGNED ICONS TEST RESULTS119

REFERENCES.....122

LIST OF TABLES

Table 1. Meanings and Contexts of Problematic Icons	27
Table 2. Survey Question Showing Only Black and White Icons	32
Table 3. Survey Question Showing Color Icons	32
Table 4. Question 1 of Survey 1.....	33
Table 5. Question 2 of Survey 1.....	36
Table 6. Question 3 of Survey 1.....	37
Table 7. Question 4 of Survey 1.....	38
Table 8. Question 5 of Survey 1.....	39
Table 9. Survey 2 Comparisons.....	41
Table 10. Descriptive Statistics for Duration.....	42
Table 11. Descriptives for Duration.....	43
Table 12. Invalid Survey Records Part 1	44
Table 13. Invalid Survey Records Part 2	45
Table 14. Duration Extreme Values	46
Table 15. Survey 1 Results for Make A Payment	47
Table 16. Survey 2 Results for Make A Payment	48
Table 17. Survey 1 Results for Discover.....	49
Table 18. Survey 2 Results for Discover.....	49
Table 19. Survey 1 Results for Baby Journal.....	50
Table 20. Survey 2 Results for Baby Journal.....	50
Table 21. Survey 1 Results for Social Activity.....	51
Table 22. Survey 2 Results for Social Activity.....	51
Table 23. Survey 1 Results for Birth and Baby Club	52
Table 24. Survey 2 Results for Birth and Baby Club	52
Table 25. Ideation Matrix and Attributes.....	56

Table 26. Survey Results Showing Most Effective Icon Choices	57
Table 27. Ideation Matrix Example.....	58
Table 28. Icon Sketches	60
Table 29. Icon Sketches for Make A Payment, Part I.....	61
Table 30. Icon Sketches for Make A Payment, Part II.....	62
Table 31. Icon Sketches for Discover	63
Table 32. Icon Sketches for Baby Journals	63
Table 33. Icon Sketches for Social Activity	64
Table 34. Icon Sketches for Brith and Baby Club.....	65
Table 35. Selected Icon Concepts	66
Table 36. Refined Icon Sketches for Make A Payment.....	67
Table 37. Refined Icon Sketches for Magnifying Glass.....	68
Table 38. Refined Icon Sketches for Compass.....	68
Table 39. Refined Icon Sketches for Baby Journal	69
Table 40. Refined Icon Sketches for Social Activity.....	69
Table 41. Refined Icon Sketches for Birth and Baby Club	70
Table 42. Final Prototype Icons	76
Table 43. Survey 3 Example.....	79
Table 44. Survey 4 and 5 Example	80
Table 45. Sample of Comprehension Test for New Icons.....	81
Table 46. Survey 3 Results for Make A Payment	82
Table 47. Survey 4 Results for Make A Payment	83
Table 48. Survey 5 Results for Make A Payment	83
Table 49. Survey 3 Results for Discover.....	84
Table 50. Survey 4 Results for Discover.....	85
Table 51. Survey 5 Results for Discover.....	85
Table 52. Survey 3 Results for Baby Journal.....	86

Table 53. Survey 4 Results for Baby Journal.....	86
Table 54. Survey 5 Results for Baby Journal.....	87
Table 55. Survey 3 Results for Social Activity	87
Table 56. Survey 4 Results for Social Activity	88
Table 57. Survey 5 Results for Social Activity	88
Table 58. Survey 3 Results for Birth and Baby Club	89
Table 59. Survey 4 Results for Birth and Baby Club	90
Table 60. Survey 5 Results for Birth and Baby Club	90

LIST OF FIGURES

Figure 1. Survey Question Example.....	29
Figure 2. Survey Filter	30
Figure 3. Make A Payment Icon.....	47
Figure 4. Discover Icon.....	49
Figure 5. Baby Journal Icon	50
Figure 6. Social Activity Icon.....	51
Figure 7. Birth and Baby Club Icon	52
Figure 8. Icon Sketch for Baby Journal.....	59
Figure 9. Final Prototypes for Make A Payment	71
Figure 10. Final Prototypes for Discover	72
Figure 11. Final Prototypes for Baby Journal	73
Figure 12. Final Prototypes for Social Activity	74
Figure 13. Final Prototypes for Birth and Baby Club.....	75
Figure 14. Prototype Icon 1 for Make A Payment	83
Figure 15. Prototype Icon 2 for Make A Payment	83
Figure 16. Prototype Icon 1 for Discover.....	85
Figure 17. Prototype Icon 2 for Discover.....	85
Figure 18. Prototype Icon 1 for Baby Journal.....	86
Figure 19. Prototype Icon 2 for Baby Journal.....	87
Figure 20. Prototype Icon 1 for Social Activity	88
Figure 21. Prototype Icon 2 for Social Activity	88
Figure 22. Prototype Icon 1 for Birth and Baby Club.....	90
Figure 23. Prototype Icon 2 for Birth and Baby Club.....	90

ABSTRACT

This graphic design research paper focused on the problems users have in understanding the meaning of icons used on mobile devices. This research was to find out why some graphical icons can help the user understand while others prevent the user from getting the meaning easily. If the icons are not meaningful to users, this study is also intended to explore how to re-design problematic icons to deliver the message more efficiently.

It is assumed that: a) People will have trouble in understanding some of the icons on mobile devices because they are over-simplified due to their reduced size. b) The design of icons on mobile devices can be improved to deliver the intended message without affecting their simplicity. This can be done through greater concern for recognizability, relevance, and uniqueness.

Two surveys were conducted to evaluate if subjects could have understood the meanings of a set of 5 problematic icons which were identified as being over-simplified to the point where they lacked recognition, relevance, and uniqueness; in response to the survey, a set of new prototype icons was designed. Subsequently, another three comprehension tests were conducted with new test subjects to see how well users were interpreting the new icons. The test results show that these subjects could understand the meanings of the new icons better compared with the

test results for the problematic icons when the recognizability, relevance, and uniqueness of the icons were increased.

Keywords: graphical icon, mobile device icon, icon comprehension test.

INTRODUCTION

In the applications of mobile devices, *Icon* refers to the small graphic image displayed on the screen. Icons have multiple purposes: branding, indicating functions, and creating visual interest in the user interface. This research paper is proposed to address the communication problems in icon design for mobile devices. Research in this area is important because the icons play a vital role in delivering messages. The goal is to get a sense of what are the reasons preventing users from understanding the meanings and how to solve this problem.

The reason to focus on the mobile platform instead of others is that the icons are very small on the mobile display. The need to have those icons in simplified and abstracted forms makes them harder for the users to understand compared with icons in other platforms (e.g. in print). It is also because the landscape of computing has dramatically changed over the past few years. Consumers are seeking connected devices, with the majority of them being mobile. The worldwide smartphone market grew 13.0% in 2015 Q2, with smartphone shipments reaching 1.44 billion units, according to data from Worldwide Quarterly Mobile Phone Tracker (IDC, 2015).

The period of time being considered in the literature review is 2004 to 2014. From 2004 to 2009, untouchable feature phones dominated the mobile market. But

smartphone and tablet sales increased sharply from 2010, and they changed user behavior dramatically by having large touchable screens.

There are numerous mobile applications in the market. Unlike applications on the desktop that have very large screens to present the information, on mobile devices the icons play an important role in helping the user understand the content because of the limited size of the screens. The design of icons for mobile devices are challenging because of the limited size of the screen. This research is to find out if some icons help the user's understanding, or prevent the user from getting the message easily. If the icons are not working, this study is also intended to explore in what ways the icon can be improved to deliver the message more efficiently.

This study has two hypotheses: a) People will have trouble in understanding some of the icons on mobile devices because they are over-simplified due to their reduced size. b) The design of icons on mobile devices can be improved to deliver the intended message without affecting their simplicity. This can be done with greater concern for recognizability, relevance, and uniqueness.

Two surveys were conducted to evaluate if subjects could understand the meanings of a set of problematic icons, after which a set of new icons were redesigned, then another three comprehension tests were conducted to see how well users interpreted the new icons.

CHAPTER 1: LITERATURE REVIEW

The literature review will focus on four main areas: icon design, semiotics, evaluation criteria and comprehension tests.

A study of icon design helps to determine how well icons are delivering messages to subjects, and the possible causes of failures in comprehension.

Semiotics is related to the topic because it is the study of how people comprehend the meanings of an icon. It is the study of signs and sign processes, indication, and communication. Semiotics pays attention to how producers create signs and if audiences understand them. Three evaluation criteria are discussed to provide a guideline for comprehension tests and future prototype design. Comprehension tests provide methods to evaluate those icons by testing them with subjects. They give us direct input on how end users react to the icons and provide suggestions for further improvements.

For this study, *Icons* refer to both icons, symbols, and graphical symbols. According to philosopher Peirce, icons and symbols are part of signs. Both icons and symbols represent other objects. Icons are graphical representation of the items that are visible, whereas symbols resemble ideas/concepts which a user has to learn (Kress & Leeuwen, 1996, p.7).

1.1 Icon Design

Icon Design means creating a graphic symbol that expresses a specific meaning. In the context of mobile devices, an icon can represent an application / program, command, popup window, option, or concept. As people usually get visual signals through three levels: representation, abstraction, and symbolism (Dondis, 1974, p.67), icons in mobile devices can be divided into three categories: images, pictures, and symbols that indicate meanings.

The icons on mobile devices' screens serve as functional links for users to access the application or data. Some common mobile icons are taken directly from icons already used across a wide range of areas. One example of these is the email icon; it is likely to use an envelope image to represent the meaning no matter what device it is seen on.

There are several types of icons that are commonly used on mobile devices. Those are desktop metaphor icons, electrical device icons, and brand icons for commercial software (Horton, 1994). The power icon is one of the typical standardized electrical device icons. Those icons can help a user to navigate an unfamiliar system easily. The desktop metaphor icons include the basic icons used in an actual office space, like the icons for a file, file folder, etc. This enables the user to understand the tasks in a common office space setting. The brand icons are

those of third-party applications, for example, the icons for Facebook and Twitter. Those icons have no functional meaning besides representing the product itself.

There are many reasons to use icons for presenting information. A good icon design can save people time and possibly improve productivity and reliability because reading and analyzing words usually takes more time (Horton, 1994, p.3).

Based on Horton's research, the benefits of icons include the following aspects:

- "Icons can represent visual and spatial concepts." Graphics work better than words in representing visual appearances or spatial relationships.
- "Icons reduce the necessity of reading." Clear and simple icons can help poor readers in understand the intended meanings.
- "Icons save space." Icons can be adjusted to a variety of sizes to allow the mobile screen to display many icons in a relatively small space.
- "Icons speed search." Icons can be recognized just by a glance. This is particularly true for standard icons that people have seen and used before.
- "Icons are more intuitive than words for conveying visual content."
- "Icons are understandable regardless of native language."
- "Icons lead to better recall." This is because: a) "Icons are more visually distinct from one another than words are"; b) We remember the icon along with its text. "Icons are restored as visual and verbal memories" while words are retained only verbally; c) "Visual memories are tightly linked to one another and to their

forms” (Horton, 1994, p.4 - p.6). Besides, icons are also better targets. Icons could be sized large enough for the user to touch in a finger-operated user interface.

It is widely accepted that icons are also recognized more quickly than similarly worded signs (Edworthy & Adams, 1996, p.78). By research of users’ ability to recognize words and symbols, their study shows that symbol signs make the message more accurate. This supports Horton’s assertion that “Icons are more visually distinct from one another than words are” (Horton, 1994, p.5).

For most situations, the icon plus label interface was always considered easier to use than either interface alone. As a result, the user could have a better understanding of system functionality (Wiedenbeck, p.70). He also mentioned that “icons can save space over text, but at the price of recognition”. For small icons, it’s very difficult for users to even recognize what they are, let alone what the picture is supposed to represent. Bigger icons can help recognition, but they also take so much space. It’s better to use some of the space for a clear text label (Wiedenbeck, 1999, p.70).

However, text labels used in icon design may create problems. First, text must be concise considering the limited size of the mobile screens, no more than one or two words. The text labels must be carefully chosen to avoid confusion. Second, text labels require extra space to be displayed. Such space could be used instead to enlarge the icon or increase the understandability of the icon. Thirdly,

text labels may lead to translation problems considering the international market. A simple text label like "Message" is a single word in English, but it could be two or three words in other languages (Wiedenbeck, 1999, p.68).

Horton (1994) agrees with that, but he believes icons are not overpowering text. He states that icons cannot replace words totally. Combining both text label and icon together is better than just using text or icon. This is because "word labels help users learn visual images initially, and the visual images help poor readers interpret word labels" (Horton, 1994, p.14). In addition to that, an icon is not always effective and might not always make the interface easy to use. A well-designed and deployed icon does. Horton also believes that it is not necessary to always make the icons perfectly obvious. It is because "an icon does not fail if it requires a few seconds of study the first time the user sees it" (Horton, 1994, p.15). The action of figuring out the meaning is a problem-solving process which engages the user and enables the user to have a deeper memory for the icon. This will speed up the recognition process when the users see the icon for the next time. As users will encounter the icon dozens/hundreds of times, it is less important that users could recognize the icon instantly after the initial delay (Horton, 1994, p.15).

Easterby has done a lot of work examining symbols to see how recognition is affected by them (Easterby, 1970). He claims that whether symbols can be understood and remembered is determined by the following characteristics:

“Continuity”—Icons that have a smooth, continuous outline are easier to perceive.

“Closure”—Icons that are closed figures are preferred.

“Symmetry”—Icons that are symmetric are easier to organize into the visual perception process.

“Simplicity”—Icons should be as simple as possible. The inclusion of fine details makes icons ambiguous and more difficult to interpret.

“Unity”—Icons should be as unified as possible. This can be achieved by enclosing solid and line figures when they occur together (Easterby, 1970, p.156).

Easterby believed using these structural properties could help create optimal conditions for recognition and comprehension by guiding the eye to the true subject or feature of importance in an icon (Easterby, 1970, p.152).

Most of his research studies are still inspiring to current icon design. However, his research is focused on icons on machines around 40 years ago. Some of his research results may not work on the most recent mobile devices which have a touchable screen filled with nothing but icons. Take the iPhone home screen as an example. If most of the icons have smooth and continuous outlines whereas only one of them has the opposite, it becomes hard to perceive the icons based on the “Continuity” principle. But the only one icon that doesn't have the general characteristic of “Continuity” becomes easy to distinguish.

More recent research Horton (1994, p.144) suggests that the following categories should be considered to make objects recognizable: use of characteristic viewpoint; exaggeration of crucial concepts; use of depth effects consistently; and consistent shadows. Horton's suggestions focus on design for digital platforms and are more specific compared with those characteristics of Easterby's.

In order to gain the greatest benefits from the use of icons, they must be designed in a careful and thoughtful manner. Don Norman states that good-looking things have better results. He found that feelings and emotional affluence have implications for the process of comprehension (Norman, 2002, p.41).

Icons should be designed to have a certain level of realism. The unnecessary picture elements should be deleted from the design. The details that should be included in the icons are those things which could add to the meaning of the icon. Those parts that will distract from the true objectives of acceptance should be deleted. Horton (1994) discusses the five different levels of image that can be used: photograph, drawing, caricature, outline, and silhouette (Horton, 1994, p.138). He believes that appropriate details make the object easier to recognize.

