

Graphic user interface design for wireless application protocol

by

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ABSTRACT

This research addresses the recognizability of icon design in Wireless Application Protocol (WAP) devices. It deals specifically with graphic user interface (GUI) and the effective functionality of the icons on WAP screens by increasing their recognizability.

In order to propose recognizable WAP icons, this research reviews a case study that focuses on the logical approach and creative processes used in graphic design. This study consists of a literature review and the procedural development of specific WAP icons. The literature review identifies performance design criteria for WAP icons, both for evaluation and design purposes. In this case study, the process of WAP icon development is broken down into three parts: realization of WAP users' needs, an investigation of images for WAP icons, and the creation for prototypical icons for WAP screens. To investigate images and develop prototypes, a matrix is used.

The prototypical WAP icons are evaluated using the performance criteria developed from the literature review. As a result of this WAP icon design process, this study develops WAP icons that can be more functional, recognizable, and standard for WAP screens. Moreover, this research not only suggests prototypical icons for WAP screens but also produces a framework with a logical process and a creative design process that can be applied to further research on WAP icon design and graphic user interface. This study should be understood as the first step of an exploratory study about WAP icon design in the field of graphic design.

CHAPTER 1. INTRODUCTION

Much of the existing research on icons has focused on recognizability. Some icons are used for the purpose of corporate identity and the enhancement of visual entertainment while others indicate certain functions. This research focuses on icon design for WAP devices. Although icon design for Wireless Application Protocol (WAP) devices has been researched and those results applied in existing WAP design, anecdotal evidence suggests that the existing icons on WAP devices are neither recognizable nor functional because of text-based interfaces, poor human factors, small screens, and slow bandwidth. Moreover, human interface designers indicate that icon systems on WAP devices must be standardized and improved. This study involves an analysis of WAP devices and icon design.

WAP is an Internet specification that empowers mobile users with wireless devices to easily access and interact with information and services instantly. The usability of existing WAP devices is limited by text-based interfaces, poor human factors, small screens, and slow bandwidth. Human interface designers point out that there is a strong need for recognizable and functional WAP icons for current WAP interfaces. Therefore, it is important to fulfill WAP users' emerging need for functional interfaces.

The goals of this research are to develop prototypical WAP icons that enhance WAP effectiveness. The development of WAP icons further extends to other fields of icon design on electronic screens. Moreover, while developing prototypical WAP icons, this study will create a framework that can be used for further research of WAP icon design and graphic user interface (GUI). To achieve this goal, issues related to WAP icon design will be explored, analyzed, and evaluated.

The literature review will include a survey of research about 1) Wireless Application Protocol, 2) characteristics of good icons, and 3) the graphic representation of ideas. Because knowledge of WAP technology is a critical factor in the development of icons, an understanding of WAP technology will provide the technical conditions involved in the development of WAP icons. Characteristics of good icons help users recognize and memorize WAP icons easily. A study of the characteristics of good icons will provide criteria for developing recognizable icons. Lastly, an understanding of the graphic representation of ideas helps users interpret the correct meaning of iconic images. The study of graphic representation will suggest methods for visually representing the functions of WAP devices into icons. These factors are interdependent and enhance iconic communication to users. Figure 1 presents the interrelationship of three important factors in the WAP icon design process as well as the basic structure of the literature review.

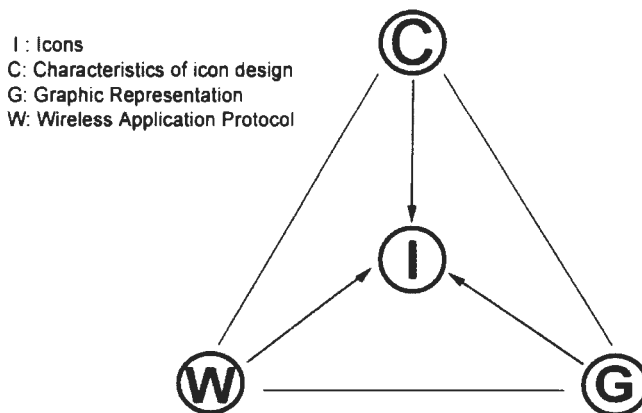


Figure 1. Icon design diagram

These three individual features are different aspects but interconnected. This triangular relationship will be used to develop an evaluation matrix for WAP icons. In combination with the study of WAP, characteristics for icon design, and graphic representation in the

literature review, criteria will be determined for developing and evaluating effective icons for WAP screens.

The procedural development for WAP icons includes research about the frequently used functions (FUFs) of WAP users. The features of FUF are refined to identify their characteristics and to create prototypes of icons that represent them. A creative matrix will be used to investigate various visual forms for visualizing FUFs on WAP devices. New alternatives for WAP icons for FUFs will be evaluating by using the criteria developed in the literature review.

This study results in alternative icons for WAP device screens that increase their functionality. By enhancing the recognizability of icons, this study will propose WAP icons that can be standardized. This investigation of images for icons for WAP screens will produce prototypical icons that can be more recognizable, functional, and comprehensive for WAP devices. Finally, the body of this study will be a framework that can be used for further WAP icon design in terms of the logical and creative process in the field of graphic design.

CHAPTER 2. LITERATURE REVIEW

A. The Overview of Wireless Application Protocol (WAP)

As the need for important communication and mobility increases, many Internet users require devices that enable them to access information anywhere and everywhere. To accommodate their needs, wireless technologies introduced Wireless Application Protocol (WAP) in the late 1990s.

WAP is an application form that utilizes a personal mobile information access device. WAP suggests a standard method to access Internet based content and services from wireless devices such as mobile phones and Personal Digital Assistants (PDAs), according to WAP Forum (2000). Although the WAP model is very similar to the traditional desktop computer Internet, it uses embedded browser software that connects to a WAP Gateway—software infrastructure residing in the Operator's Network that optimizes the transmission of content for the wireless network—and makes requests for information from web servers in the normal form of a URL. The content for wireless devices can be stored on any web server on the Internet. Content must be formatted suitably for the mobile phone's small screen and low bandwidth/high latency connection. Content is written in a markup language called Wireless Markup Language (WML). WML Script enables users to access information via their mobile phones or PDAs.

1. History of WAP

WAP was invented and is driven by the WAP Forum, a group originally formed by Nokia, Ericsson, Motorola and Phone.com (then Unwired Planet) in 1997. The WAP Forum includes 500 member companies who make up 95% of handset manufacturers, carriers equaling 100 million subscribers worldwide, infrastructure providers, software developers and many other companies providing solutions in the wireless space. Japanese I-mode The Japanese Company NTT DoCoMo developed the wireless technology know as I-mode (I stands for information) as a wireless technology in May 1999. This system was the first use of wireless communication and the model on which American WAP systems were based. This system is superior to WAP as a current-generation service. I-mode uses the CHTML (Compact HTML) language. WAP uses WML. Although, I-mode users use 'always-on connections' to access a site or e-mail, WAP users need to dial up to do so. Based on these two main streams of wireless communication, wireless phone companies have invested other international developments in WAP technology.

2. The Limitations of WAP Technology

In the fall of 2000, Nielsen Norman Group (NNG) performed WAP user tests in London. Their tests examined the usability of WAP devices in London. The conclusion of their test suggests that although numerous WAP devices are on the market today, the technology that drives them is not fully developed. Moreover, Ramsay and Nielsen in NNG mention that

the usability of current WAP services is severely reduced because of a misguided use of design principles from previous media, especially principles of web design. This situation is exactly equivalent to web design problems in 1994 (2000).

Through these tests, they found that current WAP technology is clumsy because of the poor use of web design principles, unclear labels, and menu choices written in jargon invented by WAP designers. This research explains the problematic aspect of WAP technology and interface design. Hence, NNG suggests that there is a strong need for standard terms and standard features for WAP icons while they indicate that there is no room to explain nonstandard terminology with rollover effects, icons, or captions. It is true that current WAP devices have a very small screen size. The WAP devices that NNG studied were Nokia 7110e and Ericsson R320, which were two of the most sophisticated phones available at the time of the trial. The Nokia displays up to 6 x 23 characters on screen and The Ericsson R320 up to 5 x 15 characters on screen. Both screens are significantly bigger than inexpensive models; even though their screen sizes were relatively large, they were not large enough to depict nonstandard terminology. Consequently, the NNG user tests suggest that there is a strong demand for not only technology improvements but also new a graphic interface system for WAP technologies (Nielsen, 2000).

Current WAP technology has one major problem that affects all users. Specifically, the WAP screen size is limited by the nature of hand-held devices such as Web phones and Web Personal Digital Assistants. Galitz, Wilbert O, a graphic user interface (GUI) designer, indicates that

screen design is limited by the physical characteristics of the display terminal itself important characteristics include the display screen size, the characteristics of its associated keyboard, and the character generation method and screen resolution (1993, p. 115).

The resolution of Liquid Crystal Display (LCD) that is currently used for WAP devices is limited to 72 dpi (Dot Per Inch). It can only generate simple, bold images within the limited screen size. Some devices display color. However, color is not yet popular because of the cost of advanced technology necessary for color. Thus, certain forms and colors are still impossible to produce on WAP screens. Since the size of WAP monitors becomes a limitation for screen display, WAP icons have to be designed with limited pixels. Steve Caplin, the author of *Icon Design*, states that “designers had been limited to icons that would fit within a grid of 32x32 pixels, apart from a single foray into larger sizes (2001, p.54). Although Apple computer expands the pixels sizes up to 128x128 in Mac OS X, the restriction of WAP devices’ screens does not allow 128x128 size icon their screens. Moreover, Galitz suggests the minimum sizes for easy selection in *The Essential Guide to User Interface Design*;

minimum sizes for easy for selection:

- With stylus or pen: 15 pixels square
- With mouse: 20 pixels square
- With finger: 40 pixels square (1997, p.528).

This indicates that icons cannot be big or complex. Moreover, a pixel is not changeable or reducible with the current technology. Along with the given technology of WAP, appropriately sized icons must be used. William Horton, the author of *The Icon Book* points out that “icons should be large enough to do the job but no larger. All icons of a related set should be the same [size], but deciding that size may require considering several conflicting requirements” (1994, p.205). Designing an icon on a WAP screen is the same as solving a puzzle in this limited space (Figure 2).

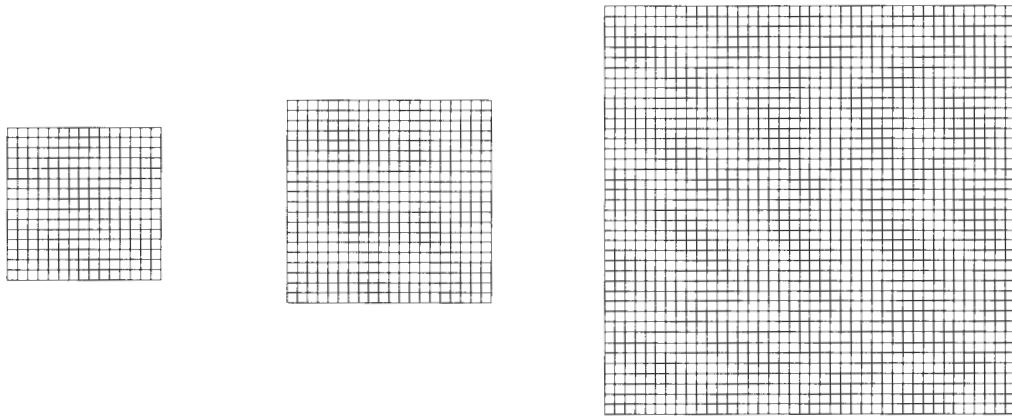


Figure 2. Three variations of icon sizes: 15x14, 20x20, and 40x40

The more complex the icons, the less effective they will be. The bigger the icons, the less space available for other information. The last limitation in WAP technology today is the operating time. Battery power defines the amount of time these devices can be used. Even though battery technology is getting better and better, there are still limitations. Consequently, limitations in WAP technology force WAP icons to be simple and clear so they can achieve more effective communication. This study will take this technical aspect into consideration while attempting to solve these iconic puzzles.

B. Characteristics of Good Icons

To develop a set of prototypical WAP icons, it is necessary to study icon design in detail. The term “icon” refers to a small graphic image that relays complex ideas through rather simple designs. Horton defines icon as the small pictorial symbols used on computer menus, windows, and screens (1994, p. 2). Many WAP companies use text-based interfaces for WAP devices although icons have already been applied for many electronic devices to improve their effectiveness. Horton mentions that “you can use an icon anywhere you would

use a word label” (1994, p.3). By replacing the text interface of WAP with a recognizable icon interface, this study will enhance the functionality of WAP devices. The icon interfaces that some companies use are not recognizable. To design recognizable icons for WAP screens, this study ought to understand what makes icons recognizable.

