

# The Effect of Morphological Elements on the Icon Recognition in Smart Phones

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**Abstract.** This study aims to explore the effect of morphological elements on the icon recognition in smart phone. 42 icons were first selected and classified in a morphological chart based on its visual design elements. Then, icons were evaluated by a group of respondents with or without design background through e-mail. Main findings include: 1) Some morphological elements may affect the recognition rates of icons. Icons imitating real objects and using conventional symbols are better in recognition rate. In contrast, some particular symbols may be difficult to recognize. 2) Gaps may still exist between designers and users. The result of this study shows that the un-answered rate of the respondents without design background is significantly higher than the ones with design background. This may suggest that gaps may still exist between designers and users. Therefore, it is recommended that a designer should bear user in mind when designing icons in order to minimize these gaps.

**Keywords:** Smart phone, Icon, Recognition rate, Morphological elements.

## 1 Introduction

The functions of mobile phone in the early days were very basic, ranging from making or receiving phone calls to sending or receiving messages. Nowadays, a much more advanced Smart Phone can deal with almost everything in one's daily lives. A Smart Phone is a mobile phone that incorporates PDA functions in a small handset. Therefore, it is a challenge for engineers to keep so many functions in small space. As a result, the design of the man-machine interface becomes very important. Under the effort of R&D team, the function of many Smart Phones, in terms of both hardware and software, are getting similar. However, differences exist in their interface design, especially the way of interaction and graphic icon design. Icon design can be considered as the entrance to the interaction of man-machine interface. Whether a user can recognize its meaning or not becomes the first step to interact with a phone set.

In an anecdotal observation, however, the recognition rate of icon design in smart phones was not very high. According to Norman's mental models [1], ideally, the design model should be identical with the user's model when designing icons. It leads to a hypothesis that the difference of the recognition rate to an icon design between

users and designers should be minor. Moreover, in a preliminary study it was suspected that the morphological structure of an icon design might have effects on the recognition of an icon. It leads to this study to explore:

1. Whether there is any difference existing between the recognition rates on icon designs of smart phones between users with and without design background.
2. Whether there is any effect of the morphological elements in icon designs of smart phone on the recognition rate to users.

## 2 Literature Review

### 2.1 The Definition of Smart Phone

Smart phone was first coined by Motorola [2]. At the beginning, any mobile phone equipped with functions more than making a phone call was called “Smart phone”. Nowadays, this term becomes much more general. It is not used exclusively by Motorola anymore. The first smartphone was called Simon designed by IBM in 1992 and shown as a concept product that year at COMDEX, the communications industry trade show held in Las Vegas, Nevada. It was released to the public in 1993 and sold by BellSouth. Besides a mobile phone, it also contained a calendar, address book, world clock, calculator, note pad, e-mail, and games. It had no physical buttons to dial with. Instead customers used a touch-screen to select phone numbers with a finger or create facsimiles and memos with an optional stylus. Text was entered with a unique on-screen "predictive" keyboard. By today's standards, the Simon would be a fairly low-end mobile phone [3]. This study summarizes definitions for a smart phone as shown in Table 1.

**Table 1.** The summary of definitions for a smart phone

appearance	The size is small, short, light and thin. The appearance is not restricted to either mobile phone or PDA.
functions	It is used mainly in voice communication. Digital transmission is also included. It uses advanced mobile operation system. It is equipped with personal information management function. The information can be exchanged or synchronized with other information products.
Input methods	It is not restricted to keyboard or touch sensitive panel. Voice recognition is also possible.

### 2.2 The Classification of Graphic Icons

At present, graphic icons are widely applied to many areas. The form is not limited to a certain kind of style. Peirce classified signs into three categories, icon, index and symbol [4]. Every category relates differently to its referent:

**Icon.** Icon means to imitate the physical image of its referent. It is much more concrete. Icon features the characteristics of its subject.

**Index.** Index relates indirectly to the concept of its referent. For example, a trapezium icon emitting sound weaves means a “loudspeaker”.

**Symbol.** Symbol neither looks alike nor relates to its referent. It is customary used or agreed by most people for a long time.

Due to the advance of computer technology, graphic icons are developed from two-dimensional image into three-dimensional image. Technologies, such as voice recognition, multimedia and animation, are used in Smart Phones. The choice of interaction between man and machine becomes much more abundant. However, the acceptance of users regarding the interface design depends largely on the evaluation of the icon designs.