Icons must not only be recognized but also remembered to be effective. Simplicity is the key to achieving these. As illustrated by Dondis, "icons cannot have a great deal of detailed information." But the more abstract the form is, "the more penetration of the public mind is necessary for the education to its

meaning” (Dondis, 1974, p.72). She also states that the symbol is even more effective for the transmission of information if it is a totally abstract figure (Dondis, 1974, p.73). Examples including the symbol of dollar (\$), plus (+) and etc.

Horton also points out that good icon design focuses on users’ needs and how users will interact with the interface (Horton, 1994). It is important to maximize the amount of resemblance to actual objects through the use of image or concept-related icons. Understanding how people “perceive, recognize, remember, and use icons guides the design efforts” (Horton, 1994, p.17), and helps this study in testing the icons.

1.2 Semiotics

Words, sounds, body language, and context are all components of signs. They combine together to create a visual language which helps us understand something. The group of theories which groups all of the signs is called semiotics (Welton & Morgan, 1992, p. 41). Semiotics studies how people understand information like icons. “Icons have the function of illustrating an argument carried by the written word, that is, of presenting the contents of the written language in a different medium” (Kress & Leeuwen, 1996, p. 14). Part of the job of semiotics, as mentioned by Hall, “is to reveal the factors which sustain and provide the

background for the various forms of communication that we often take for granted" (Hall, 2007, p. 113).

A sign is the "mediator" to the world. The signs have two aspects: signifier and signified. The first is the material that has a meaning and the second is the meaning (Saussure, 1959). Welton & Morgan have a more detailed explanation: "The signifier is the physical entity which expresses the sign" (Welton & Morgan, 1992, p. 41). For instance, the shape and color of the icons are signifiers. The signified is the concept or emotion conveyed by the sign, for example, make a payment, discover, etc. The relationship between signifier and signified varies from case to case. Hall believes two things about the relationship are important: "We can have the same signifier with different signifieds; we can have different signifiers with the same signifieds" (Hall, 2007, p. 10). A dollar sign as the signifier could mean treasure, payments, or any other things related to money. On the other hand, credit card, wallet, cash, and coin as signifiers could all mean payment as the signified.

Since signifiers and signifieds are associated with each other in various ways, the signs we use to communicate are not immediately clear to us. "Signs have to be learned with the conventions of the context in which they are embedded before they can be used" (Hall, 2007, p. 12). Older adults could connect infant bottle or the pacifier with baby better than teenagers because they learned that

from the conventions of their previous experience. Only after the conventions have been learned by the audience can the meanings that are conveyed become natural to them. This is extremely important when designing icons for different cultures or age groups. It is because what seems natural to one age group may be just the product of ingrained habits that they didn't noticed (Hall, 2007, p. 12), and people of other age groups or from different cultural backgrounds will have to learn the conventions before they can understand the meanings naturally. For example, the meanings of temptation and intelligence in "Apple" are not natural to people from eastern cultures. It is also not natural for older adults to associate Apple with the technology company and its products compared with young adults.

Literacy and educational background also decide how people understand icons. The more education people receive, the easier they can get the meaning through abstraction symbols, even though there's no other detailed explanation. Different people have different needs. Kids may not understand complex signs and images. Adults usually can process complex visual information but still depend on their personal qualities. Thus, to attain the goal of accurate information transferring, the designers' responsibility is to insure the audience can interpret symbols with their existing experience and knowledge (Dondis, 1974, p. 147).

People usually get visual signals through three levels: representation, abstraction, and symbolism (Dondis, 1974, p.67). Representation is exactly the look

of things to our eyes, for example, a realistic oil painting or a sketch portrait.

Abstraction is simple basic structures of things. For example, the restroom door signs are abstractions from human shape. Symbolism is defined by special meaning, for instance, a traffic sign. Each of these three levels has a different function and complements the other two. They can be adjusted and modified so that they can be used for different people. When icons are over-simplified on mobile devices, the shapes of the icons become geometric and abstract which make them look different than the objects. There are two basic sorts of difference. One is a difference in kind, and the other is a difference in degree (Hall, 2007, p. 58).

When the degrees of difference get big, users will have trouble recognizing the shapes.

In principle, all signs are conventional which can be explicit or implicit. Mollerup states that “an explicit convention is established by an agreement while an implicit convention is formed by habit” (Mollerup, 1999, p.82). In terms of semiotics, a motivated sign can be understood without strong convention. Users don’t need too much learning to know the meaning of the sign (Mollerup, 1999). In such a case, it’s better to use those images people already associate with the object or idea in icon design. Many times there are icons that already exist and that have become acceptable through use over time. There is no need to invent another symbol if one already exists that will clearly present the information. Examples

include the trash can icon to delete files or a floppy disk icon to designate the action of save.

When signs are arbitrary, however, there is no immediate connection between the image and the intended meaning. "While a motivated sign is a sign that shares some quality with the object to which it refers, the arbitrary sign does not have this characteristic" (Mollerup, 1999, p.84). According to Peirce, signs can be divided into icons, indices and symbols. Icons are "motivated signs and they are linked to their object by similarity" (Peirce in Mollerup, 1999, p.84). Mollerup explains that icons can be divided into images, diagrams and metaphors: a) "Images are highly representational signs that look very much like their object." The infant bottle as one of the baby supplies is an image. b) "Diagrams are schematic signs which show the structure of the object." c) "Metaphorical signs share conceptual qualities with the object." A talk bubble works by metaphor with a conceptual quality of communication and sharing. The functional icons on mobile devices can be images, diagrams, or metaphors (Mollerup, 1999, p.84).

1.3 Evaluation Criteria

Recognizability, relevance and uniqueness are the evaluation criteria for this icon study. They were selected for this research based on theories of cognitive science and visual design principles. *Recognizability* lets users identify the meanings of the icons. *Relevance* of the image ensures that users' interpretations are correct. *Uniqueness* enables users to search and identify the icons quickly.

Besides those criteria, simplicity is always considered in the evaluation and design process of this study as the icons are targeted on mobile devices. Simplicity grants users the ability to differentiate and memorize the icon easily and promptly.

1.3.1. Recognizability

According to Norman (1969), the human recognition process “works on expectation, which is guided by conceptualizations of the incoming information” and is called a conceptual driven process (Norman, 1969, p. 41). Another process involved in perception is a data driven process which starts with an image, and then the human brain “recognizes a particular combination. The process continues analyzing the information until the recognition of the incoming signals” (Norman, 1969, p. 41). The two processes are equally important to human recognition in “assisting each other in the completion of the job of understanding the world” (Norman, 1969, p. 41).

Norman further explains that “through interaction with a system that the person is learning or using, people formulate mental models of that system” (Norman, 1983, p. 7). The icon recognition process relies heavily on the mental models of the users. Mental models are constrained by the user’s life experience, technical/educational background, and previous experience with similar systems (Norman, 1983, p. 8). This means that users who are of different ages, work or study in distinctive fields, or are from different cultural backgrounds will have various and different mental models. The icon design must incorporate users’ mental models and pay attention to the difference between the mental models. In other words, if an icon is designed based on a user’s existing experience, the user can identify the icon effortlessly.

The compatibility between the visual appearance of the icon and users’ mental models determine the recognizability of the icon. The problems of the icons which may affect comprehension can arise at three levels: “a) Syntax level that governs relationship between elements within the sign; b) The meaning of the sign elements level; c) The suitability of the image for a particular physical display and set of interpreters” (Mullet & Sano, 1995, p. 193).

To recognize the icon is the very first step in understanding the icon’s meaning, and it is also a vital part in visual communication. In some cases, the communication between the information initiator’s mental model and information

receiver's mental model is broken because the mediator (the icon) is unrecognizable. That is one of the reasons why users have comprehension problems with the icons.

1.3.2. Relevance

As most of the functions on mobile devices are invisible and have no forms, most icon design exploits metaphors to visualize the functions. As Cormac points out, "metaphor involves not only semantic, syntactic, and cognitive aspects, but also the contextual aspects about culture and the individual's knowledge and living environment" (Cormac, 1985, p.22). The intention of using metaphor is to make the icon more comprehensible to users. However, metaphor is only useful when it is relevant to the receivers.

The metaphor interpretation is a challenging process for users. The metaphor must be relevant to the intended meaning to be successful. It is because "metaphor can contribute to understanding only by making us see similarities between the meaning A and B" (Cormac, 1985, p.209). Besides, even an excellent metaphor requires the receivers' thinking process to search for the correct interpretations, which is a problem-solving process. If a metaphor is not relevant to the intended meanings or carries multiple meanings, user will have to solve the complex problem before using the icon, which makes the icon less effective and problematic.

In order to present information clearly to users, every dot, line, and shape of the icons must be organized in a certain way to emphasize relevant aspects while ignoring the irrelevant areas. This is because “any irregularity will be interpreted as significant by the user, who will cheerfully ascribe to it a meaning even where none was intended. By regularizing non-critical design elements throughout the work, the design can attract the user’s attention by purposely introducing distinct irregular elements to convey certain meaning” (Mullet & Sano, 1995, p.45).

In summary, icons can communicate effectively only if the metaphor is relevant to the intended meanings.

1.3.3. Uniqueness

As mobile device users look at the apps on-the-go from time to time, they have to search rapidly for the icons to perform the task with the least effort.

According to psychologist Reed, “the number of differing features (*uniqueness*) proved to be a highly significant variable, since the greater the number of differing features, the faster the viewers scan the image” (Reed, 1973, p.62). In order to enable the users to rapidly separate the icons from other elements on the screen, the icon must be designed with the consideration of *uniqueness*.

The human image scanning process involves searching for target images, which takes time. A group of icons on the mobile screen requires users to

differentiate one from the rest of the group. Reed points that “the scanning would be faster when the target could be distinguished by itself alone than when its identification required memory examination” (Reed, 1973, p.81). *Uniqueness* helps the users to scan the images rapidly and find the target icon easily.

People identify a targeted icon from the screen based on a rapid scanning of the difference between the outer shape of the icon and the empty spaces, not on close examination of each icon’s details (Horton, 1994, p.15). Therefore, in order to make each icon unique, the relationship of the icon and its background should be taken care of with consideration.

1.4 Comprehension Test of the Icons

Comprehension testing is the procedure for quantifying the degree of understanding for proposed graphical symbols (ISO 9186-1, 2007, p.2). This can show potential problems in the design and help designers have a much broader understanding of what users are doing and how they interact with the design.

The most common problem in comprehension tests as illustrated by Horton is that the tests are done too late to help the design. He implies that testing is a part of the research instead of just a method of evaluating. He further suggests a three-step comprehension testing method which consists of: 1) Formative testing. 2)

Comparative testing. 3) Evaluative testing. These three phases overlap in time and method and each is focused on a specific area (Horton, 1994, p.290).

Formative testing targets on stimulating ideas rather than refining or verifying them. It is used to learn what to do rather than how well it did. Formative testing works best when it is simple, informal, and quick (Horton, 1994, p.291).

Comparative testing evaluates the performance of two or more designs, and it requires clear criteria for assessing the results. This is to decide which one works better than the others. Evaluative testing safeguards the quality of the icon, which is to determine if it is good enough to release (Horton, 1994, p.292).

Formative testing works best at the beginning of a study; comparative testing is most valuable in the middle phase; and evaluative testing is most effective at the end of research (Horton, 1994, p.290).

The International Committee for Breaking the Language Barrier (Kato, 1972) proposed several useful criteria for the primary evaluation of icons:

- Is it easy to associate the symbol with the message?
- Is the symbol equally appropriate for all of the cultures and situations in which it will be used?
- Will the symbol be appropriate in the future?
- Is the symbol pleasing and noncontroversial?

- Is the symbol in accordance with existing international standard symbols?
- Is the symbol easy to reproduce in a variety of situations?
- Is the symbol distinguishable from other symbols?

Though these criteria focused on road signs, the findings can be used on icons in mobile devices. This is because they all focus on users' needs and how users will interact with the signs. The criteria targeted on the communication between the information sender's mental model and information receiver's mental model instead of where the signs were presented. As a result, it could be the guidelines for icon evaluation of this study.

ISO evaluation procedures

International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. The ISO technical committees are responsible for preparing International Standards. ISO 9186-1 was created by "Technical Committee ISO/TC 145, Graphical symbols, Subcommittee SC 1, Public information symbols" (ISO 9186-1, 2007, p.1). ISO 9186-1 focused on the methods for testing comprehensibility while ISO 9186-2 targets on the method for testing perceptual quality.

The international standard ISO 9186-1 defines procedures for testing the comprehensibility of graphical symbols when there are no explanatory texts

presented to make sure that “there is only one symbol for each meaning.” The procedures describe two testing methods, the comprehension test and the comprehensibility judgement test. Both tests are intended to identify the most comprehensible variants of graphical symbols. The standard determines rules for selection of subjects, and rules for “selecting the most comprehensible graphical symbol variant for each referent” (ISO 9186-1, 2007, p.1).

Each respondent is presented with one variant in the comprehension test, and asked “What do you think this symbol means?” Each variant is ranked according to the percentage of correct answers. This is to evaluate how well the graphical symbol communicates its intended message. In the judgement test, all the variants being tested were presented to subjects for one intended meaning. The judgement test is normally “not conducted on more than three variants and the results can be used to select the variant for the comprehension test.” When there are four or more variants for one intended meaning, the judgement test “can be used to reduce the number of variants” (ISO 9186-1, 2007, p.2). ISO 9186-1 notes that “three variants are usually sufficient for the comprehension test”, which evaluates how well subjects interpret the graphical symbols in degrees. (ISO 9186-1, 2007, p.14).

Furthermore, ISO 9186-1 suggests that variants should be presented in black and white for the comprehension test. If a colored variant is used, “the contrast

between the variant and the background should be sufficient enough for the variant to be readily visible” and the colors and contrast levels are accurate and the same for all subjects (ISO 9186-1, 2007, p.4).

Variants of graphical symbols are presented to the subjects with a question like: “What do you think this symbol means?” The respondents have to write down what they think. The standard recommends that the test provide instructions guiding subjects to write “don’t know” if they are not able to assign a meaning to the symbol. In some cases, when an action is associated with the target symbol, an extra space should be provided to subjects. Subjects are required to write down the answer for “what action would you take in response to this symbol?” (ISO 9186-1, 2007, p.4).

Subsequently, independent-working judges classify the answers into five categories, ranging from "Correct understanding of the symbol" to "No response is given.” How to calculate a score for each variant is also defined the standard. According to ISO 9186-1, threshold values are given to determine which variants may be accepted as a standardized graphical symbol (ISO 9186-1, 2007, p.8).

Asking subjects to write down what they think a symbol means would be very helpful in understanding the problems in the problematic icon. But it also requires a lot of time for researchers to analysis those data. Different researchers may calculate different scores for the same answer. To increase the reliability of the

analysis, a team of researchers is needed to obtain the mean value of the analysis results from all researchers. This method is not practical when the sample size is big, but it will be very helpful in face-to-face interviews with fewer samples.