The characteristics of good icons require an adherence to several design principles in iconic communication such as simplicity, comprehensiveness, context, and scale, contrast, and proportion. Simplicity is one of the important elements. Kevin Mullet, a graphic interface designer, indicates “the benefits of simplicity are functional as well as aesthetic in nature” (1995, p.18). Comprehensiveness and cultural contexts must be considered in icon design processes because icons must convey a particular meaning to WAP users. However, the meaning of an icon can be varied depending on where an icon is applied and who is interpreting it. Additionally, this study considers the electronic context of icons on WAP devices. Scale, contrast, and proportion are interrelated in terms of the effectiveness of clear composition. The combination of these three design principles solves design problems in visual communication. Lastly, icons must not only improve functionality but also stimulate visual interest to users. To convey the characteristics of good icons to the body of the study, this literature review will explore the above design principles in detail.

1. Simplicity of Icon Design

Two major factors necessitate the simplicity of icons in this study. The first is that simple icons can provide users precise information without unnecessary information so that users can easily recognize and quickly memorize WAP icons. The second factor is that, as

stated above, the technical aspects of WAP devices are limited by current electronic technology; this technology requires simplicity. Understanding these two factors can help to create successful iconic communication.

Icon Design and Simplicity

In order to create recognizable icons, simplicity must be applied to WAP icon design. Simple icons help users to easily recognize iconic information. Because simple icons display less visual information to WAP users, they are easily learned, understood, and remembered. Mullet points out that “good design is simple, bold, and direct. It ensures that significant design elements will be noticed by removing insignificant elements wherever possible” (1995, p.39). Highly stylized or ornamental elements must be reduced as much as possible to create simple icons. If the icons are too complex and stylized, WAP users may waste time discerning the functions of icons.

Simplification of forms should be purposefully carried on throughout the design process to create the effect of simplicity. Mullet mentions that “reduction through successive refinement is the only path to simplicity. To create an elegant solution, anything that is not essential to the communication task must be removed” (1995, p.23). However, it is important for this study to be aware of how to properly reduce forms for icon design. Too much reduction may cause doubt about the meaning of the icons. Regardless of this matter, Mullet further points out that “perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away” (1995, p.17). The essence of an icon should be refined accurately for effective communication with icons.

Formal treatments for icon design require the reduction of contrast, weight, values, and shapes of icons. By employing these elements, this study will take advantage of simplicity to create aesthetic and communicative means of conveying a variety of visual impacts ranging from the most explicit to the most implicit effects.

Simplicity and Memory Retention in Icon Design

Icons must be memorable so that users not only find information quickly but also remember and recall them effectively. A lack of refinement with icons may result in chaotic and ambiguous icons that cause users difficulty in memory retention and recognition. In other words, complex icons can cause users to make mistakes, perform tasks slowly, and /or forget the icon's function easily. Icons must be refined and simplified to focus the viewer's attention on their essential aspects.

The simplicity of icons helps user to memorize and recall information quickly. Much research has proven that simple forms are more effective than complex forms. Users spend approximately 1 to 1.5 seconds recognizing an effective icon in normal conditions. Experiments by human psychologists; R.M. Granovskaya, I.Y. Bereznaya and A.N. Grigorieva, indicate the period of time to process visual information "varies from 1.52 to 1.79 seconds" (1987, p.113). Moreover, studies of traffic sign designs by the US Department of Transportation state that people "can make simple decisions once every one half second...A one-half second view is sufficient for [one] to take in all [one] needs to know to guide [one's] action" (1969, p.14). The speed of processing incoming information is conditional on the degree of the simplicity of the form. Bao, Li-Ying suggests that "people

can memorize simple forms more easily and quickly than complex forms” in her thesis *Testing the effectiveness of icon designs for computer soft ware* (1996, p.32). Moreover, Hitch, Graham, psychologist, uses long and short words to test people’s memory, and shows that “short words are easier to remember than long words. People can recall a word which they can articulate in 1 to 1.5 seconds easily”(Bao, 1987, p.125). The more complex, the more fragments of information the users have to go through. This results in less effective icons. Therefore, this study will consider the effectiveness of simplicity to facilitate memory retention among WAP users.

Simplicity in WAP Technology

In addition to the recognizability and memory retention, the simplicity of icons takes a significant role in the effectiveness of iconic communication within the electronic environment of WAP technology. Designing WAP icons is dependent on the current capabilities and limitations of electronic technology. Because of the limitations of WAP devices such as screen size and resolution, the icon design process must be concerned with the integration of simplicity with WAP icons. Moreover, slow and low bandwidth of WAP technology does not allow WAP icons to be complex. The nature of WAP forces icons to be constrained within certain sizes and simple shapes. A simple icon with a small scale can effectively communicate in a limited WAP environment. Therefore, the simplicity of icons needs to be emphasized to create functional icons within the nature of WAP technology.

2. Scale, Contrast, and Proportion in Icon Design

Scale, contrast, and proportion are used in many design practices. WAP icon design cannot be an exception. The successful relationship of scale, contrast, and proportion not only creates solutions of visual communication with significant effects but also lets WAP icons be visually stable and unified yet strong enough to convey recognizable information.

Mullet suggests that

the subtle interrelationship of scale, contrast, and proportion can be seen in every harmonious design. The effectiveness of a clear composition always depends at least as much (often more) on the relationships among the parts as it does on the parts themselves (1995, p.51).

Scale

The meaning of scale is identified by several interrelationships of design elements such as point and counterpoint and figure and ground. These interrelationships depend on careful manipulation of the graphic qualities of each element in the display. Accordingly, the scale of an icon is determined by the interrelationship between design elements as well as the whole composition. When icons are designed based on a successful interrelationship between design elements such as line, shape, value, and scale, they can be functional as a whole composition. Therefore, the achievement of this steady interrelationship needs to be considered during the WAP icon design process.

Additionally, scale becomes a critical factor by the virtue of this study; WAP is a small handheld device that has many functions and a small-scale screen. To accommodate the many functions of WAP technology, the scale of icons should respect the capabilities and

limitation of WAP screen size and resolution. The scale of WAP icons should be big enough to carry the intended information and small enough to fit to the small screen.

Contrast

Icons test the quality of display screens. Unless the icon is clear on the screen, it will not be clear to the eyes of users. Clear icons on screens ensure that users not only perceive contrast easily but also differentiate values. Contrast is often used effectively to create clarity of icons and to enhance visual communication. Mullet points out that “Contrast is always most effective when limited to one or a few dimensions” (1995, p.67). When designing icons for WAP screens, consideration of contrast is important. Lack of contrast causes a lack of readability and legibility on WAP screens. A printed image is more legible than a displayed one because it has higher contrast. Light-dark contrast is critical for reading text and recognizing small images on WAP screens. WAP screens vary considerably in the maximum light-dark contrast they can display. Because icons are affected by the backgrounds against which they appear, icons must be clear and sharp against the background screen. Horton suggests that the primary objects should have the highest degree of contrast with their background (1994, p.85). Otherwise, they are hardly recognizable to users. The lower the contrast, the larger the icon must be to be recognizable. Therefore, the contrast of WAP icons needs to be strong enough to be clear and sharp on light- dark screens.

Proportion

Proportion is an important aspect of managing design elements in WAP icon design. Since icons for WAP screens are designed in pixels by pixels, all design elements should be carefully proportioned to be recognizable. Otherwise, pixilated icons will easily lose visual stabilizations. “It determines the balance and harmony of relation between elements” (Mullet 1995, p.52). The balance and harmony of design elements within an icon control the proportioned relationships among the design elements that consist of horizontal and vertical lines, curves, and angles. By keeping the design elements in balance and harmony, WAP icons in small screens can be recognizable. Moreover, icons can reproduced in small or medium scales with the same effectiveness.

The relationship of figure and ground in an icon is another important factor in keeping the design elements proportioned. Users perceive images by virtue of contrast between figure (image themselves) and ground (background). When proportionally integrated, these figure and ground relationships ensure the effective communication of a single unified design.

3. Context of Icon

The meaning of an icon depends on the context in which it is viewed. This idea is an important factor in icon design processes because WAP icons cannot be effective unless both the icon designer and the user understand the circumstances or events that form the environment in which WAP devices exist or take place. There are two contexts for icon design: contexts inside WAP devices and those outside WAP devices. Contexts inside WAP

devices are influenced by the nature of the WAP devices themselves. Contexts outside WAP devices are influenced by users' cultural differences and previous experiences. A WAP device's own context can be limited by the nature of the device itself. On the other hand, cultural contexts can be considered outside influences contributing to environments that humans create.

Every day, humans are surrounded by many signs and symbols in the non-electronic and electronic environment. Icons in the non-electronic environment are not as concentrated as they are in electronic environments. Icons on WAP devices not only have limited screen sizes but also limited contexts. Most of the signs in the non-electronic environment exist in environments that naturally provide users with context. For instance, the sign of a cigarette in a car leads people to think "cigarette lighter." However, if the same sign is in a building, it might represent a smoking area in the building. Figure 3 shows this signage.



Figure 3. Signage of a cigarette

The context in which users see icons in the non-electronic environment helps them determine what the icon represents. However, in the electronic environment, a WAP device does not give users any visual context. An icon can only stand for itself and explain its meaning by its own characteristics. According to Bao,

the environments become extensions of the visual characteristics that enhance the features and meanings of the signs... To make an icon work itself, the image must be obvious from the crowd (1996, p.42).

Therefore, the icons on WAP devices must be exaggerated and enhanced to a certain extent, so that users can distinguish a targeted icon immediately in the crowd of information.

Besides the limited context of WAP devices, icon design is also influenced by the cultural context in which icons interpreted. When visualizing an idea to an image, this study should consider various possibilities associated with a given cultural background. Horton mentions that

The meaning of an icon depends on the associations it triggers in the mind of the user. The same image can have vastly different associations in different cultures. We must pick symbols that have the same meaning for all users. Not all symbols do (1994, p.244).

For instance, when people in Europe or the United State America see one of these symbols (Figure 4), they might think that it represents Nazi and fascism. However, people in China or other countries where many Buddhists live in would mostly be reminded of a religion or philosophy based on the teachings of the Buddha.



Figure 4. A symbol of Nazism (left) and Buddhism (right)

These two symbols are visually only a little different: one moves clockwise and the other moves counterclockwise. However, the meanings are very different. This is an example of how cultural differences can result in different perceptions of similar images. There can be other differences of interpretation as a result of cultural context. People from different cultures can interpret colors differently as well. The color white often means “dead” in Japan but usually “purity” in the United States. The same color in its own

environment carries different meanings for two countries. Therefore, WAP icons need to be understood universally. The meaning of icons will be achieved by not only understanding the limited context of WAP devices but also by applying universal contexts. WAP icons can never be effective without knowledge of the ins and outs of the circumstances or environments in which WAP devices are used in the world.

Meaning of Icons

The previous studies are focused on visual imagery in terms of effective communication with WAP icons. The next step is to understand how users interpret meaning from icons. Mihai Nadin, a psychologist and graphic interface designer, defines the three levels of processing imagery formed by the relationships of object, meaning, and interpreter (users) as syntax, semantic, and pragmatic (1988). In figure 5, below, *R* stands for representation, *O* stands for sign object, and *I* stands for interpreter.

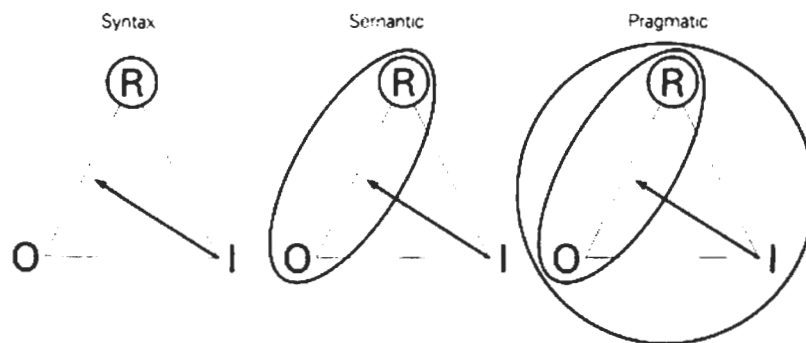


Figure 5. Sign process, Nadin (1989)

Syntax deals with the internal structure of the meaning within an object itself. Semantics is based on the relationship of an object to its meaning. Lastly, “pragmatics

considers the effect of the syntactic and semantic aspects in the relation to a particular interpreter in their personal psychological context” (Mullet, 1995, p.73). Further, Mullet points that

sign must be considered at all three levels to determine their appropriateness for a particular communication problem and to develop visual representations that can be expected to communicate effectively to a particular target audience. The critical process of representation (the focus of analysis at the semantic level) depends on establishing a clear relationship between a representation and its object (1995, p.172).