## 2.3 Studies of the Evaluation of Icons

The paired-comparison method [5] is most often used in the evaluation of icon design. Respondents are asked to pick up the most fitted name from a list to match the icon. The recognition rate can be determined through statistical analysis. The icon with bad recognition rate is subjected to redesign by the designer according to the opinion from respondents. However, objective method for the analysis of icon design is lacked. Huang [6] uses statistic to analyze the relationship between icon's image vocabulary and its morphological elements for mobile phone. Morphological analysis is a systematic method that breaks down an icon into elements. The elements are classified into items and categories.

The morphological analysis is used in the study to explore the relationship between recognition and morphological elements. The characteristics of an icon with both high and low recognition rates can then be identified.

Chen [7] and Lee [8] have done researches on the evaluation of icon design for mobile electronic products. However, the respondents were divided into groups according to their needs and habits. The respondents are categorized into people with or without design background. The purpose is to identify the difference between two groups on the recognition of icon. The result can be applied to icon design to avoid the gap between designers and users.

## 2.4 Morphological Analysis

Morphological analysis was originally used in engineering design to develop solutions for problems [9]. Solutions are classified into main categories and sub-categories first. Various solutions are then proposed through the combination of sub-categories. In this way, solutions can be explored systematically. This method was adopted for the study.

# 3 Method

## 3.1 The Research Process

The research process is divided into following five steps:

**The Selection of Sample for the Evaluation.** 6 smart phones from the top-three operation system, i.e. Symbian, Palm and Windows Mobile Smartphone, were selected

for the study. Six phones were selected, including Nokia 9500, Nokia 7710, Nokia 7650, Siemens SX1, Treo 650 and Dopod 575.

**The Collection of Icons from Smart Phones.** The graphic icons of top-three best sellers of smart phones were chosen for study. Icons of main functions were selected. As a result, 167 icons were collected.

**The Preliminary Analysis of Icons.** Icons were categorized into items and categories according to the morphological analysis (as shown in Table 2) for mobile phones proposed by Hwang [3].

**The Selection of Icons for Evaluation.** 167 icons were screened down into 42 icons. Two steps are employed as below:

*Questionnaires.* 20 respondents were asked to rank 167 icons in 5-point Likert scales, ranging from 1(used hardly) to 5 (used very often). The result was evaluated by the focus group in the following step.

*Focus group.* 5 experts in Industrial Design or Visual Communication were invited to form a focus group. They were asked to screen the icons according to the following rules:

- Icons with lower points that have the same function were screen out.
- Icons with similar morphological elements but in poor design quality were screened out.













**The Evaluation of Icons.** The confusing matrix method [10] was used for the evaluation. First, 42 icons were listed randomly on the top of the computer screen. The meanings were listed randomly on the pull-down menu for the respondent to choose from. A proper meaning was put into the box by the respondent. The result was constructed into a confusing matrix for a further analysis. Icons that matched the intended meaning would have lower confusing rate. In contrast, if icons do not match the intended meaning the confusing rate would be high. Recognition rate was then calculated with equation (1). 66.7% recognition rate was recommended by ISO [11]. Through the analysis of confusion matrix, the recognition rate and reasons for misinterpretation can be determined. Besides, independent sampling t test was conducted to determine whether the design background of the respondent affected the recognition rate.

$$(\text{Number of correct choices} / \text{Number of respondents}) \times 100\% = \text{Recognition rate} . \quad (1)$$

### 3.2 Participants

Due to the availability and willingness of participants, convenient sampling was adopted for the study. 80 young students and office workers were approached by e-mail as participants. Among them, 40 participants have design background whereas the other 40 do not have design background. The questionnaires were distributed through e-mail.

**Table 2.** An example of morphological chart

Categories	Sub-categories		
A. Types			
	A1. icon	A2. index	A3. symbol
B. Styles			
	B1.orthographic image	B2.diagonal image	B3.3-D image
C. Auxiliary elements			
	C1. yes	C2. no	
D. Backgrounds			
	D1. yes	D2. no	
E. Ways of presentations			
	E1. whole image	E2. partial image	

## 4 Results and Discussions

### 4.1 Basic Data

80 questionnaires were distributed through e-mail services. Consequently, 68 responds were received. 9 of them were rejected for missing or repeating values. Therefore, 59 effective responds were collected. The responding rate was 73.8%.

Five (8.5%) respondents are under 19 years old. 19 (32.2%) respondents are 20-29 years old. 23 (39.0%) respondents are 30-39 years old. 9 (15.3%) respondents are 40-49 years old. 3 (5.1%) respondents are over 50 years old.

Regarding background, 31 (52.5%) respondents have design background whereas 28 (47.5%) do not have design background.