When conducting the tests in screen presentations, it is advised to provide each test page with a “next page” and a “previous page” button to ensure that subjects can switch from one page to the other (ISO 9186-1, 2007, p.11). The screen size for the test should be at least 600 pixels x 800 pixels to ensure that “the graphical symbols presented are not distorted and that a sufficient number of graphical symbol variants can be displayed simultaneously” (ISO 9186-1, 2007, p.3).

ISO 9186 suggests to use at least 50 respondents to test variants for a given meaning. It is not recommended to use any subjects who have participated in any tests on that same referent (ISO 9186-1, 2007, p.11). The subjects should be representative samples of the targeted user population with regard to “age, gender, educational level, culture or ethnic background, and physical ability” (ISO 9186-1, 2007, p.12).

It is important to examine not only those icons that the subjects correctly recognize and understand, but to identify the errors or misidentifications that can occur as well. Identifying reasons for the confusion can be extremely important to the development of icons. It is especially helpful when subjects are able to identify the exact elements in the symbol that are causing the confusion.

CHAPTER 2: COMPREHENSION TEST METHODOLOGY

2.1 Objective

The purpose of the comprehension study is to evaluate the effectiveness of the sample icons. As icons are used to communicate messages to the general public, real users are involved in the study to obtain objective data, such as error-rate and task success. The purpose of this study is to gain a better understanding of what a successful icon is. It is necessary to explore the relationship between the icons and real users' comprehension ability. The study is also trying to identify the reasons why users struggle with the icons and provide recommendations for future improvement to fix the problems in problematic icons.

The icons that could be interpreted correctly by the majority of users are considered as successful, while those that couldn't be identified by most users are regard as problematic icons. It is predicted that the results of the comprehension study will indicate whether certain icons are clear in presenting their meanings.

Analysis of the unsuccessful icons will help to determine if they share common gaps in communication. Five problematic icons were chosen for this study. It is believed that they suffer from a lack for clarity caused by overly simplified form, and irrelevant, incomplete or vague message.

2.2 Comprehension Study Subjects

The survey was sent out to 36,000 college students from Iowa State University, ranging from freshmen to candidates who are pursuing doctorate degrees. They were reached through email and participated on a volunteer basis. Subjects took part in this study through an online survey with their own device, at their own time and space.

The survey was closed after 931 results were recorded. As subjects were divided into two groups randomly and evenly, the sample size for each survey is around 460.

College students are good subjects to test these icons because educated young adults have strong cognitive skills focusing on comprehension, memory, and thinking (Sears, 1986). If they have trouble understanding the meanings of those icons, the general public will have even bigger problems, as the less education people received the more difficult it is for them to comprehend the meanings through abstract symbols (Dondis, 1974).

2.3 Comprehension Study Procedure

This survey begins with the assumption that the five icons listed below have comprehension problems and that users are having trouble understanding them. The ineffectiveness of icons is normally caused by the over-simplified form, irrelevant message, vague message, and poor association between the icons and pre-existing mental models.

The original meanings of these icons and their contexts are listed in Table 1.

Table 1. Meanings and Contexts of Problematic Icons

Icon	Intended meaning	Context
	Make a payment	This icon is displayed in a mobile banking app. After clicking this icon, users could enter the payment screen and perform actions like select payment method, choose date and enter amount of money to pay, etc.
	Discover	The discover icon is found in a social app. After clicking this icon, users are able to browse text content within the chosen topics.
	Baby journals	This icon is part of an infant and mom mobile app. After clicking this icon, users could use the app to write journals and store photos about the baby.
	Social activity	Users could check available social activities by clicking this icon.
	Birth and baby club	This icon is also found in a baby related app. This baby club is a place where moms/dads could talk with each other regarding topics of baby raising, breastfeeding, etc.

For this study we need quantitative data. It will allow us to see directly which icon can associate better with the intended meaning than other icons. It could also provide information about the mistaken meanings users might perceive from the given icon. In the end, the data could provide suggestions for future improvements. The best way to get the information would be through face-to-face interviews: let participants look at the icons from the mobile devices in their hands and let them express how they feel about the association of the icons and the given meanings. Even more, during the interview they would be able to suggest what they think could be a better solution.

However, there are some time constraints that will not allow that in this case. To have better results, time needs to be used efficiently. In the end, online surveys were used to collect data from participants. Compared with interviews, online surveys offer a way to collect information from a broader audience in less time. As participants are given a list of options to choose from, the responses are short and controlled. Online surveys can also be completed at a location and a time that are more convenient to the participants.

Two types of surveys are used for the comprehension test. Survey 1 (Appendix B) asks subjects to identify the meanings of the given icon with a given list; survey 2 asks subjects to associate one of the three icons to the given words (Appendix B).

All the subjects were divided into two groups randomly and evenly. Each group got one set of five questions. The same subject was not tested twice with similar questions to avoid influence from the results of the previous test. This study is to test how well users understand those icons when they are small, so the size of the icons is set to 60 x 60 pixels which is the same size as they are on mobile devices. The following considerations are made to avoid bias in this study:

2.3.1. Survey structure

It is important to ask only one question at a time. Questions that ask subjects to evaluate more than one concept are difficult for participants to answer and could also lead to results that are difficult to interpret. A question like “What is the meaning of Icon A and how is the meaning related to the other icons?” is an example of this approach. In the survey, subjects are presented with only one question each time, and that question has only one specific answer (Figure 1).



Figure 1. Survey Question Example

As there were two surveys with similar content, it is also important that the results of one survey will not influence subjects' decisions for another. The same five problematic icons and their intended meanings are available in both surveys. It is crucial that subjects who are involved in survey 1 will not be in survey 2 (Appendix B – Comprehension Test Materials). To achieve that, the two surveys were put together and a filter was created so that participants were divided randomly and evenly to the two surveys (Figure 2).

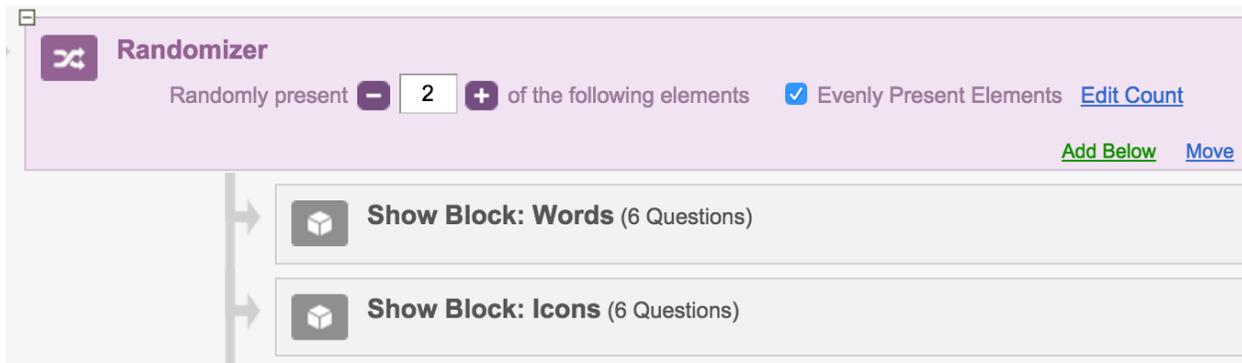


Figure 2. Survey Filter

The two surveys were then delivered at the same time to the same target group through email. By clicking the survey link in the email, each participant is directed to one of the two surveys. However, if a subject clicks the survey link again after she/he has finished the survey, it is possible that this participant will see the other set of survey questions. Except for the results of the first survey, the other results of this participant should be considered as invalid as they have been

influenced by previous results. The details about how to identify those participants will be discussed later in Chapter 3, “Clean the data” section.

When determining the order of questions within the survey, an attempt was made to eliminate the possibility of unintended influence created by questions early in the questionnaire. All the questions presented have similar words and structure. From the first question to the last one, all options were made to have the same length, normally two to three words. The correct answers were randomly distributed among four options to avoid subjects finding a pattern.

2.3.2. Styles and colors

Styles and colors could make the survey look nice. However, as people respond in various ways to different styles and colors, those styles and colors might bring in potential bias to the subjects. So it is important for the study to minimize the influence made by such decorations. All the text in the surveys has the same typeface, font size, and color. There are no other distracting elements in the survey, to ensure that it looks neutral.

Also, all the icons presented in the two surveys have the same size. For the five problematic icons, their colors and background colors were unchanged as those are part of the meaning of those icons. Styles and colors are more related to

survey 2 than survey 1 because there are more icons involved in survey 2 (Appendix B – Comprehension Test Materials).

In survey 2, the alternative icons are matched with the targeted icon in color, size, and style. If the targeted icon is in black and white, the other two icons provided are also in black and white (Table 2). If the targeted icon has colors, the other two options are also with colors (Table 3).

Table 2. Survey Question Showing Only Black and White Icons

Q6. Which one of the following icons could best represent the meaning of “Make a payment”?		
		

Table 3. Survey Question Showing Color Icons

Q9. Which one of the following icons could best represent the meaning of “Social activity”?		
		

Additionally, the two icons put together with the problematic icon have the same level of simplicity. All three of them are flat 2D icons and take the same amount of space. Lastly, all three icons in survey 2 are aligned in a row without having any one of them stand out. With those considerations, any potential bias was minimized throughout the five questions of survey 2.

2.3.3. Questions wording

In the first survey, participants are presented with one icon and four meanings to choose from (Table 4). Subjects are allowed to choose one from the four options. Only one of the options is the intended meaning that icon is supposed to communicate. To increase reliability of the data, it is very important to avoid bias in the data collection process for online surveys.

Table 4. Question 1 of Survey 1

Q1. Which one of following words could best represent this icon's meaning?



Access checking account
 Make a payment
 Save money
 None of these

The choice of words in a question is critical in expressing the intention of the survey. It is important to ensure that all participants interpret the question the same way. Small wording differences can greatly affect the answers people provide.

One of the considerations under this category is to avoid the inability to answer correctly. Closed-ended questions should include all reasonable options. It is possible that some subjects may be unable to choose any of the given answers

because they don't think they are related. It is very important to provide a choice that allows subjects to opt-out. In this study, participants are always provided with "None of these" as the fourth choice; they were not forced to choose an uncomfortable option. This increases the reliability of this study as it eliminates potential inaccurate answers.

One concern for giving an opt-out option is that participants might choose the opt-out option intentionally and reduce the reliability of the study. So data cleaning is important to this study by evaluating the answering time of the questions and their answers. If participants' answers are all the same and the time they spend on this study is much less than the mean value, those participants are considered as outliers and will be deleted from the data set. More details regarding how to clean the data will be discussed later in 3.1 Clean the data section.

Furthermore, the two misinterpretations (alternate answers) are given to subjects with careful consideration. Firstly, those two misinterpretations are closely related to the "correct" answer in meaning, and all three meanings presented to subjects are closely connected with the icon to be tested:

a) For question 1 (Table 4), the intended meaning associated with the dollar sign icon is Make a payment. The two other options offered are “Access checking account” and “Save money.” They are related to each other as all three of them are the activities the user does in a bank.

Table 4. Question 1 of Survey 1

Q1. Which one of following words could best represent this icon's meaning?



Access checking account

Make a payment

Save money

None of these

b) Table 5 below shows the second survey question. Discover was the intended meaning of that icon. “Rotate” is presented to subjects as a possible answer, since the orbit within the icon indicates movement. This icon is also very similar to the “Internet Explorer” icon in Windows, so “Internet” is another possible but incorrect option. They are all reasonable interpretations of the icon.

Table 5. Question 2 of Survey 1

Q2. Which one of following words could best represent this icon’s meaning?



- Rotate
- Internet
- Discover
- None of these

c) The intended meaning of the third icon is Baby journal (Table 6). It is very likely that this icon seems more related to baby supplies and activities because of the bottle and diaper symbols shown in the icon. All three options start with “Baby” to align with the context.

Table 6. Question 3 of Survey 1

Q3. Which one of following words could best represent this icon’s meaning?



- Baby journal
- Baby supplies
- Baby activities
- None of these

d) The intended meaning of the fourth icon is Social activities. It is related to forums as sometimes the fire symbol can be seen in online BBS forums to indicate a certain topic is hot. It is also relate to “Emergency” because of the fire and the red color. So those two are provided as reasonable but incorrect answers (Table 7).

Table 7. Question 4 of Survey 1

Q4. Which one of following words could best represent this icon’s meaning?



Social activities

Forum

Emergency

None of these

e) The intended meaning of last one in this group is Birth and baby club.

“Birth and baby” is the context of this icon, and it’s much easier to get it if subjects are viewing this icon in the app. By showing this icon separately, it is considered successful if the user could get the meaning of “Social club.” If the option of “Birth and baby club” was provided, the user would quickly skip it as there is no sign of baby or birth in the icon. “Q & A” and “Customer service” are the two possible meanings as the two talking bubbles indicate conversations between two persons.

Table 8. Question 5 of Survey 1

Q5. Which one of following words could best represent this icon’s meaning?



Q & A
 Social club
 Customer service
 None of these

The second consideration for the wording of those five questions is the property of the words. If the meaning to be tested is a verb, the misinterpretations will also be a verb. Take the first question as an example: “make a payment” is an activity people will do. To match with this, the other two misinterpretation options

are “Access” and “Save” which are both verbs. Similarly, in question 3, the meaning to be tested is Baby journal. To match with this, two options given are “Baby supplies” and “Baby activities” which are both nouns.

The possibility that certain words may be viewed as biased or may potentially provoke emotional reactions has been considered. Neutral words were used to make the survey look as fair as possible.

2.3.4. Selection of meaningful options.

The meaningful option ties together with the result of the survey closely. If the options are not closely relevant to the meaning being tested, subjects might end up choosing the opt-out option (which in our case is “None of these”).

It is useful in learning what symbols are not working, but it is not helping in understanding what visual metaphors might be meaningful for subjects. With that in mind, the icons in Table 9 were chosen for the five questions in survey 2.

Table 9. Survey 2 Comparisons

Icon	Intended meaning	Compared icons	
	Make a payment		
	Discover		
	Baby journals		
	Social Activity		
	Birth and baby club		

CHAPTER 3: COMPREHENSION TEST ANALYSIS

3.1 Clean the Data

The data value that lies outside most of the other values in a set of data is called an outlier. Outliers can occur in any database and reduce the reliability of the data. Data cleaning is the process of removing outliers from a set of data.

For the survey of problematic icons, 931 results were recorded. A simple way to detect the outliers is by checking the relationship between their mean value, standard deviation, minimum value, and maximum value. Table 10 shows the descriptive statistics for duration of the test. The unit is seconds. We can learn from that table that it took subjects one minute and a half to finish the survey on average. The maximum value could be an outlier as it is more than three standard deviations away from the mean value. But that does not necessarily indicate that the minimum value is valid.

Table 10. Descriptive Statistics for Duration

	N	Minimum	Maximum	Mean	Std. Deviation
duration	931	3.00	8031.00	94.6928	321.39468
Valid N (listwise)	931				

The problem with the information in Table 10 is that the standard deviation could be too big as it is influenced by the outliers in the data set. As demonstrated in Table 11, 95% of the data lies between 74 and 115. It means that, for the majority of the subjects, the survey took them one to two minutes from start to finish.