In WAP icon design, the understanding of syntax, semantic, and pragmatic imagery processes that extend the meaning of an icon to WAP users is critical to developing clear communication.

C. Graphic Representation of Ideas

Icons are a graphic representation of ideas. When icons are well represented graphically, the promise of clear communication can be achieved. Clear graphic representation helps users to interpret the correct meanings of icons. To make the meanings of icons apparent, this study must understand how to visualize ideas. This research responds to the challenge to define visual forms for electronic functions featured on WAP screens. Applying icons to represent WAP functions involves many concepts and forms of representation. According to Horton’s method, there are three ways of representing ideas graphically in icon design.

Concrete image - show the subject itself or at least physically resemble it if it is possible

Metaphor - show a related object

Abstract - use abstract symbolologies: shape, color, position, and pattern, texture (1994, p.34)

WAP icons consider the combination of these three methods to refine their appropriateness for a particular communication problem and to develop representations that can be expected to communicate effectively to WAP users. The icons for WAP functions can be assigned by virtue of this likeness to or resemblance of that object. For example, on cell phones, an image of a phone handset is often used to symbolize the effect of making phone calls. A metaphorical representation suggests the functionality of a suite of an icon in GUI. For an example, the image of a key as an icon to represent information that is secure or requires accessibility clearance is an example of a metaphorical representation. Abstract forms symbolize invisible system operations. Mullet defines abstract representation as “the processes of reconstructing the meaning of a sign by identifying the sign object and grasping the significance of the connection between object and representation” (1995, p.172). To complete communicate through abstract representations in GUI, users must make a connection between the abstract representation and the corresponding systems. For instance, the plus and minus icons often indicate calculator functions to users of WAP devices and other GUI. After investigating the graphic representation of icons based on concrete, metaphoric, and abstract representation, this research will establish an interactive matrix for developing WAP icons.

1. Concrete Images

Pictorial images are very effective in representing familiar concrete objects from users' everyday experiences. By showing a subject itself or the physical resemblance of a subject, an icon can deliver a specific message to users. Horton states that

the physical similarity between the real-world object and its graphical representation ensure that the subject is recognized reliably. Often when symbols mimic the subject, we forget that they are symbols at all and treat them as if they were the objects being discussed (1994, p.34).

However, the concrete images can be depicted when functions have physical shapes or resemblances between the objects and their graphic representation. Concrete images in icon design involve many methods. The first is to use illustrations of subjects that have physical forms. For instance, to refer to the functions of 'calculator or news,' the icons can present themselves directly (Figure 6 and 7).



Figure 6. Calculator, *Palm OS 3.5*



Figure 7. Newspaper, *Apple Macintosh OS 9.2*

The second method is to use visual appearances of the actions performed or to show objects arranged the way they would appear to the user performing or observing the action. Figure 8 and figure 9 show an icon that depicts the action of writing.



Memo Pad

Figure 8. Memo pad, *Palm OS 3.5*



Graffiti

Figure 9. Graffiti, *Palm OS 3.5*

A structural analogy which shows an object with an analogous structure can be used to show the organization of information. This can be extended to portray a pattern of relationships, for instance, the organization of information in Palm system 3.5, figure 10 and figure 11.



Prefs

Figure 10. Preferences, *Palm OS 3.5*



Figure 11. Drop down menu, *Palm OS 3.5*

2. Metaphor

The most WAP functions are invisible. If ideas do not have visual forms, they employ other substitutes that recall these ideas to users' minds. Metaphorical representations are often used to visualize formless ideas indirectly. To clarify the representation of invisible functions in electronic devices, icons can be used to depicted visual equivalents when they cannot show concrete forms of ideas. Use of visual equivalents of incoming ideas leads users to stimulate existing knowledge, and then understand what the visual equivalents actually mean. Earl R. Mac, Cormac, the author of *A Cognitive Theory of Metaphor*, defines the essence of metaphor as "an unusual juxtaposition of the familiar and the unfamiliar" and suggests that "metaphors allow us to extend our knowledge by juxtaposing normally unrelated referent are similar" (1985, p.17). The use of metaphor is the most appropriate idea because of the invisibility of WAP functions. Therefore, it is important to study metaphor in detail.

According to Horton (1994), there are five metaphorical methods: synecdoche, litotes, hyperbole, euphemism and synaesthetic analogy. Synecdoche, the use of a single or familiar part to stand for a whole object, is familiar to most users because of their familiarity with road signs. It can be applied to very complex objects or indistinct objects to represent a concept. For example rather than showing a person making phone call to represent 'making

a phone call,' by showing a small, recognizable part, the whole concept can be delivered (Figure 12).



Figure 12. Icons for making phone calls, *Audiowox.TM* (right)

Litotes are another way to represent verbal communication in icon format. Litotes are affirmative statements formed by the negation of the contrary. Double negatives are normally discouraged in verbal communication but work well graphically. For example, to show freedom, the negation of imprisonment (Figure 13) can be used. However, these do not always work because there are several ways of reversing or denying concepts (Figure 14).



Figure 13. Icon for freedom, *Icon Book*



Figure 14. Icon for freedom, *Icon Book*

Hyperbole or exaggeration makes icons distinguishable to users. Horton indicates that “this technique is valuable when you must clearly distinguish among otherwise similar objects or concepts” (1994, p. 44). GUI often utilizes hyperbole or exaggeration of objects to make icons prominent. Using the bomb as an icon for system error certainly overstates the severity of the problem (Figure 15).



System error

Figure 15. Icon for system error, *Icon Book*

In a Macintosh computer interface, whenever users throw away files into the trashcan, the trashcan becomes swollen (Figure 16). It does not matter how much trash users put into the trashcan; it keeps the same shape until users empty the trashcan (Figure 17).



Trash

Figure 16. 100 piece of trash,
Apple Macintosh OS 9.2

Trash

Figure 17. 1 piece of trash,
Apple Macintosh OS 9.2

Both of these examples demonstrate exaggeration or hyperbole by overemphasizing ideas.

Euphemism is used for showing indirectly something that is shocking or disturbing. Euphemism linguistically means that a word or phrase used in place of a term that might be considered too direct, harsh, and offensive. It can be an effective way to stimulate users' reactions quickly. For instance, to show bodily injury, a bandage can appear as an icon (Figure 18). When users see the bandage icon, they can immediately assume it is related to physical injury.

Figure 18. Bandage, *Icon Book*

Synaesthetic analogy is related to human feelings. For example, Figure 19 shows the roundness of sound and Figure 20 shows the sharpness of sound. Sound does not have its own image. However, by connecting human feelings about sensation with images, sound can be represented in a variety of visual formats.

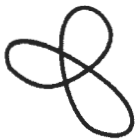


Figure 19. Smooth, *Icon Book*



Figure 20. Rough, *Icon Book*

Convention is a way to depict functions in iconic communication. GUI often borrows other sign systems that users are familiar with. The sources of these conventions need to be learned and understood by all users. For instance, icons shown on industrial, historical or public signs around us can communicate well because we are familiar with the conventions of these sign systems. Horton states that

most technical and industrial activities have evolved their own system of visual symbols. In designing interfaces for these disciplines, you should use the symbols that are already familiar to the readers (1994, p.46).

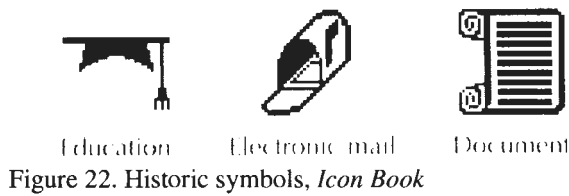
As an example of an industrial or institutional symbol, the image of a broken glass (Figure 21) usually represents that the contents of a box are fragile. Figure 21 is a widely practiced and well-established icon.



Fragile

Figure 21. Fragile, *Icon Book*

Historical symbols are another way of representing ideas. This study must consider what users think or remember something looks like more than what it actually looks like. Users easily understand the icon of a graduation cap, mailbox, and document (Figure 22) to represent ‘education, electronic mail, and word document’ because they are the most common symbols of education, electronic mail, and document in our lives.



Public signs and symbols provide a broad vocabulary of familiar symbols that many users already know. For instance, Figure 23 means ‘prohibited’ to all users because it is so ubiquitous.



Figure 23. Symbol for prohibited, *US Transportation*

Through these metaphoric representations, the functions of WAP can be visualized. There are various other metaphors to represent formless ideas such as metaphorical methods: synecdoche, litotes, hyperbole, euphemism and synaesthetic analogy, etc.

3. Abstract Forms

Abstract icons do not relate directly to concrete objects but express something that can only be appreciated intellectually. Visible forms that characterize the abstract meanings and functions of WAP icons can be formed. Bao indicates that abstract concepts, processes, or situations, because they are less tangible, depend on less direct forms of representation in which even a well-designed image may be difficult to interpret correctly (1996, p.26). WAP users may be able to recognize some abstract forms based on their existing knowledge. Users' existing knowledge is all the information, facts, truths, and principles learned throughout their lifetime. Mullet mentions that "images for abstract processes or conditions are purely conventional — they must be learned before they can become useful" (1995, p.200). Consequently, abstract icons oblige users to learn in the same way that people learn a foreign language. Abstract icons require users' learning processes to be useful. Because of this fact, the use of abstract icons to represent formless functions becomes a challenging task for both graphic designers and users.

Uses of abstract forms for icons of electronic devices involve several methods that often stimulate users' existing knowledge. Users spend more time learning new icon systems if an icon system that has been borrowed from a system well known by users does not present the same challenge. For instance, Figure 24 is a well-known abstract icon system for VCRs and tape recorders to show the functions of 'rewind,' 'play,' and 'advance one frame,' and 'fast forward.'



Figure 24. Icon system for VCRs and tape recorders, *Icon Book*

This system is often used for other applications such as web browsers and WAP screens to depict the function of 'go back' and 'go forward' (Figure 25).

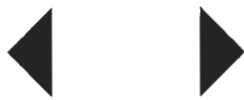


Figure 25. Back and forward in Internet browser, *Icon Book*

When borrowing a certain system's icons to represent abstract functions of other applications, context becomes an important aspect because the information vehicles are different. Although the icons may be the same, their meanings can be varied in different application systems. Giving users visual cues that enable clear interpretation is very important with abstract icons. Otherwise, users would be puzzled. Bao states that

the multiple messages carried by one image lead the users to a guessing game. Users can easily become frustrated since their goal is to complete their tasks and not to engage in a game. The more ineffective the icon design, the longer the guessing process, and the more frustrated the users may become (1996, p.24).

Therefore, to define the meanings of abstract icons, this study must consider the interrelationship between syntax and context.

As a result of careful icon design, icons can become effective communication vehicles when their graphic representations are achieved. The significant aspects of iconic communication are the quickness and directness of recognition and identification. Mullet

indicates that iconic communication is dependent on the quality and familiarity of the image and its appropriateness for the concept being represented (1995, p.203). Some functions are well represented with concrete images. Some functions can be well visualized by being represented by metaphor. Abstract icons can signify some invisible functions, while some operation features can be comprehended effectively by concrete and abstract images. The combination of these three ways of representing ideas graphically will be used in this study to design functional WAP icons. However, these three ways cannot always solve all communicative problems in iconic communication. Bao mentions that

under certain circumstances, one is more effective than the other. For instance, if an abstract concept or action does not possess any linkage to any concrete images, and it also cannot be communicated through an analogy or metaphor clearly, then perhaps, it may be communicated more effectively with words than images (1996, p.28).

In other words, the use of words directly is a primitive way of representing ideas when the three kinds of iconic representations do not lead users directly to the correct meanings. Bao points out that “the choice of one or the other depends on usability” (1996, p.29). It does not matter what graphic representations are applied to communicate effectively. What matters is that the graphic representation of icons is recognizable and that the icon clearly suggests the function it represents. Therefore, the clarity of graphic representation is an essential criteria of icon design.