Table 11. Descriptives for Duration

		Statistic	Std. Error
duration	Mean	94.6928	10.53329
	95% Confidence Interval for Mean	Lower Bound 74.0210 Upper Bound 115.3646	
	5% Trimmed Mean	70.3805	
	Median	65.0000	
	Variance	103294.538	
	Std. Deviation	321.39468	
	Minimum	3.00	
	Maximum	8031.00	
	Range	8028.00	
	Interquartile Range	32.00	
	Skewness	20.791	.080
	Kurtosis	470.956	.160

It leaves us to consider the possibility that those records with duration value smaller than 74 or larger than 115 could be outliers. As undergraduate students are required to take surveys to get credits, it is very reasonable to doubt that some of the subjects might not have treated the survey very seriously.

Tables 12 and 13 show part of the survey records with duration value descending in order. In those tables, Q16 to Q24 (first five columns) are the five questions for survey 1 and Q28 to Q36 are the other five questions in survey 2. It is

The 24 records in Table 13 have duration value between 18 to 35. In other words, those are the results from 24 subjects who finished the survey in 35 seconds. Similar to the records in Table 12, it is clear that half of the records are incomplete and they should be deleted from the database.

Table 13. Invalid Survey Records Part 2

-	-	-	-	-	-	-	-	-	-	-	-	-	18.00
2	-	-	-	-	-	-	-	-	-	-	-	-	20.00
-	-	-	-	-	-	-	-	-	-	-	-	1	21.00
-	-	-	-	-	-	-	-	-	-	-	-	-	21.00
2	-	-	-	-	-	-	-	-	-	-	-	-	22.00
-	-	-	-	-	-	-	-	-	-	-	-	-	23.00
2	2	1	3	1	1	-	-	-	-	-	-	-	24.00
1	4	-	-	-	-	-	-	-	-	-	-	-	24.00
-	-	-	-	-	-	-	-	-	-	-	-	-	25.00
1	3	1	3	1	1	-	-	-	-	-	-	-	29.00
-	-	-	-	-	-	-	-	-	-	-	-	-	29.00
-	-	-	-	-	-	2	4	4	3	2	1	-	30.00
4	4	1	4	1	1	-	-	-	-	-	-	-	30.00
3	4	1	4	3	1	-	-	-	-	-	-	-	30.00
-	-	-	-	-	-	-	-	-	-	-	-	-	30.00
-	1	-	-	-	1	-	-	-	-	-	-	-	31.00
3	4	1	3	5	1	-	-	-	-	-	-	-	31.00
2	4	-	-	-	-	-	-	-	-	-	-	-	31.00
-	-	-	-	-	-	3	5	3	3	1	1	-	33.00
-	-	-	-	-	-	2	5	3	5	2	1	-	33.00
-	-	-	-	-	-	2	4	3	5	1	1	-	33.00
1	-	-	-	-	-	-	-	-	-	-	-	-	33.00
-	-	-	-	-	-	3	1	1	-	-	-	-	33.00
-	-	-	-	-	-	2	4	3	5	1	1	-	34.00
-	-	-	-	-	-	3	4	3	3	1	1	-	34.00
-	-	-	-	-	-	3	-	-	-	-	1	-	35.00

For those who completed the surveys, their values were compared with the mean values of each question. After analysis of the standard deviation of each

question, the mean value of each question, and the error rate, there is no obvious evidence that indicates those records are invalid. Therefore those records were kept even though their duration value is much smaller than the average.

Those five cases with large duration values in Table 14 were eliminated from this study as they are three standard deviations from the mean value. As we have 931 as sample size, there is no significant difference in the result after those five cases have been removed from the dataset.

Table 14. Duration Extreme Values

			Case Number	Value
duration	Highest	1	610	8031.00
		2	865	5240.00
		3	292	1486.00
		4	231	868.00
		5	759	851.00
	Lowest	1	914	3.00
		2	834	7.00
		3	910	8.00
		4	701	9.00
		5	323	9.00 ^a

Finally, if there are two cases from the same IP address, it means that it's possible a subject took the survey twice. As we discussed earlier, the results of one survey will influence the results of the other heavily as the two surveys have similar content. Thus those cases with the same IP address should be deleted from

the set. After analysis of the data, each of the records came from a unique IP address. There is no guarantee that those 931 records are from 931 subjects as the same subject could use more than one computer to take the survey. But for our study, we will not consider that possibility as it is extremely unlikely.

3.2 Analysis of the Results

The analysis of the effectiveness of icons will be based on statistical results along with the criteria for evaluation of icons discussed in an earlier chapter. It is divided into five parts in line with the five problematic icons.

3.2.1 Make a payment

It can be seen from Table 15 that when 451 subjects were asked what the dollar sign (Figure 3) means, 50% of them chose Make a payment which was the meaning it should stand for. This icon (Figure 3) worked as it was highly *recognizable* and it has a certain level of *relevance* to the intended meaning, even though the message that came from the icon was not *unique*.



Figure 3. Make A Payment Icon

Table 15. Survey 1 Results for Make A Payment

Answer	Bar	Response	%
Access checking account		79	18%
Make a payment		225	50%
Save money		65	14%
None of these		82	18%

More than 94% of 446 subjects did not choose the target icon (Figure 3) in survey 2 (Table 16). Those two options are working because they are *recognizable*, *unique*, and *relevant* to the topic. The dollar icon needed to be improved in *relevance* and *uniqueness* to better represent the intended meaning.

Table 16. Survey 2 Results for Make A Payment

Answer	Bar	Response	%
		28	6%
		177	40%
		241	54%

3.2.2 Discover

More than half of the subjects understood the meaning correctly for Discover (Table 17). Figure 4 is working because of the concept it has, which is the planet, is *relevant* to the intended meaning. But a large number of them believe this icon means something else (Percentage of “None of these” = 38%). It is not working for other people as the shape is too abstract to *recognize*.

However, when subjects in survey 2 were presented with options that can be *recognized* easily and were *relevant* to the intended meaning (Table 18), Figure 4 was abandoned for lower comprehensibility.



Figure 4. Discover Icon

Table 17. Survey 1 Results for Discover

Answer	Bar	Response	%
Rotate		15	3%
Discover		225	51%
Internet		34	8%
None of these		171	38%

Table 18. Survey 2 Results for Discover

Answer	Bar	Response	%
		52	12%
		141	32%
		252	57%

3.2.3 Baby journal

The Baby journal icon (Figure 5) is the most ineffective icon among the five. As the icon was not *relevant* to a journal at all, it's not surprising that 90% of subjects thought it was baby supplies (Table 19). 90% subjects in Table 20 prove that with a consideration of *relevance* and *recognizability*, the icon in Table 20 could successfully deliver the message to users.



Figure 5. Baby Journal Icon

Table 19. Survey 1 Results for Baby Journal

Answer	Bar	Response	%
Baby Supplies		396	90%
Baby Journal		13	3%
Baby Activities		27	6%
None of these		5	1%

Table 20. Survey 2 Results for Baby Journal

Answer	Bar	Response	%
		21	5%
		393	88%
		31	7%

3.2.4 Social activity

The image for Social activity (Figure 6) produced 11% correct recognition, while 62% of the subjects took it as an emergency icon (Table 21). The fire symbol is *clear* and *recognizable*. But it has a *relevance* problem as the red color and the fire symbol together lead to the meaning of emergency. It's better to avoid using the image people already associate with one object to represent the other. The alternate icons of people holding hands or a hand shaking icon shown in survey 2 could be better images for social activity (Table 22). According to test results, they presented the message clearly and specifically.



Figure 6. Social Activity Icon

Table 21. Survey 1 Results for Social Activity

Answer	Bar	Response	%
Social activities		50	11%
Forum		29	7%
Emergency		274	62%
None of these		88	20%

Table 22. Survey 2 Results for Social Activity

		318	72%
		28	6%
		96	22%

3.2.5 Birth and baby club

The icon for Birth and baby club (Figure 7) produced 70% mistakes (Table 23). The shapes of talking bubbles seem to be clear as 52% people get the meaning of Q & A. But the icon (Figure 7) has a *relevance* problem because of its poor connection to the meaning of birth and baby. It is also not *unique* enough to represent the club meaning. So when it was presented with other two baby related icons, subjects skipped over it as there was no baby-related information (Table 24).



Figure 7. Birth and Baby Club Icon

Table 23. Survey 1 Results for Birth and Baby Club

Answer	Bar	Response	%
Q & A		230	52%
Customer Service		41	9%
None of these		39	9%
Social Club		130	30%

Table 24. Survey 2 Results for Birth and Baby Club

Answer	Bar	Response	%
		305	69%
		136	31%
		3	1%

These comprehension test results prove the hypothesis that users have problems in understanding the mobile icons. Based on the analysis, each problematic icon has at least one problem in the categories of recognizability, relevance, or uniqueness. The problems are caused by unclear, vague, or incomplete information transmitted by the icon.

In some cases, the problematic icon was oversimplified so it became too abstract for users to understand. In other cases, the problem was caused by an irrelevant message conveyed in the icon. Also, some of the messages were delivered incompletely or vaguely so there was a poor association between the icons and pre-existing mental models which led to comprehension problems.

As it was pointed out in Chapter 1.2, Semiotics, the relationship between signifier and signified varies from case to case. We can have the same signifier with different signifieds (Hall, 2007, p. 10), this leads to comprehension problems regarding to relevance and uniqueness. The results in these two surveys indicate that when signifiers have multiple signifieds, it becomes difficult for subjects to associate the signifier with a specific meaning. For example, a dollar sign as a signifier means treasure, payments, or any other things related to money. Some of the messages conveyed in the dollar sign are not relevant to the intended concept, which is Make a payment.

When icons are over-simplified, the shapes of the icons become geometric and abstract which make them look different than the objects they refer to. The Discover icon (Figure 4) consists of a few over-simplified circles and cannot be identified as a planet easily, which prevents users from getting the intended meaning of discover.

CHAPTER 4: PROTOTYPE DESIGN METHODOLOGY

4.1 Objective

In order to improve the effectiveness of their intended meanings, all five of the target icons were redesigned based on the outcome and analysis of surveys 1 and 2. Through the statistical analysis of the survey results and the assessment of the effectiveness of those icons, some shortcomings in those problematic icons were revealed. The ineffectiveness of the icons seemed to be caused by over-simplified form, incomplete message, vague message, and/or poor association between the icons and pre-existing mental models. The purpose of this prototype design is to determine which kind of modifications could improve the effectiveness of those intended messages in order to create better connections between the symbols and people's minds.

4.2 Methodology in Prototype Design

There was a lot of productive feedback from the comprehension test; for example, a compass symbol could be a better metaphor than the eye symbol regarding the message of "Discover." But that information is not enough in creating icons that are recognizable, clear in message, and unique: many different solutions needed to be tested. To enhance the effectiveness of the icons, an ideation matrix

was used to generate concepts at the initial stage. The two most important elements in the matrix are conceptual attributes and design principles. Attributes are the characteristics that are associated with the message. The attributes could be an object, an action, a place, an emotion, or an abstract concept. Take “Social activities” as an example (Table 25): “hands” as one attribute is an object; “broadcasting” is an action; “connect” and “interactions” are abstract concepts.

Table 25. Ideation Matrix and Attributes

Message	Attributes
Make a payment	Hand over money, money goes out, “Pay”, credit card, wallet, cash, coin, dollar sign
Discover	Magnifying glass (world map), man with binoculars (telescope), compass, hiking, footprint, radar
Baby journals	Diary, calendar, pen, writing, mom holding baby, baby, or baby related item
Social activity	Holding hands, group, people, connect, broadcasting, globe, interaction
Birth and baby club	Breast feeding, changing diaper, bottle, stroller, community, forum

Some of the objects were selected because the previous test results indicate that they have potential (Table 26). Examples include the hand for Payment,

compass for Discover, diary for Baby journal, and the holding hand attribute for Social activity concept.

Table 26. Survey Results Showing Most Effective Icon Choices

		241	54%
		252	57%
		393	88%
		318	72%

The other important element in creating the matrix is design principles. The principles used on the ideation matrix are similarity, direction, radiation, gradation, repetition, anomaly, contrast of line and mass, contrast of curved lines and straight lines, contrast of large and small shape, and contrast of negative and positive space.

4.3 Concept Ideation

The next step was to put recognizable objects and attributes on the y axis of a table and put design principles on the x axis (Table 27). By doing that, a matrix with empty blocks in the center was created.

Table 27. Ideation Matrix Example

	Similarity	Direction	Radiation	Gradation	Repetition	...
Diary						
Calendar		Calendar + Direction				
Pen/Writing					Pen + Repetition	
Protecting			Mom + Radiation			
Caring						

The matrix above was used to generate new icon concepts for Baby journal. Each empty block was filled with one sketch that cross-referenced the objects or attributes on its y axis and one design principle on the x axis. The ideal situation is to fill all the empty blocks with sketches that relate to both object/attribute and

design principle. More than one object/attribute and design principle could be mixed together in this matrix.

This ideation matrix is an appropriate tool for the prototyping phase because it is capable of meeting the three criteria of successful icons: *recognizable*, *relevant*, and *unique*. Those design principles in the matrix will impose some constraints on those icons to make them recognizable and clear in shape. For example, this can be seen when one sketch has “contrast of negative space and positive space” as its design principle (Figure 8). The recognizable objects will determine if the icon could be clear in representation or create a good association. By randomly blending objects and design principles together, the icon could have a unique combination of concept and form.



Figure 8. Icon Sketch for Baby Journal

With the help of the ideation matrix, 160+ sketches were created for this study. Some of them are presented in Table 28; the full list of sketches can be found in Appendix D – Redesigned Icon Sketches.

Table 28. Icon Sketches

<p>Make a payment</p>
<p>A collection of 12 hand-drawn sketches for 'Make a payment'. The top row shows a hand holding a dollar sign, a hand holding a dollar sign, a hand holding a coin, a hand holding a card with a dollar sign, a hand holding a card with a dollar sign, and a hand holding a coin. The bottom row shows a hand holding a dollar sign, a hand holding a card with a dollar sign, a hand holding a card with a dollar sign, a hand holding a card with a dollar sign, a hand holding a card with a dollar sign, and a hand holding a card with a dollar sign.</p>
<p>Discover</p>
<p>A collection of 14 hand-drawn sketches for 'Discover'. The top row shows a magnifying glass over a document, a magnifying glass over a document, a magnifying glass over a document, a compass, a compass, a compass, and a compass. The bottom row shows a magnifying glass over a document, and a magnifying glass over a document.</p>
<p>Baby journal</p>
<p>A collection of 14 hand-drawn sketches for 'Baby journal'. The top row shows a baby in a book, and a baby in a book. The bottom row shows a baby in a book, and a baby in a book.</p>
<p>Social activity</p>
<p>A collection of 12 hand-drawn sketches for 'Social activity'. The top row shows a group of people, and a group of people. The bottom row shows a group of people, and a group of people.</p>
<p>Birth and baby club</p>
<p>A collection of 12 hand-drawn sketches for 'Birth and baby club'. The top row shows a baby in a book, and a baby in a book. The bottom row shows a baby in a book, and a baby in a book.</p>

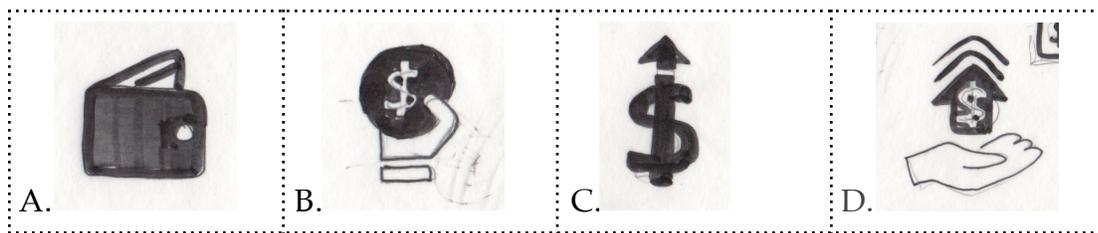
Based on the three criteria (recognizability, relevance, and uniqueness), some sketches were selected for further exploration while others were abandoned.

Following are the considerations in the icon evaluation process that deemed some to be called unsuccessful sketches.

4.3.1 Make a payment

Wallet is one of the attributes for the payment icon (Table 29 - A). After sketching it out with simple shapes and lines, however, it looks like a book and is therefore not *recognizable* to users. This is because a wallet doesn't have a *unique* shape compared with a book, and size - the major difference between them - is not easy to show in a small icon.

Table 29. Icon Sketches for Make A Payment, Part I

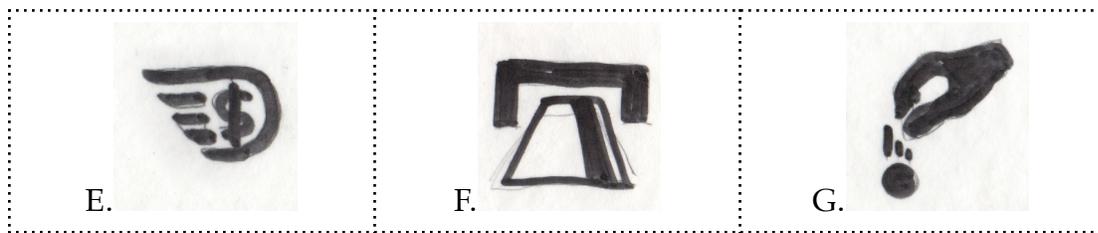


The sketch in Table 29 - B was not selected because the message in this icon is not *clear*. A hand is shown in the lower half of the icon, but it is *unrecognizable* as the shape is too abstract.

Table 29 - C tried to show a dollar sign with an arrow to indicate the cash flow. But the message is not clear enough about payment, and the arrow is too small to be *recognizable*.

Similar to the other options, Table 29 - D shows a movement to express the action of “make.” The problem caused by the black arrow around the dollar sign is it looks like a house. It has *relevance* and *recognizability* problems.

Table 30. Icon Sketches for Make A Payment, Part II



The wing symbol in Table 30 - E has the meaning of speed and flying in the human mind. This sketch has a *relevance* problem as it relates more to getting quick money rather than making a payment.

Table 30 - F has *relevance* and *uniqueness* problems as the message delivered may be related to multiple things. It could mean “the place to insert card.” Furthermore, this action of inserting a card may not necessarily connect to payment; it could also be to withdraw cash.

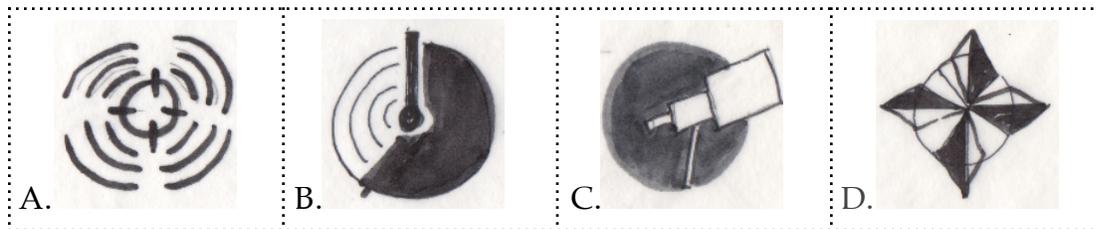
The major concern for the concept in Table 30 - G is that the message also looks like dropping something rather than making payments. It is also not *clear* that the round shape is a coin.

4.3.2 Discover

The two sketches in Table 31 - A and Table 31 - B have *relevance* and *recognizability* problems. They could represent the meaning of detecting, but they seem more military related instead of being for general purposes.

Table 31 - C has both *relevance* and association problems. A telescope might not be a good image as the intended message is not about space.

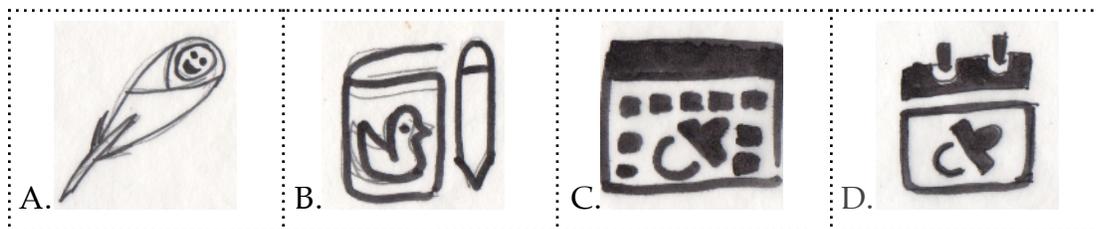
Table 31. Icon Sketches for Discover



4.3.3 Baby journals

As the icons are targeted on mobile devices, the details in Table 32 - A and Table 32 - B might be hard to identify when the sizes are small.

Table 32. Icon Sketches for Baby Journals



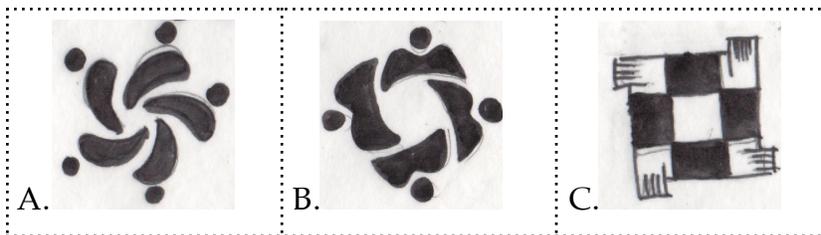
In Table 32 - C and Table 32 - D, pacifiers are not *clear* without those details in the outline. The calendar was not *recognizable* in such level of simplicity.

4.3.4 Social activity

The icons in Table 33 - A and Table 33 - B are trying to show a group of people holding hands. As the lines are very simple, it is hard to *recognize* the human body out of the shape.

Similarly, when the shapes are rectangular in Table 33 - C , it becomes hard to get the meanings, especially for this case as social activity is not a specific item.

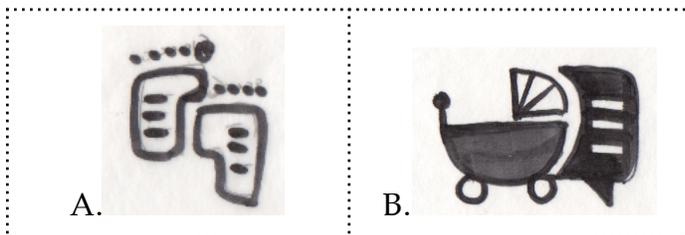
Table 33. Icon Sketches for Social Activity



4.3.5 Birth and baby club

The footprint icon in Table 34 - A is not *unique* enough to build a connection with a baby when the user cannot sense the size of them. The footprint also has a *relevance* problem as there is no clear connection with Birth and baby club. The stroller in Table 34 -B is meaningful for birth and baby related ideas. But the concern is when it has been reduced, some details that keep the stroller clear might become *unclear* and difficult to *recognize*.

Table 34. Icon Sketches for Birth and Baby Club



With the less successful icons above having been eliminated from consideration the following ones were identified for refinement (Table 35). They have higher potential to deliver the message successfully as they fit better with the criteria.

Table 35. Selected Icon Concepts

Message	Icon concepts	
Make a payment		
Discover		
Baby journals		
Social Activity		
Birth and baby club		

4.4 Concept Refinement

Based upon those ten concepts generated from the matrix, the shapes and lines were further explored in those icons. The exploration and thought process for the refinement phase is described below.

4.4.1 Make a payment

The message of hand and money is clear enough (Table 36 - A). But when users are making a payment, there is usually a gesture or movement involved.

Table 36. Refined Icon Sketches for Make A Payment



As it shows in Table 36 - B and Table 36 - C, the short lines were added to indicate the movement and add uniqueness.

4.4.2 Discover

The problem with the magnifying glass icon is that, because the shape of it is too simple, it's hard to distinguish it from a candy.

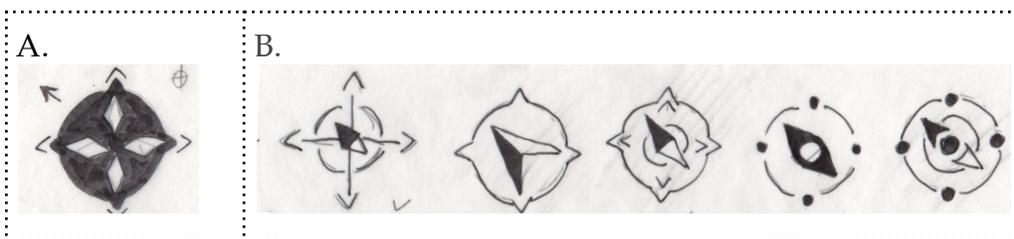
The proposed solution to this is to add more information and highlight the key function of the magnifying glass, thus increasing recognizability (Table 37).

Table 37. Refined Icon Sketches for Magnifying Glass



Table 38 - A is not clear as a symbol of a compass. But it has potential since the comprehension study showed that a compass associates with "Discover" very well. As shown in Table 38 -B, explorations included adding clear arrows for four directions, trying different shapes with the pointer in the center, etc.

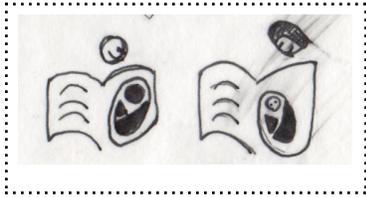
Table 38. Refined Icon Sketches for Compass



4.4.3 Baby journal

Different head positions were tested for the mom and different directions for the baby in the arm were tested for clarity and recognizability (Table 39).

Table 39. Refined Icon Sketches for Baby Journal

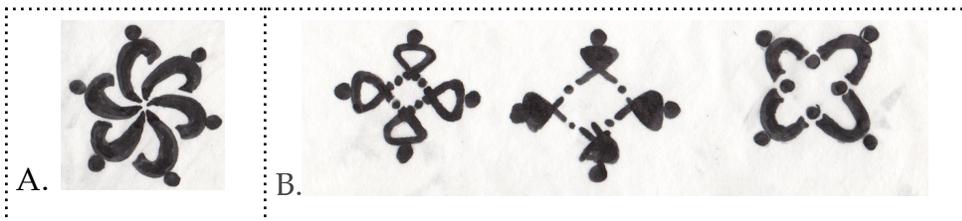


4.4.4 Social activity

The main intended message in those sketches is a group of people who are helping each other or a single person in a group.

The dots indicate the head of the person and those lines were trying to show the body and arm of a group of people (Table 40).

Table 40. Refined Icon Sketches for Social Activity



4.4.5 Birth and baby club

Table 41 -A is to show a talk bubble symbol next to a wrapped baby.

However, because of the rectangular shape the one on the right is too solid and it has no details in itself; the dark rectangle looks like a shadow come from the shape on its left. The concept is improved by adding three short lines for the talking bubble symbol (Table 41 -B). Different angles and different sizes were also experimented with (Table 41 -C).

Table 41. Refined Icon Sketches for Birth and Baby Club



4.5 Final Prototype

With the help of the ideation matrix, at least two unique concepts were generated for each icon. Computer refinements was created to experiment with the size of the empty space between shapes, the sizes of the elements. It is to understand if those changes could help with clarity.

4.5.1 Make a payment

Figure 9 shows some of the iterations for this topic.

The hand symbol should have more details in order to let people understand what it is. To achieve that, the thumb and its relationship with the hand is identified by a bold line (Figure 9-B). But the round corner of the rectangle is not helping as it is trying to illustrate cash or checks which are more rectangular. Helping as it is trying to illustrate cash or checks which are more rectangular.

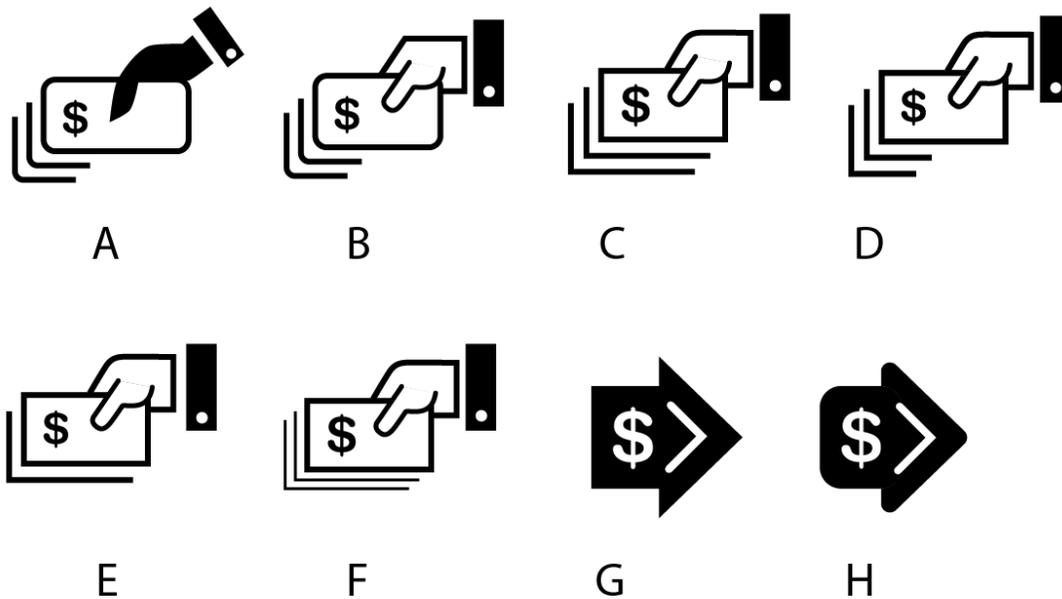


Figure 9. Final Prototypes for Make A Payment

By comparing option B and D in Figure 9, we can see that the bottom left corner of D expresses the meaning of movement better than it does in B.

4.5.2 Discover

Figure 10 shows some of the iterations for this topic.

The refined magnifying glass symbol is much more clear compared with the earlier sketches. The rectangular shape which indicates some part of it has been enlarged is very helpful in communicating the message (Figure 10 - B).