CHAPTER 3. PROCEDURAL DEVELOPMENT OF WAP ICONS

Creating prototypical icons for WAP screens requires a multi-step solution for the design problems that current WAP devices have. These steps, which can be a framework to create graphic user interface (GUI) for WAP devices, include the following:

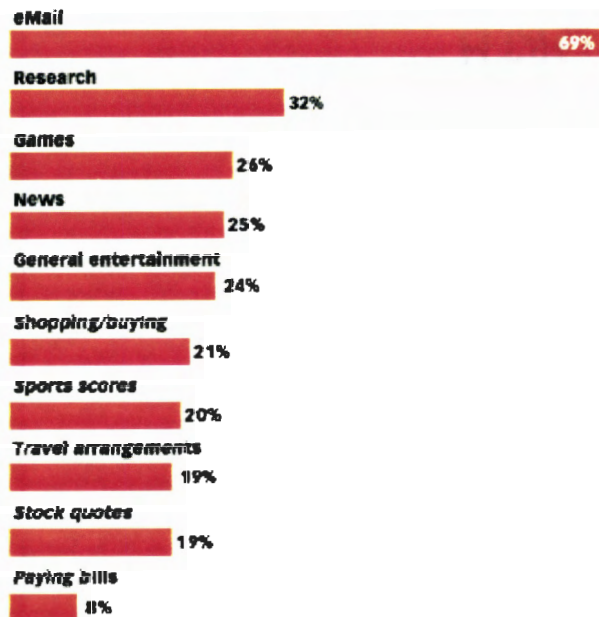
- Identification of the WAP user's needs
- Analysis of the WAP user's needs
- Investigation of images for WAP icons (style)
- Development of WAP icons
- Presentation of Final prototypical WAP Icons on WAP screen

First, an identification and analysis of WAP users' needs will enable this study to consider and develop WAP icon design processes in terms of accommodating users' needs. Also, this procedural development will involve investigation of images for icon development, development of icons, icon evaluation, icon refinement, and finally making sure icons show up on screen the way they have been designed. This research will not only identify WAP users' needs and how to visualize appropriate forms for WAP icons, but also produce a framework and sequence from preliminary ideas to the final icon design.

A. Identification of WAP Users' Needs

According to eMarketer, a private Internet company and e-business statistic provider to more than 140 countries, there are four frequently used WAP functions: email, search, news, games (Figure 26).

Top 10 Wireless Internet Activities for Wireless Internet Device Owners in the US, 2001 (as a % of owners)



Source: TNS Intersearch, 2001

Figure 26. Top 10 Wireless Internet activities, Jackson (2001)

These statistics show what users do with their WAPs. According these statistics, 69 percent of WAP users use their WAP for Email, 32 percent of them use it for research, 26 percent for Games, and 25 percent for News. Eddie Cheung reports that I-mode, developed by the Japanese Company NTT DoCoMo as a wireless technology in 1999, is one of the leading pioneers in wireless communication markets in the world.

One of the most important factors behind the phenomenal growth of I-mode is the abundance of content relationships between the operators and the content providers. As I-mode is about to be exported to Europe, mobile operators are looking into what content will create the most compelling consumer experience – so gripping that consumers will actively open their wallets and pay for it (Cheung 2001).

I-Mode Content Categories In Japan, 2000

	Percentage of total number of sites	Sites accessed via DoCoMo's official menu
Entertainment	31%	64%
News/Weather/Information	6%	19%
Shopping/Living	4%	5%
Mobile banking, finance	42%	4%
Dictionary/Convenient tools	4%	4%
Town Information/admin.	9%	2%
Travel/Traffic/Maps	3%	1%
Gourmet/Recipes	1%	1%
Total	100%	100%

Source: NTT DoCoMo, 2000

©2000 ©2001 eMarketer, Inc.

www.eMarketer.com

Figure 27. I-Mode content categories in Japan, 2000

The above two reports indicate what users need from their wireless Internet services. The challenge of this research is to conduct an exploratory study related to WAP icon design. By designing icons for these four functions (Email, Search, News, and Games), this research will provide a prototype that can extend to the further study and development of WAP icons.

B. Analysis of WAP Users' Needs

In order to develop icons for the Email, Search, News, and Game functions, it is important to analyze what the characteristics and meanings implicated in these frequently used functions (FUFs) are. This enables this research to not only indicate characteristics of these FUFs but also identify appropriate methods that visualize the functionality of WAP icons.

1. Email

Checking email is the most common function of wireless communication devices.

Email represents electronic mail. This function allows users to exchange their messages and files electronically. To promote this function, the icon of checking email often borrows the actual envelope image (Figure 28). Because checking email does not have visual forms, the concrete image, a literal image of a mail envelope, is frequently used in Internet browsers, email software, and PDA devices. Typography is often used for icon design and additional information. Borrowing a familiar image that users know is a way of using metaphor or appealing to convention. Therefore, designers can metaphorically and abstractly visualize icons for this function.



Figure 28. Existing email icons, *Palm OS 3.5 and Microsoft Internet Explore*

2. Search

Search functions are means to find information that users want to access. The search function essentially “asks” the wireless communication tool to examine computer files, disks, databases, or networks in order to find particular information. Icons for the Search function often use the images of magnifiers. This function also uses a conventional metaphor to represent its usage. Because it does not have visual form, the icon for the search function should be represented by metaphorical and abstract images.



Figure 29. Existing search icons, *Palm OS*

3. News

News is a means of finding information about current events or international developments publicized in newspapers and broadcast media. Although WAP users frequently use this function, no icons have yet been developed to represent it on WAP devices. This research found that most existing WAP indicators of news are text-based interfaces that can be replaced by icons. Also, the News function does not have any typical visual forms. Therefore, to represent the function of news, metaphor and abstraction will be applied in this study.

4. Games

Game icons on WAP devices suggest electronic games accessed by WAP users. Games such as solitaire, Tetris, and Pacman are popular among users of handheld devices for amusement purposes. This research found that most existing WAP indicators of games are text-based interfaces that can be replaced by icons. Even though some icons for game functions have been developed, they are often used for a specific games only. This suggests the need for game icons that can be easily used by WAP users. Moreover, game functions do not have physical resemblances to signify their functions. Therefore, to represent the function of games, metaphor and abstraction will be applied during the icon development process.

Analysis of the characteristics of FUFs in WAP devices reveals that metaphorical and abstract representations are the only ways to visualize these four formless functions. While there are some icons for email and search functions that are borrowed from web browsers or web design, they are metaphorical icons. Since no icons have been developed for news and games in WAP icons, text is often used to indicate news and game functions. The challenge of this study is to visualize these four functions that do not have forms. In order to visualize and find appropriate images for the FUFs' icons, image investigation is necessary.

C. Investigation of Images for WAP Icons (Style)

Another preliminary task prior to creating the FUF icons for WAP devices is to experiment with various styles of icons. Although icon design focuses on a communication issue, "style" should also be considered a factor when creating WAP icons. The form of presentation for WAP icons could influence users' reactions. Shih-Miao Huang, Shieh, Kong-King, and Chai-Fen Chi, computer interface researchers in Taiwan identify factors affecting the design of computer icons. According to their research, one of the most important factors is the style of icons. They indicate that

although the essential considerations for icon design are comprehensibility and identifiability, the results of the research demonstrate that "style" should also be considered as a factor when creating a computer icon (Huang, Shieh et al, 2001,.).

In iconic communication, the success of communication is dependent on the clear relationship between an icon and its meaning. The same information can be presented in different graphic styles. Horton categorizes five different ways of drawing icons specifically

for monitor screens (Figure 30): photograph, simple drawing, caricature, outline, and silhouette (1994).

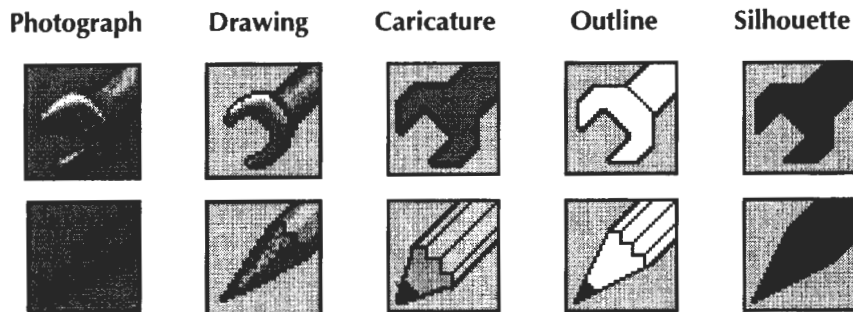


Figure 30. Horton's five ways of drawing icons, *Icon Book*

These categories are based on the degree of abstraction – from photographic realism to silhouette. The five categories rely on concrete images. Further, he suggests the use of a characteristic viewpoint, the exaggeration of crucial concepts, the use of depth (3D), and dropping shadows to make icons more recognizable and distinctive. In this study, Horton's five styles and his additional suggestions are taken into consideration for WAP icon development. Additionally, the styles of Swiss, typography, gesture, and line are used to expand more possibilities for WAP icons in this research. These styles are often used in the development of symbol and logo design. Along with these nine styles, various possibilities for icon development for WAP are investigated. Advantageous characteristics of each style can be applied to WAP icon design.

1. Nine Styles for Icon Development

Photography style is used in icons to provide representational objects in iconic communication. Photographic icons provide users a high level of detail to make complex

information recognizable. Showing an object itself can be an effective communication technique if the technology is available to generate detailed icons.

Simple drawing style is often used for icon design in computer system screens. “Probably, the most common icon style is a simplified drawing” (Horton, 1994, p. 140). This style requires a clear outline contour and distinctive interior detail that helps users distinguish among objects sharing a common profile such as the rectangular or circular shape of objects.

Caricature style drives from simple drawing style. Though sharing the idea of simple drawing, this style exaggerates critical details of objects. The techniques of caricature are to distort or enlarge certain crucial elements that represent the characteristics of the images well. Caricature can be a useful way of drawing complex detail in WAP screens.

Outline style creates simpler forms than the caricature style. Objects are illustrated as an outline contour with only the most prominent details shown. This style is selected because it is good for small icons that represent a familiar object having a distinct profile. However, it can be an effective style when the objects are composed of just edges and lines.

Silhouette style is the most defined, simplified, and bolded icon style. This style is often used for road signs and package signs. By using a solid color contrasting with an object’s background, icon designers can create the essence of information. However, this technique requires objects that do not lack a distinctive profile.

Swiss style, which has an international influence, is a style based on functionality and clear communication. It appears very simple visually but results in strong communication. These characteristics led the Swiss style to influence current graphic design in many areas such as poster design and symbol design. To create high quality communication with icon design, Swiss style is selected.

Typography style can be another way of indicating WAP functions. Designers must make sure to use simple text font and style. Otherwise, typography can be invisible and impossible to depict on LCD screens. Typography can be a useful tool for computer literate users, especially in the case of the FUFs that are well known among World Wide Web users.

Gesture style is a way of drawing expressive lines. Along with changes of line quality such as thin, thick, smooth, and rough, gesture style directs viewers' eyes. Moreover, "such characteristics tend to evoke emotional responses in the viewer" (Zelanski, 1996, p.62). Because of these characteristics, WAP icons designed with this style can be more dynamic in conjunction with the mobility of WAP devices.

Line style is one of the basic design elements for creating various visual expressions such as line itself, texture, and typography. Lines in icon design can serve as very simple visual expressions to communicate with users. It is an especially suitable style for WAP screens because the screen size is limited.

An identification of WAP users' needs suggests that email, news, search, and games are FUFs by WAP users. An analysis of the WAP users' needs defines appropriate graphic representation as metaphorical or abstract images representing the four FUFs. Image investigation for WAP icons proposes the use of the nine styles explained above that can enable this study not only to test various visual forms but also to create unique qualities for WAP icons. Based on factors found in above the three processes, this research will create prototypical icons for WAP screens.

D. Development of WAP Icons

Important information was found in the identification and analysis of WAP users' needs. First, the most frequently used functions were suggested by eMarketer, a private Internet company and e-business statistic provider. These functions are email, news, search, and game functions. Moreover, recognizing the characteristics of FUFs enabled this study to find out appropriate means to visualize FUFs that are formless functions. Therefore, metaphoric and abstract representation will enable users to identify FUFs. Lastly, the image investigation for WAP icons suggested nine styles to develop various icons. The above information indicates that the most important factors in icon design were function and form. This study took these factors into consideration to design prototypes for WAP icons.

This research will use a matrix in order to incorporate all of the above design factors. Such a matrix depends on morphology or discovering all possible relationships among design factors. This matrix (morphology) will inform the actual creation of icons to represent WAP FUFs. Once these icons are developed, they will be evaluated, refined, and, finally, realized on a WAP screen.

1. Morphology

This study needs to create many possible solutions for WAP icons based on form and function. In order to produce as many ideas as possible, morphology was used in this study. The idea of morphology is to discover all possible relationships through the matrix among design factors in order to solve complicated design problems. A matrix is used not only to establish a clear pattern of relationships but also to identify many possible solutions. Ho

Chang Lyu defines morphology in *A computerized morphological database of safety and health issues in bathroom design*.

A basic morphological principle is that all forms are built of subparts and can be recombined to create new forms. Therefore, morphological activity has three primary functions: dissecting forms, defining subparts, and combining subparts (1990, p.59).

WAP icon development process factors are analyzed and identified functions and forms. The analysis of FUFs and the identification of possible forms in WAP devices become two interrelated factors to create interrelationships in a matrix. By listing four FUFs on the horizontal columns and nine possible visual forms on vertical columns, this research on WAP icons combines various interrelationships between function and form to improve the functionality of WAP devices. Based upon functions and forms of WAP icons, the interactive matrix is structured (Table 1). By concepts crossing on both vertical and horizontal axes, systematically, many WAP icons can be produced by virtue of these morphological arrangements.

2. Creating WAP Icons – Method of Research

By using the icon development matrix, thousands of icons are rendered systemically to represent each of the WAP FUFs. They vary in style. For instance, photography, simple drawing, caricature outline, silhouette, Swiss, typography, gesture, and line styles are all used. They are executed with pencils, brushes, markers, and computer applications. The visual forms for the FUFs' icons are depicted using metaphor and abstract design form. Moreover, some icons are a hybrid of styles and metaphor or abstraction.

WAP Icon Development Matrix

Table 1. WAP Icon development matrix

<div> <div>FUF</div> <div>Styles</div> </div>	Email		Search		News		Games	
	M	A	M	A	M	A	M	A
Photography								
Simple Drawing								
Caricature								
Outline								
Silhouette								
Swiss								
Typography								
Gestures								
Line								

FUF= Frequently Used Function, M=Metaphor, A=Abstract

Preliminary sketches for icon design are mostly done on paper and by hand so that the icon design process would not be restricted by anything but the designers' creativity.

Additionally, semantic words related to FUFs are used to extend many ideas. For instance, the word "Email" can be extended to checking mail, sending, receiving instant message, and stamps. "News" can be extended comprehensively to weather, newspaper, and network, etc. The idea for "Search" can be comprehensive with many other words such as investigator, explorer, or finder, etc. The word "Games" could be replaced with sports, play, and card games, etc. Using semantic words with FUFs can increase more possible and diverse icons for WAP screens.

In preliminary icon development, the WAP icon development matrix enables this study to systemically create more than a thousand icons. These more than thousands icon were scanned and digitized for WAP screens. The attached Appendix illustrates a part of this preliminary icon development. I printed and displayed them on the walls of my office so that I could select and evaluate them for the following steps (Figure 31).

Among the thousands of icons, 24 email icons, 20 news icons, 24 search icons, and 24 game icons were carefully selected for icon evaluation. The selection of these icons was based on the literature review, which suggested characteristics of icons that enhance recognizability. Figures 32, 33, 34, and 35 are selected email, news, search, and game icons respectively.

All selected icons in each category were numbered for evaluation. Various styles were selected to examine and explore the possibility of icon styles while the selection was based on the design criteria.