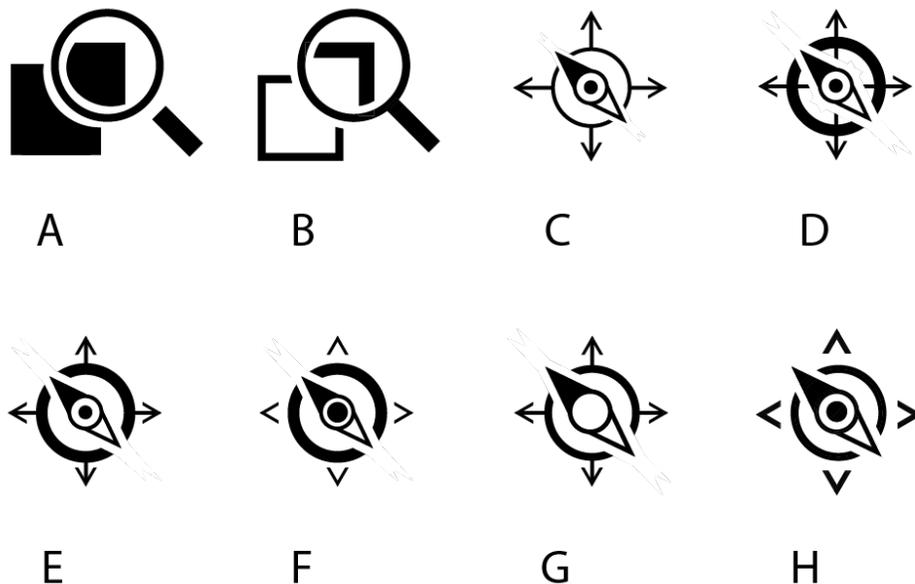


Figure 10. Final Prototypes for Discover

For the compass concept, various sizes and shapes were tested for the arrows. The icons G and H in Figure 10 have a larger pointer in the center compared with other four. Additionally, the other elements in those two icons are

not distracting. For those reason, Figure 10 - G and Figure 10 - H work better among the six compasses in representing the message of Discover.

4.5.3 Baby journal

Figure 11 shows some of the iterations for this topic.

The main problem to solve for this set of icons is the recognizability problem of the pencil. The two short white lines on Figure 11 - C, D, E, and F are helping in illustrating the shape of the pencil body. The positive and negative space contrast at the bottom part of Figure 11 - E and F make the pencil symbol distinguishable and enhanced the clarity of it. For the four icons in the second row, the relationship between the baby wrap and the book was explored. The shape of baby wrap fits for the curve of option H and I pretty well.

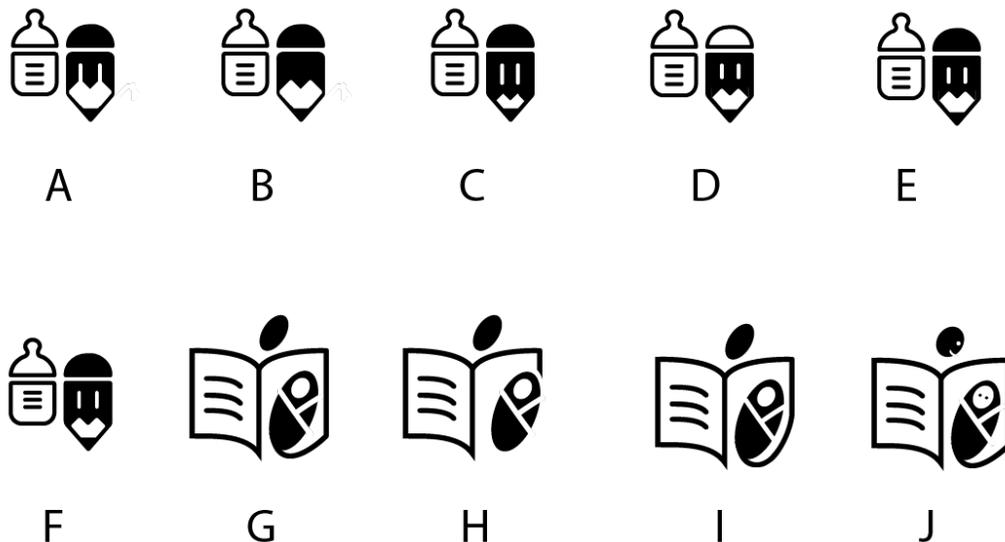


Figure 11. Final Prototypes for Baby Journal

4.5.4 Social activity

Figure 12 shows some of the iterations for this topic.

For this category, geometrical shapes were used to show a group of people.

The six symbols from C to H are intended to show four different people; in each the arms have different shapes. One of the round shapes is bigger than the others to indicate the relationship between one person and a group of people.

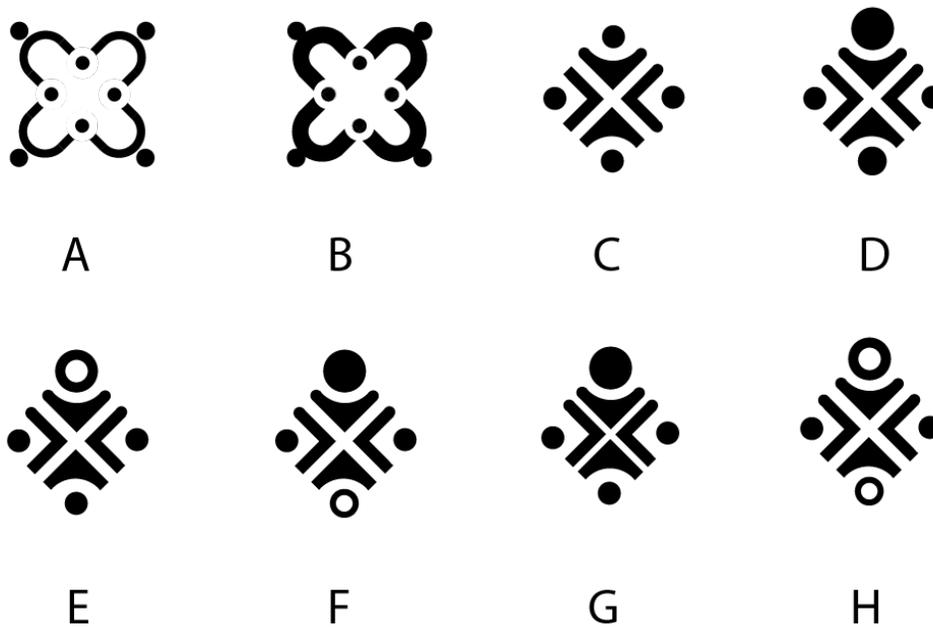


Figure 12. Final Prototypes for Social Activity

4.4.5 Birth and baby club

Figure 13 shows some of the iterations for this topic.

Tests were performed to see how the position and direction of the triangular shape at the bottom of the talking bubble changes the recognizability of the shape (Figure 13 - A to Figure 13 - D). It turns out that it is much clearer that those are talking bubbles when the triangular shape is in the middle part of the talk bubble. Similarly, option E is the one that works best in the lower group of four icons. The tail of the talking bubble is more noticeable, which helps with recognizability.

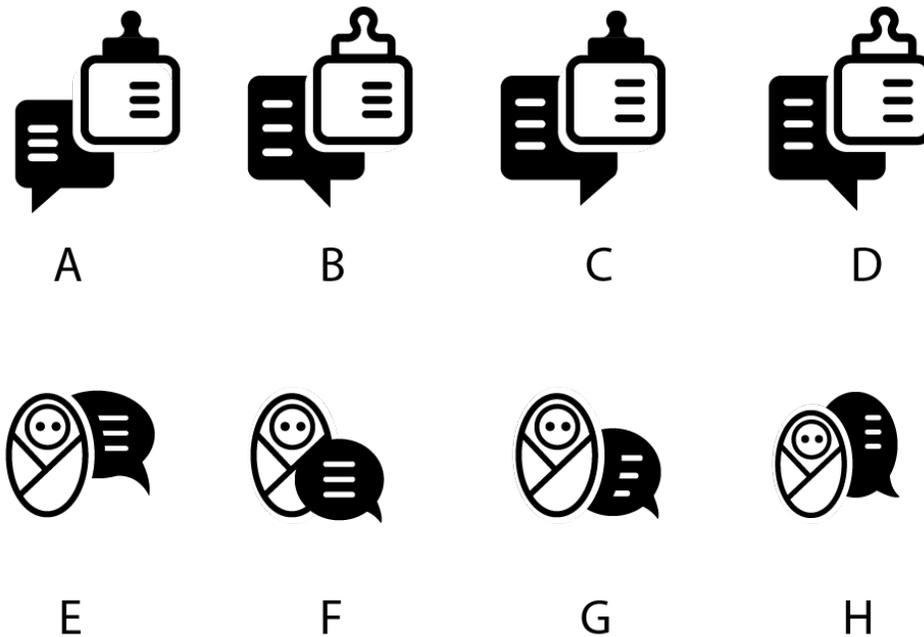
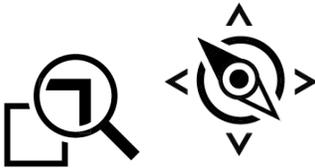


Figure 13. Final Prototypes for Birth and Baby Club

Table 42. Final Prototype Icons

Make a payment

Discover

Baby journal

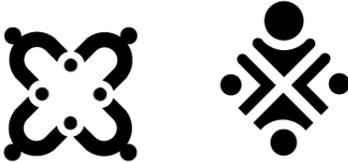
Social activity

Birth and baby club


Table 42 on the previous page shows the final set of prototype icons. They all have relatively simple forms as “icons cannot have great deal of detailed information” (Dondis, 1974, p.72). This is to ensure that icons are not only recognized but also remembered to achieve effectiveness. Simplicity is also the key for this study because those icons are targeted on mobile devices where they need to be recognized in very small sizes.

However, the more abstract the form is, the more penetration of the public mind is necessary to understand the meaning. Appropriate details were kept for those icons (Table 42) to make them easier to be recognized, for example: the shape of the hand in the Make a payment icon; the illustration of the pencil tip in the Baby journal icon; and the cap of the infant bottle in the Birth and baby club icon. Each of these details enable users to identify the objects easily. These prototypes also maximize the amount of resemblance to actual objects to increase the comprehensibility.

Besides, the design of these prototypes paid a lot attention on the viewpoint that each object is shown. Side-views of hand, pencil, and infant bottle could most clearly reveal these objects. But for compass and infant wrap, top views could better show their distinct shapes.

Abstract figures are adopted for some icon concepts, as Dondis (1974) points out that they will make the symbols even more effective for the transmission of

information. Examples include the arrow figure in the icon for Make a payment and the talking bubble in the Birth and baby club icon.

Lastly, the objects within each icon were designed to share similar shapes and curves with each other to make the icon visually appealing; for example the infant bottle and the pencil images in the Baby journal icon are sharing the same shape. This makes the icon look good, and it helps people understand the meaning because - as Don Norman states - feelings and emotional affluence have implications for the process of comprehension (Norman, 2002, p.41).

CHAPTER 5: COMPREHENSION TEST OF THE PROTOTYPE ICONS

Three comprehension tests were carried out to test whether the prototype icons could score better on comprehensibility (survey 3, survey 4, and survey 5). Survey 3 asked subjects to choose one icon out of three options, which follows the same survey structure as survey 2. Table 43 shows one of the questions in this category. The two new icons were displayed along with the original icon for subjects to choose from. An opt-out option was always provided to subjects to increase the validity.

Table 43. Survey 3 Example

Q1. Which one of the following icons could best represent the meaning of "Make a payment"?			
			None of these

Survey 4 and survey 5 requested participants to select one meaning out of three to match with icons (Table 44). These follow the same survey structure as survey 1.

Table 44. Survey 4 and 5 Example

Q6. Which one of following words could best represent this icon's meaning?



- Make a payment
- Access checking account
- Save money
- None of these

Similar to the two surveys for the problematic icons performed earlier, the following four areas have been taken into considered to increase data reliability: question wording, meaningful options, survey structure, survey styles and colors.

Table 45. Sample of Comprehension Test for New Icons

Q13 Which one of following words could best represent this icon's meaning?



- Baby Education
- Baby Journal
- Baby Supplies
- None of these

As can be seen in Table 45, one of the options was changed from “Baby Activities” to “Baby Education.” This is because a book symbol was introduced in the new icon and it is important to learn if subjects might associate it with the meaning of education or journal.

The survey was sent out to 36,000 college students and 1,774 results were recorded. As subjects were divided into three groups randomly and evenly, the sample size for each survey is around 590.

5.1 Analysis of Test Results of the Prototype Icons

The analysis of test results for new icons is divided into five parts in line with the original five problematic icons. The icons that were recognized by over 67% of the subjects are considered effective.

5.1.1 Make a payment

85% of the subjects chose one of the new symbols as the correct representative for “Make a payment” in survey 3 (Table 46). Particularly, the selection rate for option 3 is very high, reached by 70% of all subjects.

Table 46. Survey 3 Results for Make A Payment

Answer	Bar	Response	%
		78	15%
		50	9%
		370	70%
None of these		34	6%

When participants were asked to select a meaning that could best be associated with the hand icon in survey 4 (Table 47), more than 73% subjects chose the correct answer. This is because it has high level of *recognizability*, *relevance*, and *uniqueness*.



Figure 14. Prototype Icon 1 for Make A Payment

Table 47. Survey 4 Results for Make A Payment

Answer	Bar	Response	%
Make a payment		418	73%
Access checking account		94	17%
Save money		11	2%
None of these		46	8%

67% of the subjects chose “Make a payment” as their answer for the arrow icon (Figure 15), which means that this icon delivered the message successfully. It is just not as effective as the hand icon, based on the data in Table 48.



Figure 15. Prototype Icon 2 for Make A Payment

Table 48. Survey 5 Results for Make A Payment

Answer	Bar	Response	%
Access checking account		81	13%
Make a payment		413	67%
Save money		25	4%
None of these		94	15%

Those two prototype icons were working because they fit the criteria: they have very *simple* form, so subjects can *recognize* them when they were in small size; the message delivered was complete and not vague; they represented *unique* meanings; and they were *relevant* to the intended meaning.

5.1.2 Discover

77% of all the subjects picked one of the two new icons. They both are more efficient in delivering the message compared with the original icon, which was picked by only 8% of the subjects (Table 49).

Table 49. Survey 3 Results for Discover

Answer	Bar	Response	%
		41	8%
		183	35%
		223	42%
None of these		82	16%

It is easy to see in survey 4 that subjects associated this icon with both search and discover. It proved that Figure 16 could be *recognized* by users. As search and discover are very close to each other in meaning, it is considered successful even though it has some *relevance* problem (Table 50).



Figure 16. Prototype Icon 1 for Discover

Table 50. Survey 4 Results for Discover

Answer	Bar	Response	%
Search		217	38%
Discover		245	43%
Inquiry		7	1%
None of these		96	17%

The data in survey 5 suggest that the magnifying glass is not a good symbol for discover as subjects already have built a strong connection between that object and search (Table 51). Figure 17 is not as effective as Figure 16 because it has *relevance* problems.



Figure 17. Prototype Icon 2 for Discover

Table 51. Survey 5 Results for Discover

Answer	Bar	Response	%
Search		317	52%
Inquiry		78	13%
Discover		85	14%
None of these		129	21%

5.1.3 Baby journal

Even though 40% of the subjects chose the pencil icon as an answer for Baby journal, it is considered unsuccessful because more than 40% of the participants chose the opt-out option (Table 52).