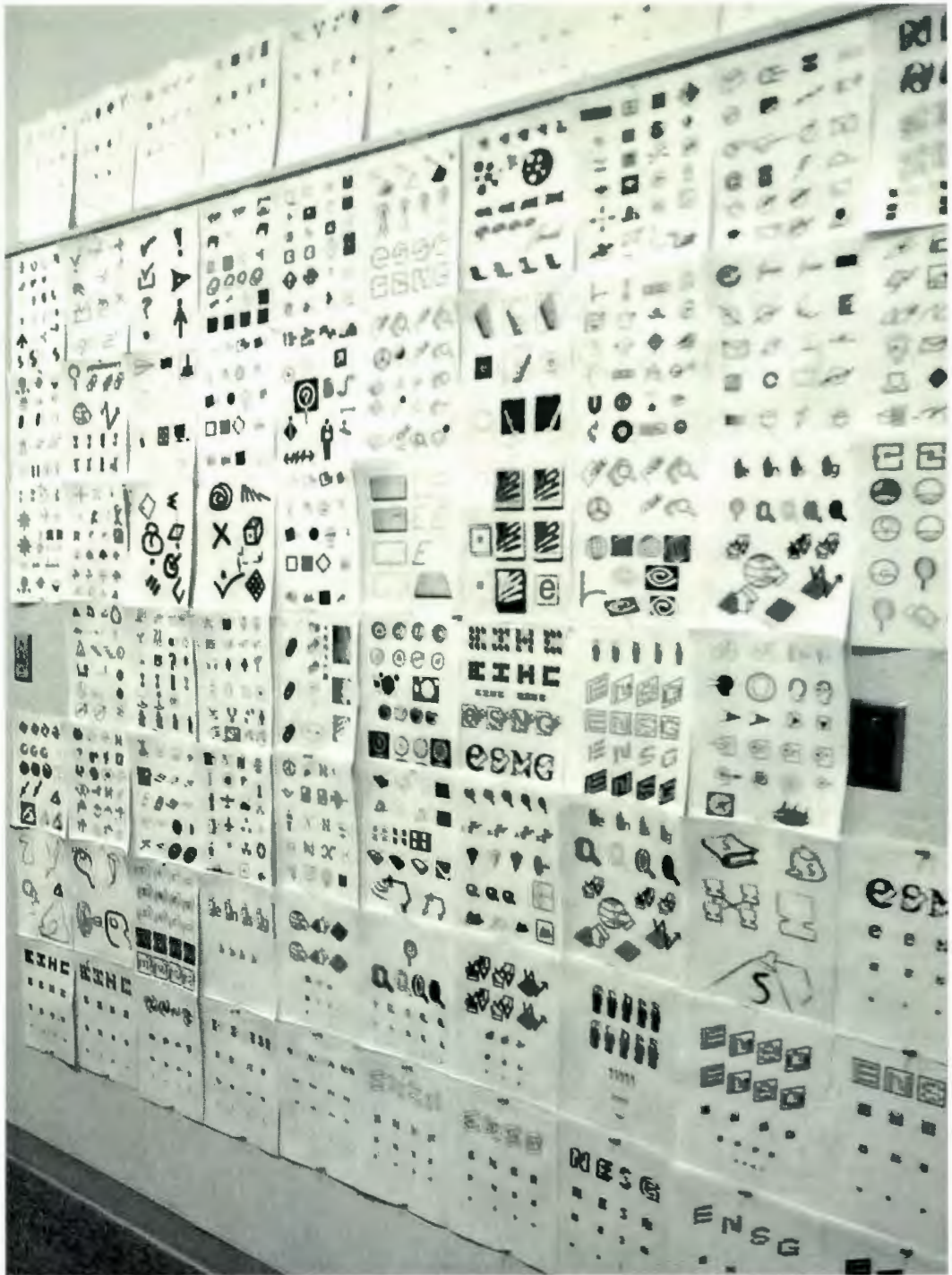


Figure 31. Development of WAP icons on the walls

Selected Email Icons

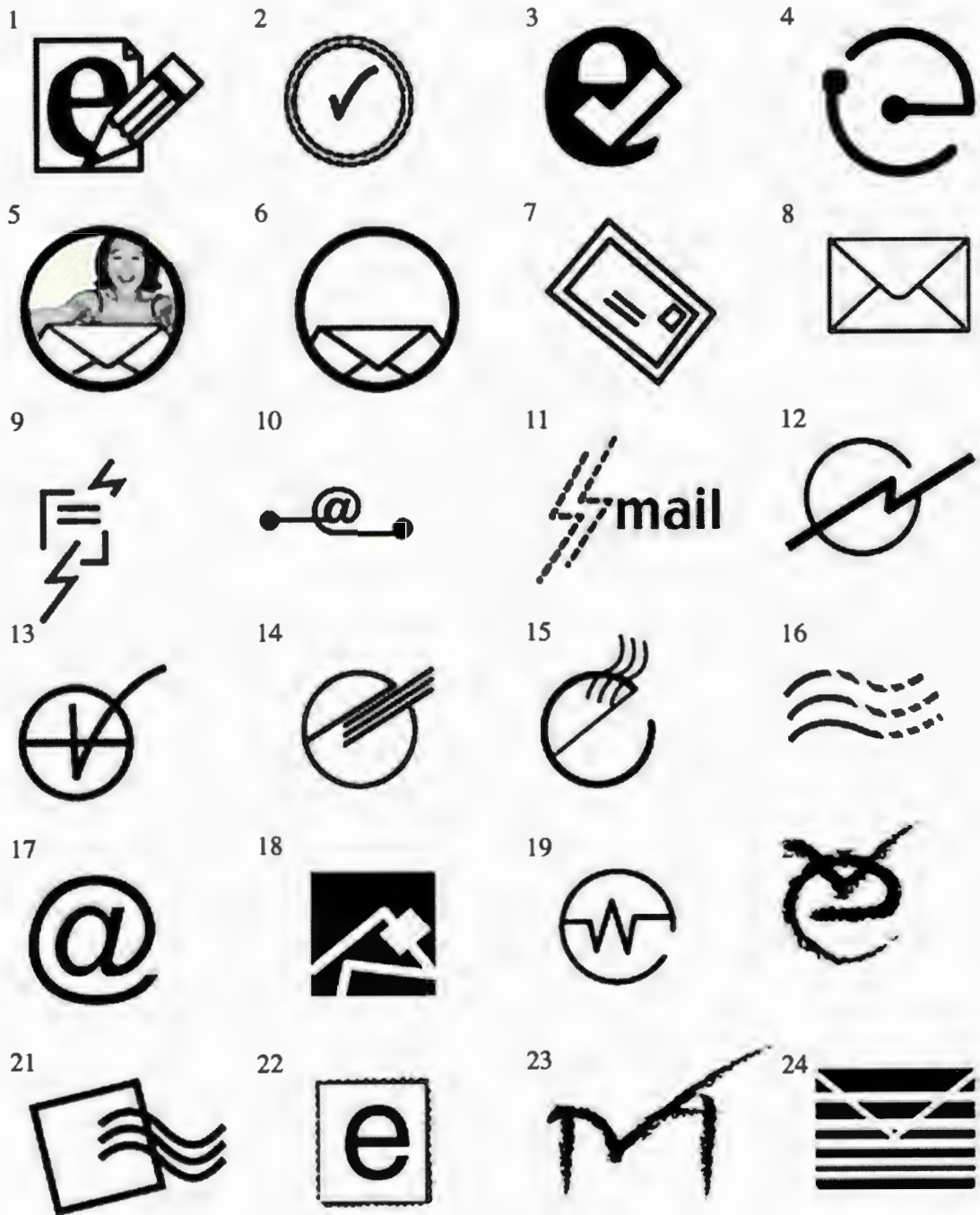


Figure 32. Selected email icons

Selected News Icons

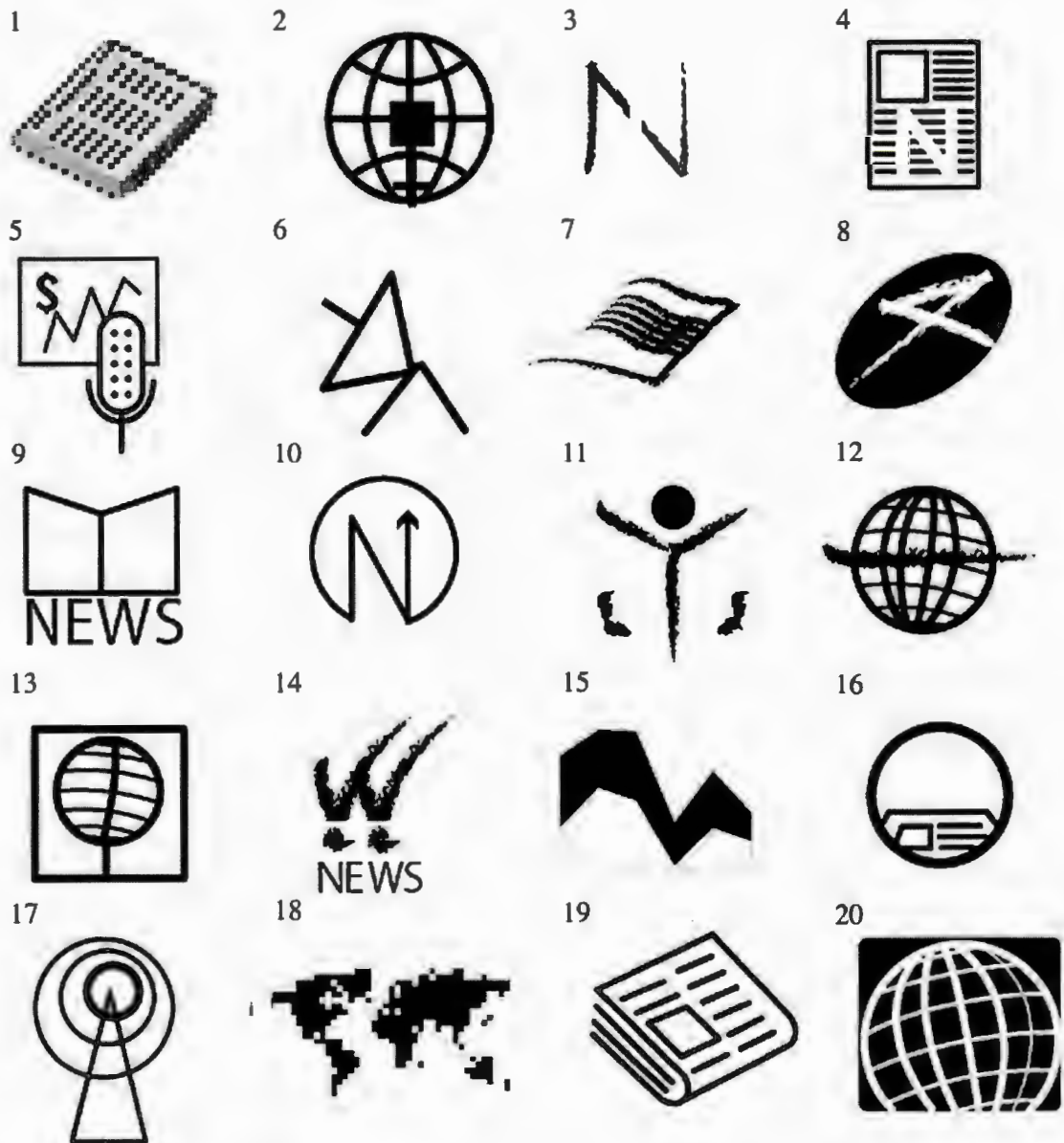


Figure 33. Selected news icons

Selected Search Icons

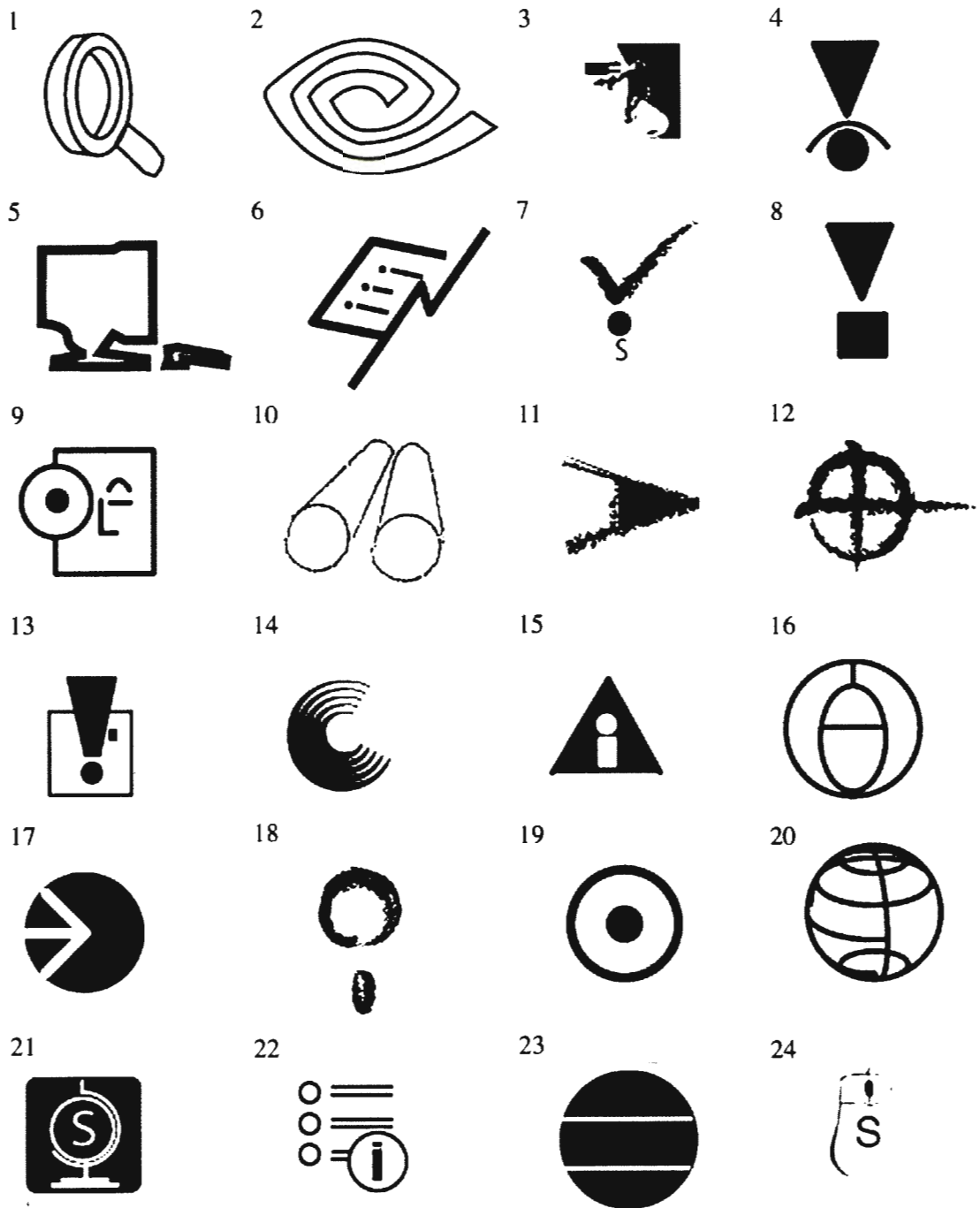


Figure 34. Selected search icons

Selected Game Icons

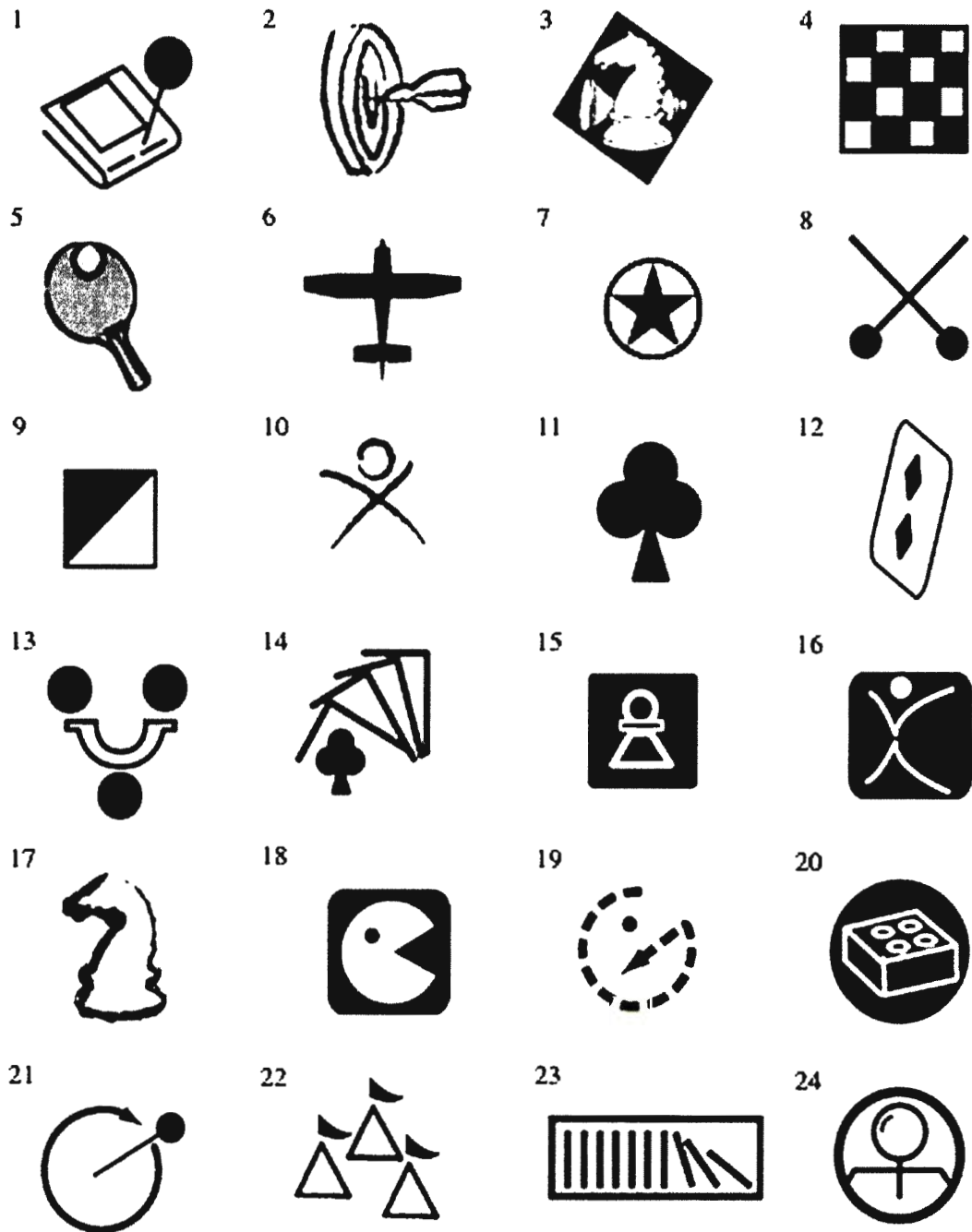


Figure 35. Selected game icons

3. Icon Evaluation

The next step was to evaluate the selected icons for FUFs by applying the design criteria that was developed in the literature review. They are: simplicity, contrast, proportion, stability, clarity, precise information, universal understanding, appropriate for context, semantic correction, syntactic correction, pragmatic correction, visual interest, high recall, and easy to learn and teach (Table 2). Based on these 15 design criteria, the design criteria matrix was developed to evaluate selected icons. Each category has one point. The total of all categories is 15 points. Throughout the self-evaluation process (Table 3, 4, 5, and 6), the icon group that had highest number of points out of 15 emerged and was selected for the design refinement process. In the refinement process, the final selected icons will be examined on WAP screens in order to determine their ability to withstand the technical limitations previously mentioned.

Figure 36 shows the evaluation process for selected icons. The points range from 4 to 14 and are displayed in the graph below to distinguish point ranges for each icon category. The graph displays the point ranges that all FUFs' icons are located in. Each colored dot represents a FUFs' icon. To select the icons to be developed in the refinement process, the icons are grouped in three: low level, from 4 to 7; middle level, from 8 to 11; and top level, from 12 to 15. Then the icons on the top level are averaged. Only three icons on the top level averaged from 12 to 14 points. Therefore, three of each FUF category were chosen to be refined within three size formats; 40x40 (to use fingers to activate functions), 20x20 (to use a stylus pen to activate functions), and 15x15 (to use a mouse to activate functions). The selected icons for this process are illustrated in figure 37, 38, 39, and 40.

Evaluation Matrix of the Final WAP Icons

Table 2. Icon evaluation matrix

[illegible]

Evaluation for Email Icons

Table 3. Email icon evaluation

[illegible]

Evaluation for News Icons

Table 4. News icon evaluation

Total Points: 15			5
Easy to learn and teach	X	X	11
High Recall		X	10
Visual Interest		X	
Pragmatic Correction			
Syntactic Correction			
Semantic Correction		X	
Appropriate for Context	X	X	
Universal Understanding			
Precise information	X		
Clarity		X	
Not too stylized		X	
Stability	X	X	
Proportion	X	X	
Contrast		X	
Simplicity			
1			
2	X	X	
3	X	X	
4		X	
5		X	
6	X	X	
7		X	
8		X	
9		X	
10		X	
11		X	
12		X	
13	X	X	
14		X	
15	X	X	
16	X	X	
17	X	X	
18		X	
19	X	X	
20	X	X	
21			
22			
23			
24			

Evaluation for Search Icons

Table 5. Search icon evaluation

	Simplicity	Contrast	Proportion	Stability	Not too stylized	Clarity	Precise information	Appropriate for Context Universal Understanding	Semantic Correction	Syntactic Correction	Pragmatic Correction	Visual Interest	High Recall	Easy to learn and teach	Total Points: 15
1	X	X	X	X	X	X		X	X			X	X	X	12
2			X		X	X			X			X	X		6
3		X	X	X					X			X	X	X	7
4	X	X	X	X	X	X		X	X	X		X	X	X	12
5		X	X	X	X	X			X	X		X	X	X	10
6	X	X	X	X	X	X			X			X	X	X	10
7	X	X	X		X				X			X			6
8	X	X	X	X	X	X	X	X	X				X	X	11
9	X	X			X	X	X	X	X	X		X	X	X	11
10	X	X	X	X	X	X			X			X	X	X	10
11	X		X		X				X			X	X	X	7
12	X	X	X	X	X				X			X	X	X	9
13	X	X	X	X	X	X	X		X			X	X	X	11
14		X	X	X					X			X			5
15	X	X	X	X	X	X			X	X		X	X	X	11
16	X	X	X	X	X	X			X			X	X	X	10
17	X	X	X	X	X	X			X			X	X	X	10
18	X	X			X							X	X	X	6
19	X	X	X	X	X	X			X			X	X	X	10
20	X	X	X	X	X	X	X		X			X	X	X	11
21		X	X	X	X	X	X	X	X	X		X	X	X	12
22		X	X	X		X			X			X	X	X	8
23	X	X	X	X	X	X			X			X	X	X	10
24				X			X	X	X		X	X	X	X	8