Table 52. Survey 3 Results for Baby Journal

Answer	Bar	Response	%
		42	8%
		212	40%
		53	10%
None of these		221	42%

When reviewing the data in survey 4 and 5, it was noticed that the majority of the subjects *related* pencil and book symbols to education. Journal is the second stronger association (Table 53).



Figure 18. Prototype Icon 1 for Baby Journal

Table 53. Survey 4 Results for Baby Journal

Answer	Bar	Response	%
Baby Journal		137	24%
Baby Supplies		72	13%
Baby Education		238	43%
None of these		113	20%

For the book and baby icon (Figure 19), more than half of subjects chose the opt-out option, which implies this icon has a huge comprehension problem.

Based on the criteria, this icon has *recognizability* problem when it was displayed in a small size. It could be further improved by making the image more *relevant* to a journal.



Figure 19. Prototype Icon 2 for Baby Journal

Table 54. Survey 5 Results for Baby Journal

Answer	Bar	Response	%
Baby Education		178	30%
Baby Journal		93	15%
Baby Supplies		6	1%
None of these		324	54%

5.1.4 Social activity

The new social activity icons are considered as inefficient, as only 31% of subjects understand the meaning of them based on survey 3.

Table 55. Survey 3 Results for Social Activity

Answer	Bar	Response	%
		39	7%
		44	8%
		126	24%
None of these		317	60%

Most of the subjects didn't *recognize* Figure 20 or they didn't think it *relevant* to the intended meaning (Table 56). The form is over simplified as it's hard to find the human bodies in the symbol.



Figure 20. Prototype Icon 1 for Social Activity

Table 56. Survey 4 Results for Social Activity

Answer	Bar	Response	%
Forum		100	18%
Social activities		68	12%
Flower		17	3%
None of these		373	67%

Figure 21, however, has the possibility to be successful with some modification. The data show that subjects have *recognized* the human bodies in it as more than 50% subjects chose social activities and forum as its meaning (Table 57).



Figure 21. Prototype Icon 2 for Social Activity

Table 57. Survey 5 Results for Social Activity

Answer	Bar	Response	%
Social activities		150	25%
Forum		161	27%
Flower		113	19%
None of these		172	29%

Another possible reason for the high failure rate for this set of icons is that social activity is a very broad concept. Students who are pursuing advanced degrees may have different interpretations of this than undergraduate students.

5.1.5 Birth and baby club

When subjects were asked which one of the icons could best represent the meaning of baby club, the data in the table demonstrate that both new icons are efficient as 79% of subjects have *recognized* one of these two icons with the meaning of “Birth and baby club” (Table 58). The *unique* shapes of the two prototypes also separate them from the problematic icon.

Table 58. Survey 3 Results for Birth and Baby Club

Answer	Bar	Response	%
		295	56%
		121	23%
		2	0%
None of these		105	20%

When the two icons (Figures 22 and 23) were tested separately, most people selected Q&A over the meaning of club (Tables 59 and 60). This totally makes sense as baby Q&A is one of the major components of a baby club. That is to say subjects *recognized* the two icons as conversations but they were not sure what “club” means specifically.



Figure 22. Prototype Icon 1 for Birth and Baby Club

Table 59. Survey 4 Results for Birth and Baby Club

Answer	Bar	Response	%
Birth and baby Q & A		373	67%
Birth and baby club		23	4%
None of these		81	15%
Birth and baby customer service		81	15%



Figure 23. Prototype Icon 2 for Birth and Baby Club

Table 60. Survey 5 Results for Birth and Baby Club

Answer	Bar	Response	%
Birth and baby club		22	4%
Birth and baby customer service		96	16%
None of these		47	8%
Birth and baby Q & A		434	72%

CHAPTER 6: LIMITATIONS AND FURTHER STUDY

This research paper is an exploratory step in learning the problems that prevent users from understanding graphical icons on mobile devices. Further research in human cognitive processes is needed to more fully study the causes and solutions. While many considerations were taken for the comprehension test process, it is impossible to totally avoid bias. This is especially obvious when testing icons as human eyes are easily attracted by high contrast objects.

This paper did not research how various age groups might interpret the same information differently. The teenagers who grew up with smartphones will definitely have different conceptual models compared with adults who did not. Cultural difference is another big area that was not included in this research. Adults can process complex visual information based on their own living experience, which can vary a lot between cultures. To deliver the message efficiently, it is important to assure the audience can interpret icons within their experience and within their cultural context.

As this study didn't focus on one specific user group, the test results of baby related icons may not be accurate. The icon recognition process relies heavily on the mental models which are constrained by a user's life experience. It is definitely

easier for new moms to recognize baby related images than college freshmen because moms have more baby related life experience.

This study has some limitations as the icons were not tested on mobile devices. Although the icons were set to the same size as on mobile devices, subjects may have seen it in multiple sizes due to the various proportion and resolution of the computer displays they took the survey with.

This study didn't test if colors could help or prevent users from understanding the meanings. One of the reasons is that, "the experience of color appears to be subjective and personal rather than objective and scientific" (Hall, S. 2007, p. 90). The color of red means love to one person while it means violence to another. On top of that, previous tests didn't reveal "what those various colors actually mean to us" (Hall, 2007, p. 90). Besides, based on ISO 9186-1, if a colored variant is used, "the contrast between the variant and the background should be sufficient enough for the variant to be readily visible" (ISO 9186-1, 2007, p.4) and the colors and contrast levels should be accurate and the same for all subjects. However, it is very challenging to let all the subjects get the same color and contrast when they were taking the survey on their own devices, since different displays or different viewing conditions can change the colors and contrast dramatically. As a result, when colors are involved in this study, it's hard to tell if

the comprehension problems are caused by the wrong colors subjects perceived or something else.

Further research could be conducted to test the level of importance regarding each of the criteria: recognizability, relevance, and uniqueness. One way to identify this is by isolating those criteria. A series of studies could be performed with the icons after improving one of the criteria. Assume that 10 icons are identified as problematic by research X, and the comprehension problem for each of these ten icons is caused by a combination of recognizability, relevance, and uniqueness. After that, those ten icons can be redesigned with recognizability improved dramatically. In other words, none of the redesigned icons has recognizability problems. Thenceforth, research 1 is executed with redesigned icons. Similarly, research 2 and 3 are carried out with relevance and uniqueness improved separately. By comparing the recognition rate of results of research 1, 2 and 3, the conclusion can be reached.

Though this study focused on mobile devices, the findings could benefit additional research areas, including but not limited to the fields of computer icons, smart TV icons, car dashboard icons, and/or road signs. The theories that support icon comprehension are similar no matter what platform the icon is presented on. It is all about the communication between the information initiator's mental model and information receiver's mental model. Any icon that is used as the mediator of

communication should be *recognizable* to users, *relevant* to the intended meaning, and *unique* enough to have higher comprehensibility.

CHAPTER 7: CONCLUSION

In order to create functional icons that could deliver messages efficiently to target users, visual design principles and theories of cognitive psychology must be combined and applied throughout the design process. This study reveals that huge improvements in effectiveness can be achieved with the help of cognitive theories and the proper use of design principles.

The purpose of redesigning and testing the icons is to further explore the problems preventing users from understanding the graphical icons. In order to create more effective icons, some of the prototype icons, like social activity, need further exploration to reach higher effectiveness. However, the overall outcome of this study is very encouraging since the prototypes did show increased comprehension.

People usually get visual signals through three levels: representation, abstraction, and symbolism (Dondis, 1974, p.67). Most of the icons on mobile devices use abstraction and symbolism that is limited by screen size. The level of abstraction and the convention of the symbolism become the key factors that determine how well users comprehend the icons.

In terms of semiotics, a motivated sign can be understood without strong convention. Users don't need too much learning to know the meaning of the sign

(Mollerup, 1999, p.82). In such a case, it's better to use those images people already associate with the object or idea in icon design. Many times there are icons that already exist and that have become acceptable through use over time.

On the other hand, the attempt to associate a motivated sign with other meanings will cause problems in comprehension. The test results of the Discover prototype design indicate that the magnifying glass has a strong connection with search rather than other meanings. Similarly, the fire icon for Social activity has a closer relationship with emergency rather than other concepts.

When signs are arbitrary, however, there is no immediate connection between the image and the intended meaning. In such cases, the icon comprehension process requires users' skills, such as world knowledge experience, spatial ability, visual attention, pattern recognition, etc. (McDougall, S., & Curry, M. 2004, p. 74). When the icons were over-simplified they became more abstract and less clear, users had problems in perceiving their intended meanings. As icon perception is closely related to icon interpretation (McDougall, S. & Curry, M. 2004, p. 73), users will have trouble in understanding the intended messages when icons were over-simplified.

A lot of comprehension problems are caused by irrelevant metaphors. It is because "metaphor can contribute to understanding only by making us see similarities between the meaning A and B" (Cormac, 1985, p.209). If a metaphor is

not relevant to the intended meanings, the user will have difficulty understanding the icon, which makes the icon less effective and more problematic. The problematic diaper icon for Baby journal is caused by an irrelevant metaphor, since the elements in this icon have no connections to the meaning of journal at all. The solution is adding baby related objects to this icon. Objects like pencil, book, or diary can make the icon more relevant to the intended meaning.

Even an excellent metaphor requires the receivers' thinking process to search for the correct interpretations, which is a problem-solving process. Choosing elements that relevant to the intended meaning will reduce the searching and problem-solving time; as a result it increases the comprehensibility of the icon. In order to present information clearly to users, every dot, line, and shape of an icon must be organized in a certain way to emphasize relevant aspects while ignoring the irrelevant areas.

As mobile device users look at the apps on-the-go from time to time, they have to search rapidly for the icons to perform the task with least efforts. In order to enable the users to rapidly separate the icons from other elements on the screen, the icon must be designed with the consideration of uniqueness. One of the problems in the dollar sign icon for Make a payment and the talking bubble icon for Birth and baby club is that these two icons convey multiple meanings. Those

two icons are not exclusively representing the intended meanings, and leads to comprehension problems.

The final prototype icons were designed to have relatively simple forms to ensure that they are not only recognized but also remembered to achieve effectiveness. Simplicity is the key for this study also because those icons are targeted on mobile devices where they need to be recognized in very small sizes.

However, the more abstract the form is, the more effort from users is necessary to understand the meaning. Appropriate details were kept for the prototype icons to make them easier to be recognized, for example, the cap of the bottle in Birth and baby club icon enables users to identify the infant bottle easily.

Additionally, the design of these prototypes paid a lot of attention to the viewpoints that each object is shown. Side-views of hand, pencil, and infant bottle could most clearly reveal these objects. But for compass and infant wrap, top views could better show their distinct shapes.

Lastly, the objects within each icon were designed to share similar shapes and curves with each other to make the icon visually appealing; for example the infant bottle and the pencil images in the Baby journal icon are sharing the same shape. This makes the icons look good, and it helps people understand the meaning because Norman (2002) states that feelings and emotional influence have implications for the process of comprehension.

The icon prototypes were designed to solve the problem of *recognition*, *relevance*, and *uniqueness* while still maintaining extremely simplified forms.

Related comprehension tests prove that icons with simple forms could possibly deliver the message efficiently if they carefully consider *recognizability*, *relevance*, and *uniqueness*.

APPENDIX A – IRB FORM

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 7/2/2015
To: Fei Yang
3224 Memorial Union
CC: Dr. Lisa Fontaine
158 College of Design
From: Office for Responsible Research
Title: Icon Comprehensibility Evaluation
IRB ID: 15-291

Study Review Date: 7/2/2015

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 an Application for Approval of Research Involving Humans 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 designees 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.

Exempt Study Information

Please provide Yes or No answers, except as specified. Incomplete forms will be returned without review.

Part A: Key Personnel

1. List all members and relevant qualifications of the project personnel and define their roles in the research. Key personnel include the principal investigator, co-principal investigators, supervising faculty member, and any other individuals who will have contact with the participants or the participants' data (e.g., interviewers, transcribers, coders, etc.). This information is intended to inform the committee of the training and background related to the specific procedures that each person will perform on the project. For more information, please see Human Subjects – Persons Required to Obtain IRB Training.

NAME	Interpersonal contact or communication with subjects, or access to private identifiable data?	Involved in the consent process?	Contact with human blood, specimens, or other biohazardous materials?	Other Roles in Research	Qualifications (i.e., special training, degrees, certifications, coursework, etc.)	Human Subjects Training Date
✓ Lisa Fontaine	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Supervise experiments	MA, MFA	05/01/2005
✓ Fei Yang	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Conduct Usability Study, Data Analysis	BS, MFA Candidate	01/25/2015
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			

APPENDIX B – COMPREHENSION TEST MATERIALS

Survey 1

Q1. Which one of following words could best represent this icon's meaning?



- Access checking account
- Make a payment
- Save money
- None of these

Q2. Which one of following words could best represent this icon's meaning?



- Rotate
- Internet
- Discover
- None of these

Q3. Which one of following words could best represent this icon's meaning?



- Baby Journal
- Baby Supplies
- Baby Activities
- None of these

Q4. Which one of following words could best represent this icon's meaning?



- Social activities
- Forum
- Emergency
- None of these

Q5. Which one of following words could best represent this icon's meaning?



- Q & A
- Social Club
- Customer Service
- None of these

Survey 2

Q6. Which one of the following icons could best represent the meaning of "Make a payment"?



Q7. Which one of the following icons could best represent the meaning of "Discover"?



Q8. Which one of the following icons could best represent the meaning of "Baby Journal"?



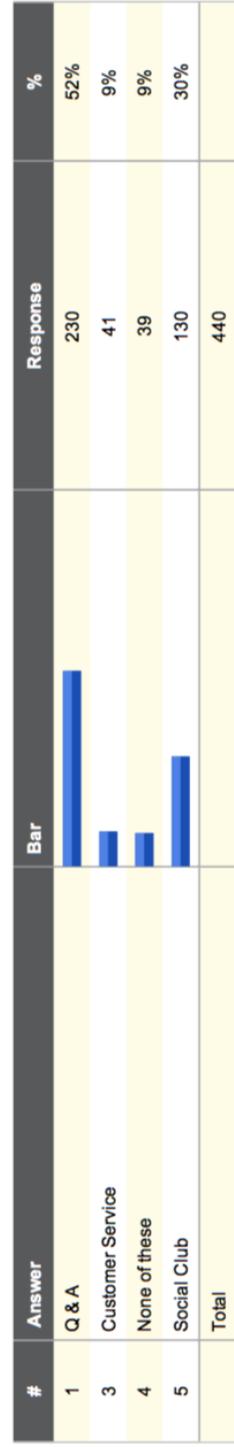
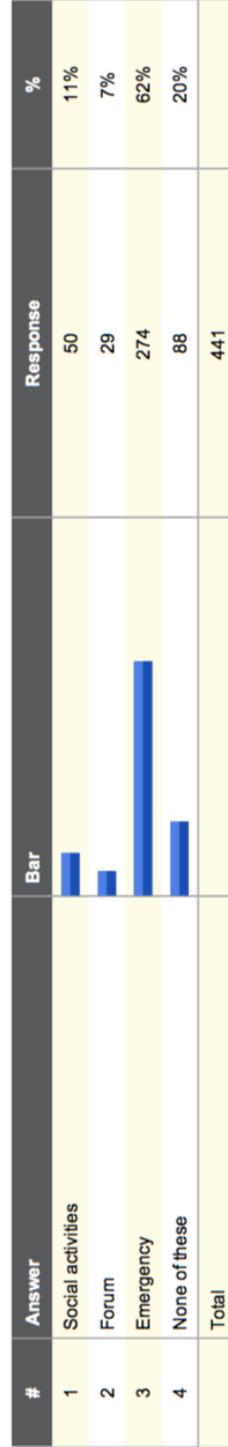
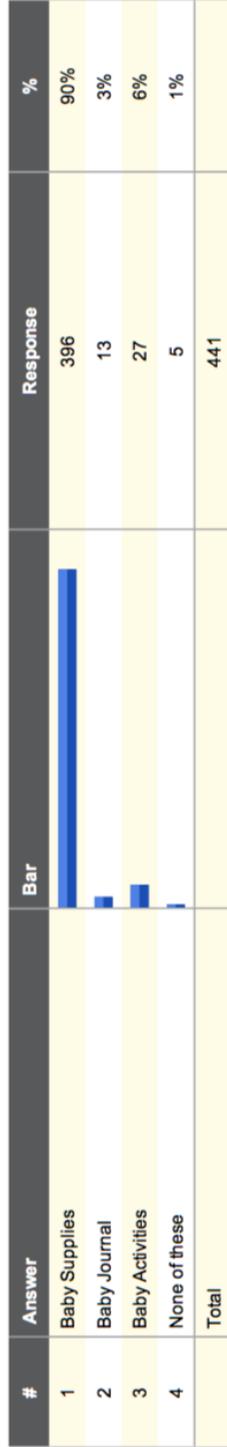
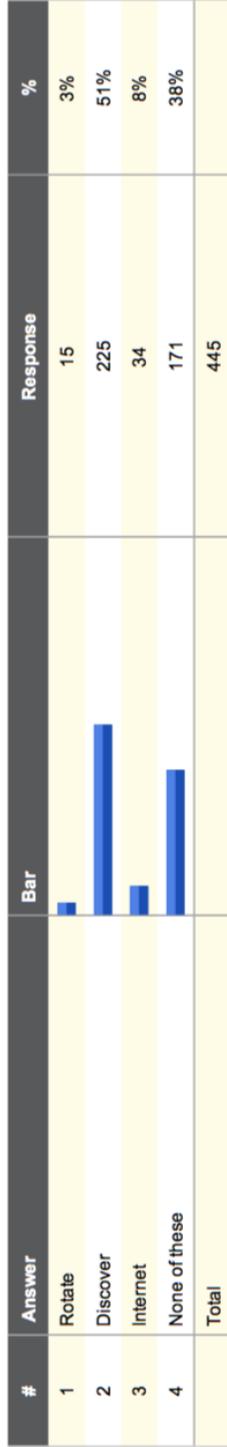
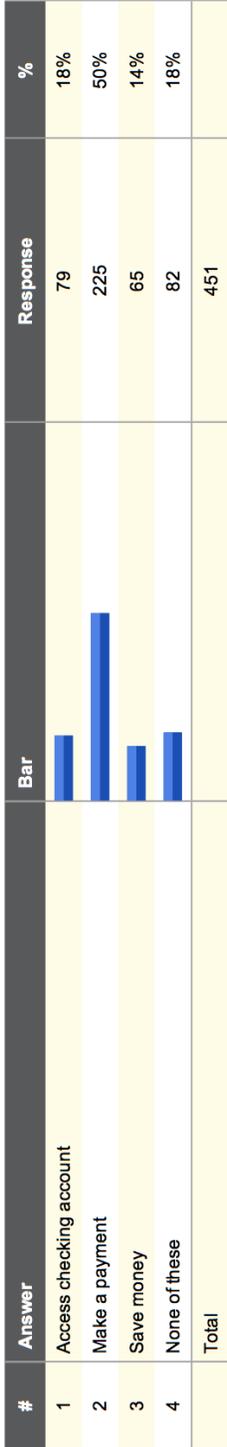
Q9. Which one of the following icons could best represent the meaning of "Social Activity"?



Q10. Which one of the following icons could best represent the meaning of "Birth and baby club"?



APPENDIX C – COMPREHENSION TEST RESULTS



Survey 2 Results

Answer	Bar	Response	%
		28	6%
		177	40%
		241	54%
		52	12%
		141	32%
		252	57%
		21	5%
		393	88%
		31	7%
		318	72%
		28	6%
		96	22%
		305	69%
		136	31%
		3	1%

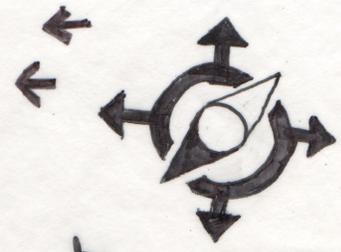
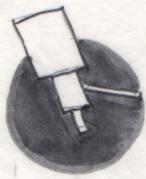
Repetition

Emulation

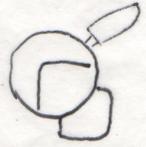
Line/Mass



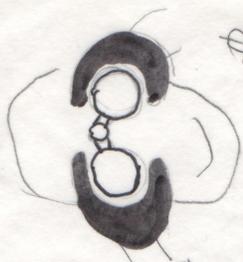
Gradation



Discover



⊕



⊕



⊕



Magnifying
Glass

Man with
binoculars

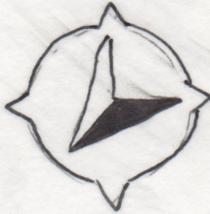
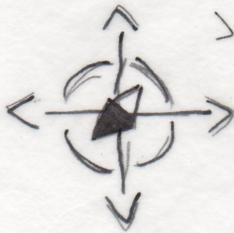
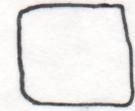
Telescope

Compass

Hand
Holding

Radar

Discover



5 >

5 >

>

>

>

>

>

>

>



APPENDIX E – REDESIGNED ICONS COMPREHENSION TEST

Survey 3

Q1. Which one of the following icons could best represent the meaning of “Make a payment”?			
			None of these
Q2. Which one of the following icons could best represent the meaning of “Discover”?			
			None of these
Q3. Which one of the following icons could best represent the meaning of “Baby Journal”?			
			None of these
Q4. Which one of the following icons could best represent the meaning of “Social Activities”?			
			None of these
Q5. Which one of the following icons could best represent the meaning of “Birth and baby club”?			
			None of these

Survey 4

Q6. Which one of following words could best represent this icon's meaning?



- Make a payment
- Access checking account
- Save money
- None of these

Q7. Which one of following words could best represent this icon's meaning?



- Search
- Discover
- Inquiry
- None of these

Q8. Which one of following words could best represent this icon's meaning?



- Baby Journal
- Baby Supplies
- Baby Education
- None of these

Q9. Which one of following words could best represent this icon's meaning?



- Forum
- Social activities
- Flower
- None of these

Q10. Which one of following words could best represent this icon's meaning?



- Birth and baby Q & A
- Birth and baby customer service
- Birth and baby club
- None of these

Survey 5

Q11. Which one of following words could best represent this icon's meaning?



- Access checking account
- Make a payment
- Save money
- None of these

Q12. Which one of following words could best represent this icon's meaning?



- Search
- Inquiry
- Discover
- None of these

Q13 Which one of following words could best represent this icon's meaning?



- Baby Education
- Baby Journal
- Baby Supplies
- None of these

Q14. Which one of following words could best represent this icon's meaning?



- Social activities
- Forum
- Flower
- None of these

Q15. Which one of following words could best represent this icon's meaning?



- Birth and baby club
- Birth and baby Q & A
- Birth and baby customer service
- None of these

APPENDIX F – REDESIGNED ICONS TEST RESULTS

Results of survey 3

#	Answer	Bar	Response	%
1			78	15%
2			50	9%
3			370	70%
4	None of these		34	6%
1			41	8%
4			183	35%
5			223	42%
6	None of these		82	16%
1			42	8%
3			212	40%
4			53	10%
5	None of these		221	42%
3			39	7%
4			44	8%
5			126	24%
6	None of these		317	60%
1			295	56%
2			121	23%
3			2	0%
4	None of these		105	20%
	Total		523	

Results of survey 4



#	Answer	Bar	Response	%
1	Make a payment		418	73%
2	Access checking account		94	17%
3	Save money		11	2%
4	None of these		46	8%
Total			569	



#	Answer	Bar	Response	%
1	Search		217	38%
2	Discover		245	43%
3	Inquiry		7	1%
4	None of these		96	17%
Total			565	



#	Answer	Bar	Response	%
1	Baby Journal		137	24%
2	Baby Supplies		72	13%
3	Baby Education		238	43%
4	None of these		113	20%
Total			560	



#	Answer	Bar	Response	%
1	Forum		100	18%
2	Social activities		68	12%
3	Flower		17	3%
4	None of these		373	67%
Total			558	



#	Answer	Bar	Response	%
1	Birth and baby Q & A		373	67%
3	Birth and baby club		23	4%
4	None of these		81	15%
5	Birth and baby customer service		81	15%
Total			558	

Results of survey 5



#	Answer	Bar	Response	%
1	Access checking account		81	13%
2	Make a payment		413	67%
3	Save money		25	4%
4	None of these		94	15%
Total			613	



#	Answer	Bar	Response	%
1	Search		317	52%
2	Inquiry		78	13%
3	Discover		85	14%
4	None of these		129	21%
Total			609	



#	Answer	Bar	Response	%
1	Baby Education		178	30%
2	Baby Journal		93	15%
3	Baby Supplies		6	1%
4	None of these		324	54%
Total			601	



#	Answer	Bar	Response	%
1	Social activities		150	25%
2	Forum		161	27%
3	Flower		113	19%
4	None of these		172	29%
Total			596	



#	Answer	Bar	Response	%
1	Birth and baby club		22	4%
3	Birth and baby customer service		96	16%
4	None of these		47	8%
5	Birth and baby Q & A		434	72%
Total			599	

REFERENCES

- Agar, J. (2013). *Constant touch: A global history of the mobile phone (Rev. and updated ed.)*. London: Icon.
- Blackcoffee (Firm). (2006). *1000 icons, symbols + pictograms: visual communications for every language*. Gloucester, MA : Rockport.
- Blair-Early, A. & Zender, M. (2008). User interface design principles for interaction design. *Design Issues*, 24(3), 85-107.
- Koutsourelakis, C. & Choriantopoulos, K. (2010). Icons in mobile phones: Comprehensibility differences between older and younger users. *Information Design Journal*, 18(1), 22-35.
- Cartman, J. & Ting, R. (2008). *Strategic mobile design: creating engaging experiences*. Peachpit Press.
- Cormac, E. (1985). *A cognitive theory of metaphor*. Cambridge, Mass.: MIT Press.
- Cui, Y. Oulasvirta, A. & Ma, L. (2011). Event perception in mobile interaction: Toward better navigation history design on mobile devices. *International Journal of Human-Computer Interaction*, 27(5), 413-435.
- Dewar, R. E. (1994). *Design and evaluation of graphic symbols. Proceedings of Public Graphics*. The Netherlands: Univ. of Utrecht.
- Dondis, A. (1974). *A Primer of Visual Literacy*. Cambridge, Mass.: The MIT Press, 1974.
- Easterby, R. & Zwaga, H. (Eds.). (1978). Developing effective symbols for public information. *Information Design: The design and evaluation of signs and printed Material* (pp. 277-297). New York: John Wiley & Sons.
- Easterby, R. S. (1970). The perception of symbols for machine displays. *Ergonomics*, 13(1), 149-158.
- Edworthy, J. & Adams, A. (1996). *Warning Design: A Research Perspective*. Bristol, PA: Taylor & Francis.
- Hall, S. (2007). *This means this, this means that: a user's guide to semiotics* (p. 176). Laurence King Publishing.
- Harbeck, J. (2011). Index, icon, symbol: a tale of abduction. *The Indexer*, 29(4), 157-160.
- Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. New York: John Wiley & Sons.

- Huang, S. M., Shieh, K. K., & Chi, C. F. (2002). Factors affecting the design of computer icons. *International Journal of Industrial Ergonomics*, 29(4), 211-218.
- IDC. (2015). *Smartphone Vendor Market Share*. Retrieved November 18, 2015, from <http://www.idc.com/prodserv/smartphone-market-share.jsp>. International Data Corporation (IDC).
- ISO 9186-1. (2007). *Graphical symbols – Test methods – Part 1: Methods for testing comprehensibility*. Geneva: International Organization for Standardization.
- ISO 9186-2. (2008). *Graphical symbols – Test methods – Part 2: Method for testing perceptual quality*. Geneva: International Organization for Standardization.
- Kato, S. (1972). *A new universal language for the new human environment*. *International Conference on Highway Sign Symbolology*. Washington, DC: International Road Federation and U.S. Department of Transportation.
- Kress, G. & Leeuwen, T. (1996). *Reading images: The grammar of visual design*. London: Routledge.
- Krug, S. (2005). *Don't make me think: A common sense approach to web usability*. Pearson Education India.
- Lin, C. (2013). Exploring the relationship between technology acceptance model and usability test. *Information Technology and Management*, 243-255.
- Lin, R. (1994). A study of visual features for icon design. *Design studies*, 15(2), 185-197.
- McDougall, S., & Curry, M. (2004, September). More than just a picture: Icon interpretation in context. In *Proceedings of First International Workshop on Coping with Complexity*. University of Bath 16-17th September 2004. (p. 73).
- Mollerup, P. (1999). *Marks of excellence: The history and taxonomy of trademarks*. London: Phaidon.
- Mullet, K. & Sano, D. (1995). *Designing visual interfaces: Communication oriented techniques*. Englewood Cliffs, NJ: SunSoft Press.
- Muter, P., & Mayson, C. (1986). The role of graphics in item selection from menus. *Behaviour & Information Technology*, 5(1), 89-95.
- Norman, D. A. (1969). *Memory and attention*. New York: Wiley.
- Norman, D. A. (1983). Some observations on mental models. *Mental models*, 7(112), 7-14.
- Norman, D. A. (1988). *The psychology of everyday things*. New York: Basic Books.

- Norman, D. A. (2002). Emotion & design: attractive things work better. *Interactions*, Vol. 9(4), pp.36-42.
- Reed, S. (1973). *Psychological processes in pattern recognition*. New York: Academic Press.
- Saussure, F. (1959). *Course in general linguistics*. New York: Philosophical Library.
- Sears, D. O. (1986). College sophomores in the laboratory: Influences of a narrow data base on social psychology's view of human nature. *Journal of personality and social psychology*, 51(3), 515.
- Sonderegger, A. & Sauer, J. (2010). The influence of design aesthetics in usability testing: Effects on user performance and perceived usability. *Applied ergonomics*, 41(3), 403-410.
- Wiedenbeck, S. (1999). The use of icons and labels in an end user application program: An empirical study of learning and retention. *Behaviour & Information Technology*, 18(2), p68-82.
- Welton, P. & Morgan, J. (1992). *See what I mean: An introduction to visual communication*. London: E. Arnold.
- Zwick, C. & Schmitz, B. (2005). *Designing for small screens mobile phones, smart phones, PDAs, pocket PCs, navigation systems, MP3 players, game consoles*. Lausanne: AVA.