Evaluation for Game Icons

Table 6. Game icon evaluation

	Simplicity	Contrast	Proportion	Stability	Not too stylized	Clarity	Precise information	Universal Understanding	Appropriate for Context	Semantic Correction	Syntactic Correction	Pragmatic Correction	Visual Interest	High Recall	Easy to learn and teach	Total Points: 15
1		X											X	X	X	4
2			X				X		X	X	X		X		X	7
3		X	X	X		X	X		X	X	X		X	X	X	11
4	X	X	X	X	X	X			X				X	X	X	9
5	X	X	X	X	X	X	X		X		X		X	X	X	12
6		X	X	X		X							X	X	X	7
7	X	X	X	X	X	X			X				X	X	X	10
8	X	X	X		X	X							X			6
9	X	X	X	X	X	X			X					X		8
10	X	X	X	X	X	X			X				X	X	X	10
11	X	X	X	X	X	X			X		X		X	X	X	11
12	X	X			X	X	X		X	X	X		X	X	X	11
13	X	X	X	X	X	X			X				X	X	X	10
14		X				X	X		X	X			X	X	X	8
15	X	X	X	X	X	X	X		X				X	X	X	11
16		X			X	X			X				X	X	X	7
17		X	X	X					X				X	X	X	7
18	X	X	X	X	X	X	X		X	X	X		X	X	X	13
19	X	X	X			X			X				X	X	X	8
20		X	X	X	X	X			X	X			X	X		9
21	X	X	X	X	X	X			X				X	X	X	10
22		X	X	X	X	X			X				X	X	X	9
23		X	X	X	X	X			X				X	X	X	9
24		X	X	X	X	X			X				X	X		8

Evaluation graph for selected icons

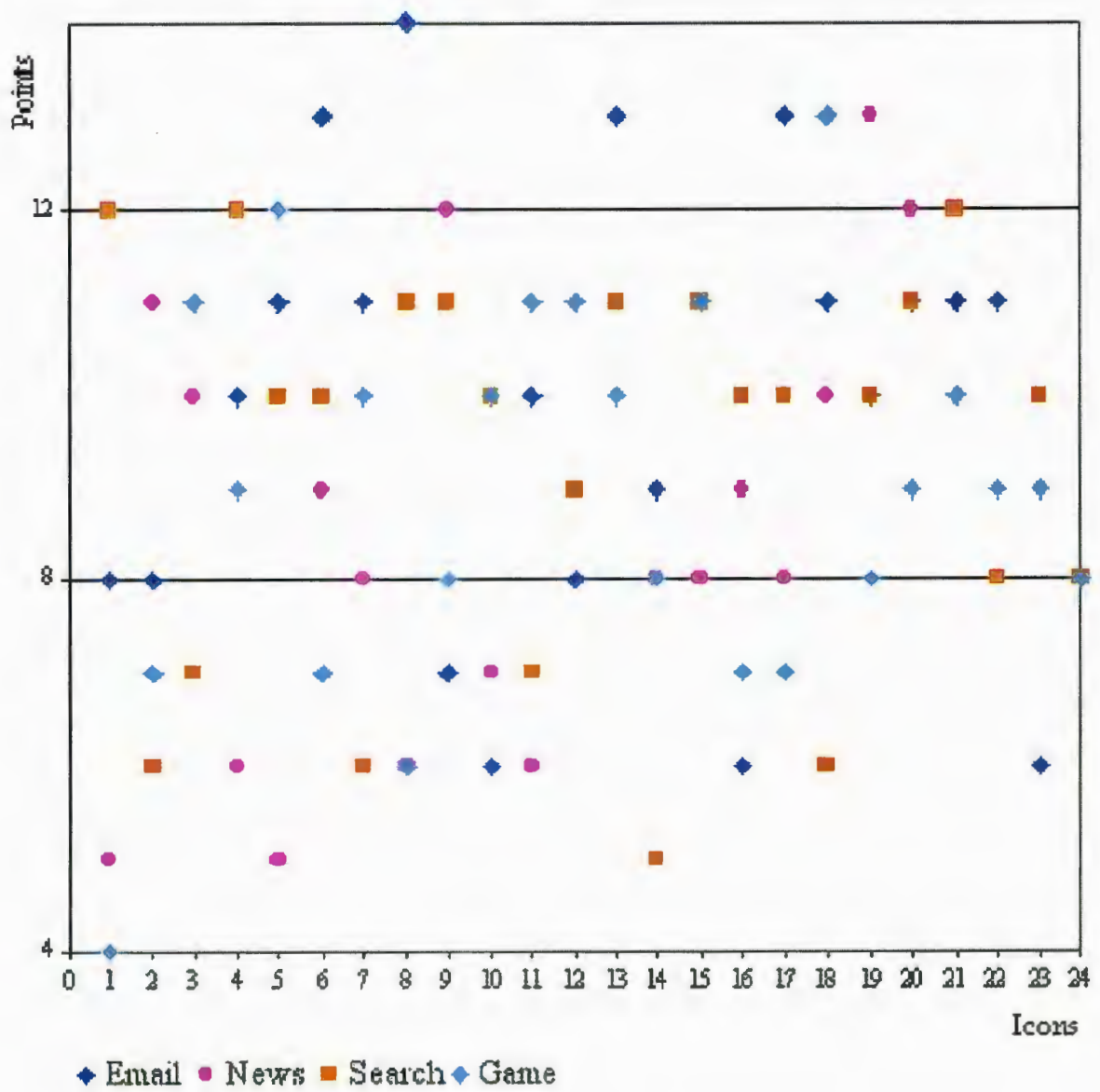


Figure 36. Evaluation graph for selected icons

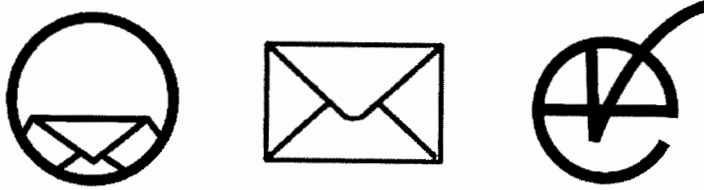


Figure 37. 3 Selected email icons



Figure 38. 3 Selected news icons



Figure 39. 3 Selected search icons



Figure 40. 3 Selected game icons

4. Icon Refinement Process

Effective WAP icons must be small because of the limited screen size of WAP devices. The refinement process tested final icons for the technical aspect of fitting easily within WAP screens. The three selected icons that took the highest points in each function were displayed into three icon sizes: 40x40, 20x20, and 15x15. In order to keep the icons recognizable and simplified, some pixels, lines, and shapes were reduced or manipulated as the size of the icons were decreased. For instance, to create a news icon, lines and shapes are simplified in order to keep it recognizable (Figure 41).

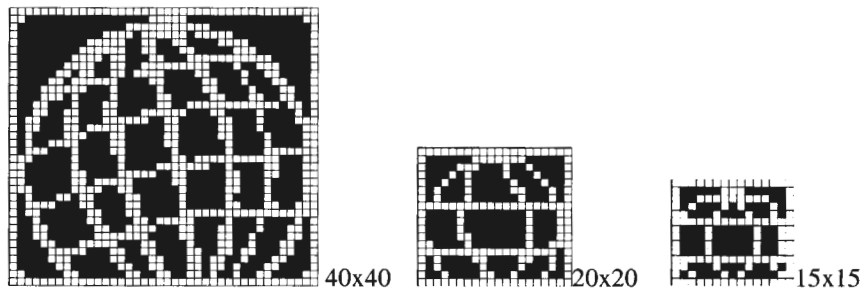


Figure 41. Image manipulation process



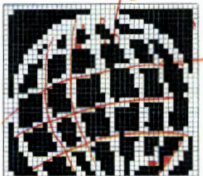
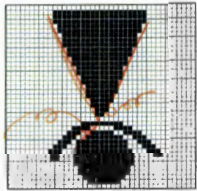
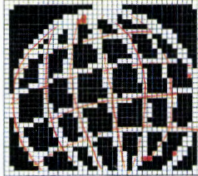
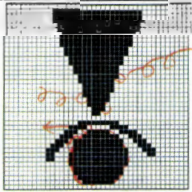

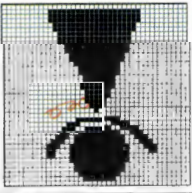
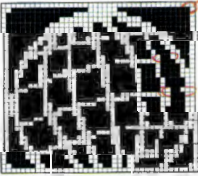
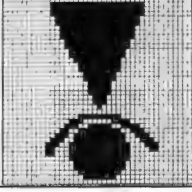
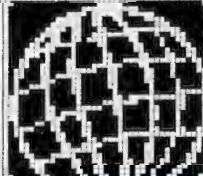
As figure 41 suggests, icons are bitmap images in which the design is created in a certain grid. In other words, WAP icons use black squares to create dots, lines, and shapes. In icon design, anti-alias is generally not an option within such a small grid because it requires extra pixels to create smoothness between icons and the screen. This becomes a severe restraint in icon design.

5. Final Icon Design Process

All refined icons are designed with pixels by pixels. In the first step, the original icons were scanned into digital formats. In the second step, they were resized to three actual

sizes with 72 dots per inch. Once they were scaled down to smaller sizes, grids were applied in order to measure the number of pixels and manipulate dots, lines, and shapes. For the refinement process, each step was printed on paper and renovated by hand. The manual processes below are two examples that show several refinement steps of the final news and search function (Table 7).

Table 7. Icon refinement steps

	Original Scanned Icon		Original Scanned Icon
	Refinement 1		Refinement 1
	Refinement 2		Refinement 2
	Refinement 3		Refinement 3
	Refinement 4		Final Icon Design
	Final Icon Design		

Throughout this computer and manual drafting process, final FUF icons were reproduced within pixels by pixels (Table 8, 9, 10, and 11). The variations of the icon sizes are based on use by finger, stylus pen, or mouse. By developing three various sizes, each icon on WAP screens can be used for typical input devices such as mouse, stylus, and finger.

6. Final Prototypical WAP Icons on a Screen

Icons must be instantly recognizable by WAP users on hard-to-see screens. The final step in WAP icon design process is to apply refined icons to the actual screen because the recognizability of icons differs from paper to screen. Icons on paper are designed using ink. On the other hand, icons on a screen are designed using pixels and lighting. Also, unlike computer monitors, most WAP device screens use gray scale in that they are often bright green or gray to conserve battery lifetime. In order to create various colors on WAP screens, LCD screens must have three sub-pixels with red, green, and blue that shorten the battery life. Therefore, by utilizing the refined WAP icons on a gray screen, this study tests the recognizability of WAP prototypical icons. In order to test the recognizability of the refined WAP icons, this research uses a Treo 180 made by Handspring ©. The Treo 180 is currently the newest PDA produced by Handspring © (Figure 42). This device is both a phone and a PDA and allows users to browse the Web and check messages or email.

Table 8. Three variations of final email icons













Original Email Icon	40x40	20x20	15x15
			
			
			

Table 9. Three variations of final news icons













Original News Icon	40x40	20x20	15x15
			
			
			

Table 10. Three variations of final search icons

























Original Search Icon	40x40	20x20	15x15
			
			
			

Table 11. Three variations of final game icons

Original Game Icon	40x40	20x20	15x15
			
			
			

The line drawing on the right side is the actual size of *Treo 180*. This WAP device is 4.3 x 2.7 x 0.7 inches (11 x 6.9 x 1.8 cm) and weighs 5.2 ounces (147 g). The *Treo 180* has a 160x160 pixel screen. This is a relatively bigger size than other brands.



Figure 42. Treo 180, Handspring ©



Figure 43. Email icons in the screen

The three email icons seem to be visible in the three different sizes (Figure 43). However, among the three refined email icons, the middle one, the envelope image maintains the original image well in the three sizes: 40x40 for finger, 20x20 for stylus pen, and 15x15 for mouse cursor.



Figure 44. News icons in the screen

The images of the three news icons are visible in the three different sizes (Figure 44). However, once they are refined to the 15x15 size, they seem to be invisible. The middle one, the newspaper image, maintains the original image well in all three sizes. The first one, the news icon with typography maintains the original image well until it gets smallest size.



Figure 45. Search icons in the screen

Overall, the three search icons are recognizable in the three different sizes (Figure 45). However, when the original images are displayed in 15x15, they are changed because of the decreased numbers of pixels. The circle with line in the last icon was invisible. So, I inversed the negative and positive space to maintain recognizability. Although the positive and negative space of the last icon was changed, I was able to keep the original information by keeping them proportioned.



Figure 46. Game icons in the screen

Overall, the three game icons are recognizable in the three different sizes (Figure 46). However, the first Ping-Pong icon loses its recognizability in terms of keeping context. The line drawing with 15x15 pixels fades away within the gray screen. The Pacman icon seems to be the strongest one because other icons are not electronic games and they also lose their original shape when displayed in 15x15 pixels. The chess icon for games is invisible when it scales down to the 15x15 size.



Figure 47. All FUF icons in the screen

Among the defined icons on the screen, the above icons appear to be the most recognizable (Figure 47). All of the above icons use a common method to represent their functions, the use of metaphor. Metaphor is based on the idea that use of visual equivalents of incoming ideas leads users to stimulate existing knowledge and then understand what the visual equivalents actually mean.

The envelope icon depicts the function for checking Email well because it is the most common symbol of electronic mail on the World Wide Web. Moreover, by using line style, it accommodates the limitations of WAP technology. Even at the smallest size, it maintains the recognizability. The use of an actual image for the News function is the most recognizable. This icon was developed through the use of Caricature style. Though sharing the idea of simple drawing, critical details of a newspaper are exaggerated to be more recognizable. The magnifying lens icon for the Search function is a well-known icon on the Internet. Because it stimulates users' existing knowledge within the image of a magnifying glass, it is the most recognizable icon for the search function. The Pacman icon seems to be the strongest Game icon because the other icons do not represent electronic games and lose their original shape in 15x15 pixels.

CHAPTER 4. SUMMARY AND CONCLUSION

A. Summary

Along with the development of technology, accessibility of information can be accomplished more easily and faster with Wireless Application Protocol (WAP) through mobile communication tools. Mobile communication not only demands lighter, smaller, and handier communication tools but more effective and easy graphic user interfaces (GUI) that allow users easy access to their information. To develop effective and easy GUI within WAP technology, this research was conducted not only to suggest prototypical icons for WAP screens but also to produce a framework for icon development involving the logical and creative design processes of a creative matrix.

In the literature review, the interconnected criteria of the study of WAP, characteristics of good icons, and the graphic representation of ideas were identified to develop an evaluation matrix for WAP icons. New alternatives for WAP icons for Frequently Used Functions (FUFs) were evaluated by using the criteria developed in the literature review.

The procedural development for WAP icons included the identification and analysis of WAP users' needs, and the investigation of images for WAP icons. The analysis of the FUFs of WAP users was refined to identify their characteristics and to create prototypes of icons that represent these functions. Also, various visual forms were investigated in order to visualize the FUFs on WAP devices. Based on these procedures, a morphologic matrix was structured in order to discover all possible relationships among WAP users' needs and the

images and functions of WAP icons. The matrix was used not only to establish a clear pattern of relationships but also to identify many possible solutions within the icon development processes.

By using this WAP icon development matrix, more than a thousand WAP icons were systemically executed to represent each of the WAP FUFs. They represented nine different styles: photography, simple drawing, caricature outline, silhouette, Swiss, typography, gesture, and line. Moreover, some icons represented a hybrid of these styles.

The thousands of developed icons were then self- evaluated for the final icon design process. In the final icon design process, three selected icons for each FUF were transferred to three actual sizes with 72 dots per inch. Once they were scaled down to smaller sizes, grids were applied in order to measure the number of pixels and manipulate dots, lines, and shapes. For the refinement process, each step was printed on paper and renovated by hand. The selected and refined icons were applied to a WAP device screen to test their recognizability.

This study resulted in a set of FUFs' prototypical icons for WAP. This study is an inquiry into the basic criteria for effective communication of WAP graphic user interface design. It is a study that evaluates graphic user interface designs based on the criteria of iconic communication in combination with both the application of current technology and an investigation of icon design for WAP devices. Furthermore, this study explores and demonstrates a case study to enhance the effectiveness of GUI for WAP screens. The recommendations of this study are limited to logical creative processes and experimental image investigations for WAP iconic communication. It is an analysis of its immediate and long term needs and suggests a set of criteria for improving the functionality of WAP tools

through the use of icons. Hence, this study suggests a framework for development of WAP icons – from the research on users' needs to the visualization of final icon designs on a WAP screen. The framework can be extended to other fields of icon design on electronic screens.

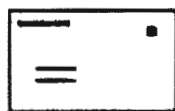
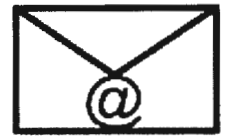
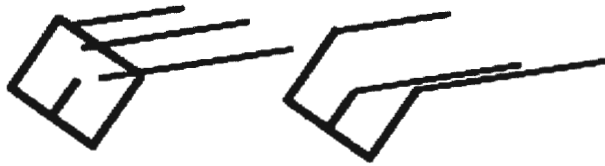
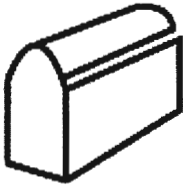
B. Conclusion

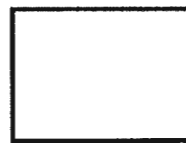
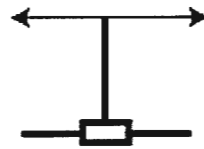
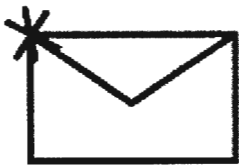
This study is only a preliminary step in investigating the criteria and experimental processes for effective iconic communication of WAP devices. While this study develops a set of icons with frequently used functions such as Email, News, Search, and Game, this systematic approach can be applied to the development of icons for other functions. Further research in the unification of the final WAP icons, color application, formal user tests, and human cognitive process are needed, along with the evolution of WAP technology to enhance the communication of WAP icons. Hence, it is important not only to create effective GUI but also to build reliable and fast services for WAP technology. The goal of WAP GUI design would be achieved in conjunction with further development of WAP services. This study should be understood as the first step of an exploratory study about WAP icon design in the field of graphic design.

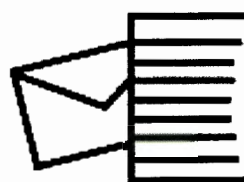
Finally, for WAP communication to be successful, interdisciplinary collaboration is necessary not only to make progress in the area of iconic communication but also to develop the communicability of WAP icon design into more advanced stages of effectiveness. Graphic designers, industrial designers, psychologists, computer engineers, and linguists

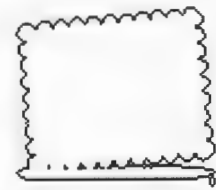
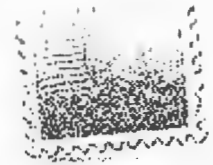
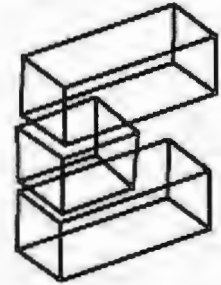
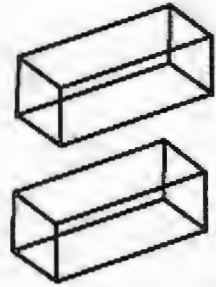
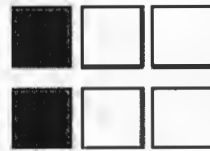
must work together to create effective WAP icons. Graphic designers are an integral part of this team because they work to enhance the quality of WAP devices for human beings.

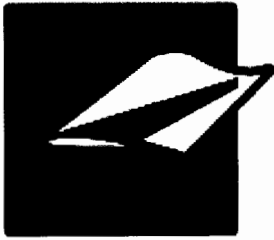
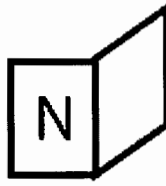
APPENDIX – IMAGE INVESTIGATION FOR WAP ICONS

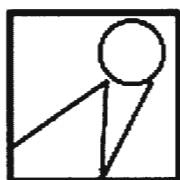
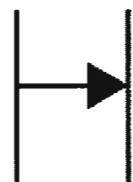
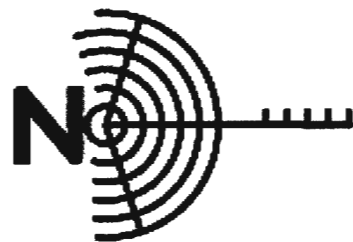
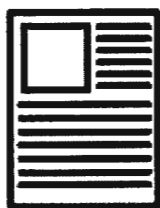


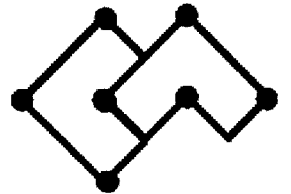
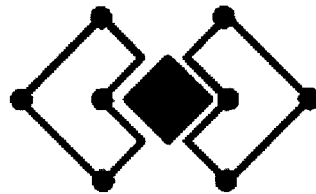
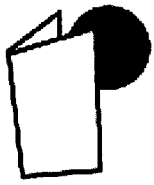


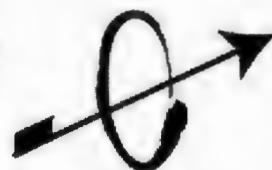
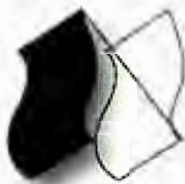


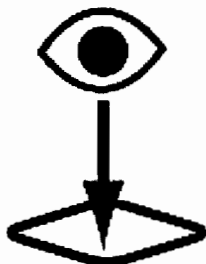
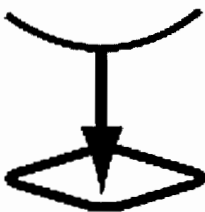


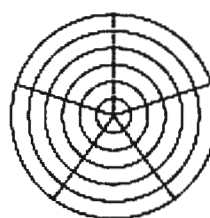
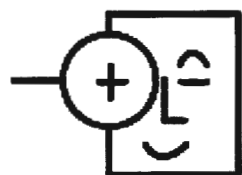
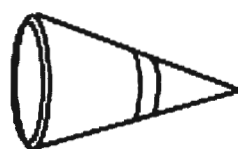


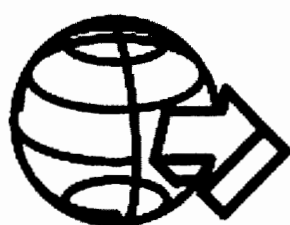
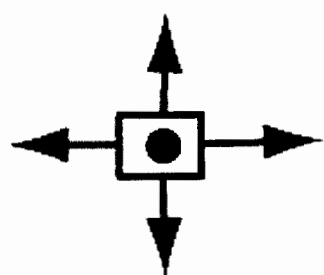


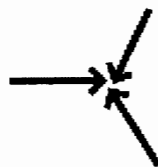
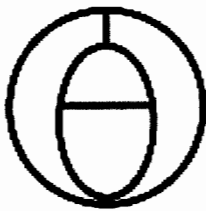
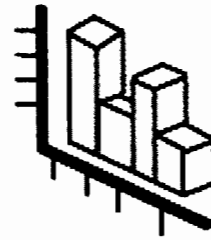
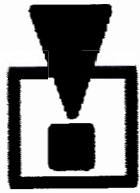


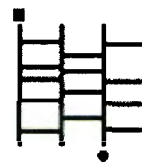
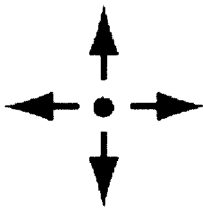
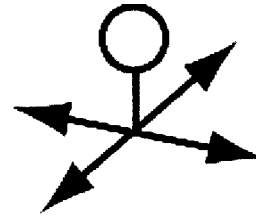
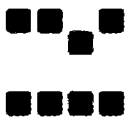
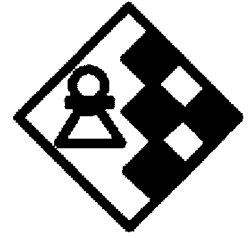


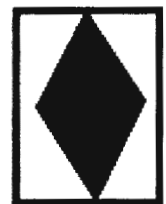
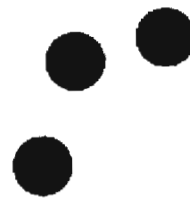
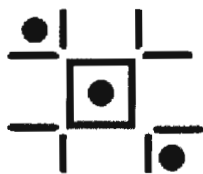
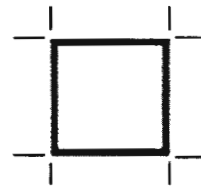
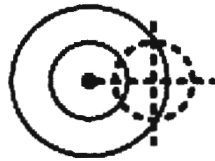
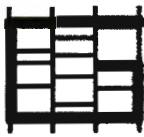


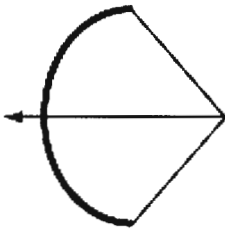


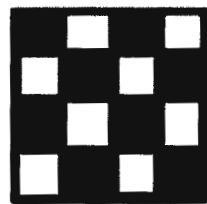
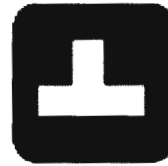












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