### 4.2 Icons Recognition Rate Analysis

28 icons meet ISO standard with the recognition rate over 66.7% while the rest of 14 icons, i.e. one third of tested icons, fail to meet the standard. (See Table 3) This result conforms to the anecdotal observation mentioned in the introduction.

**Table 3.** The recognition rates of icons











































. No.	A1	A2	A3	A4	
Address book					
Recognition rate (%)	81.4	78.0	52.5*	47.5*	
No.	B1	B2	B3	B4	B5
message					

Table 3. (Continued)

Recognition rate (%)	98.3	81.4	87.8	69.5	55.9*
No.	C1	C2	C3	C4	
Phone call record					
Recognition rate (%)	76.3	23.7*	22.0*	57.6*	
No.	D1	D2	D3	D4	
setting					
Recognition rate (%)	94.9	94.9	93.2	18.6*	
No.	E1	E2	E3	E4	
camera					
Recognition rate (%)	100.0	100.0	98.3	100.0	
No.	F1	F2	F3	F4	
Synchronize data					
Recognition rate (%)	62.7*	57.6*	52.5*	72.9	
No.	G1	G2	G3	G4	
calendar					
Recognition rate (%)	98.3	62.7*	93.2	86.4	
No.	H1	H2	H3	H4	H5
Media player					
Recognition rate (%)	100.0	98.3	100.0	59.3*	89.8
No.	I1	I2	I3	I4	
Check list					
Recognition rate (%)	72.9	66.1*	72.9	49.2*	
No.	J1	J2	J3	J4	
Note book					
Recognition rate (%)	94.9	69.5	67.8	69.5	

\* Recognition rate < 66.7%

4.3 Analysis of the Recognition Rate Against Design Background

Table 4 shows the recognition rate, error rate and un-answered rate for the respondents with design background are 77.8%, 17.9% and 4.3% respectively, whereas, the respondents without design background are 70.7%, 18.9% and 9.3% respectively. It is observed that the recognition rate for the respondents with design background is higher than the respondents without design background. However, both the errors rate and un-answered rate for the respondents without design background are higher than the respondents with design background. Furthermore, the data in Table 3 were tested in independent sampling t test. The result showed that the differences between two groups in both recognition rate ( $p > 0.05$ ) and errors rate ( $p > 0.05$ ) are insignificant. However, the unanswred rate of the respondents without design background is significantly higher than the ones with design background ( $p < 0.05$ ).

It can be inferred from the result above that the respondents with design background may be better in recognizing the meaning of the icons than the ones without design background because they are well-trained in visual design. On the

contrary, the respondents without design background may have difficulties in recognizing the icons for the lack of design training. Therefore, it is recommended that a designer should bear users in mind when designing icons. Characteristics of different users should be considered. To use straightforward designs as much as possible may be helpful. Besides, a user evaluation could be very important for improving the design quality. Moreover, recognition errors may happen if the designer designs icons based solely on his own experience.

**Table 4.** The average of recognition rate, error rate and un-answered rate

respondents	Number	Recognition rate s. d.	Error rate s. d.	Un-answered rate s. d.
With design background	31	77.8 (22.0)	17.9 (18.8)	4.3 (6.9)
Without design background	28	70.7 (23.7)	19.9 (18.1)	9.3 (10.1)
total	59	74.2 (23.0)	18.9 (18.4)	6.8 (9.0)

#### 4.4 The Effect of Morphological Elements

The relationship between the morphological elements of icons and their recognition rate is discussed in this section to determine the morphological effects on icon recognition.

**Types.** The types of morphological elements may affect the recognition of icons.

*Icons are better in expressing meaning.* An icon depicting a real object is much better in expressing its meaning and will have a higher recognition rate. For example, icons with the highest recognition rate in the study, E1, E2, E3 and E4 use an image of camera to represent the function of taking a picture. Respondents can easily recognize its function is related to a camera. Other examples, B1, G1 and J1 use the image of envelop, calendar and notebook respectively to represent their functions. They bear also very high recognition rate.

*Conventional Symbols Have Higher Recognition Rate.* A conventional symbol may have no direct connection to its meaning. However, once people get use to it, however, its meaning can also be accepted. For example, H1, H2 and H3 use a music note to represent playing music. H5 uses a triangle shape to represent “playing” just like the playing symbol in our disc player. D1, D2 and D3 belong to index category. They use a wrench to symbolize “setting-up” something. They all have higher recognition rate than their counterpart.

*Particular Symbols May Be Difficult to Recognize.* Symbols for particular usages may be difficult to recognize. For example, H4 means “Real Player”, media player software in PC. However, not every one was familiar with it. Its recognition rate is only 59.3%.

**Auxiliary Elements.** Auxiliary elements may be helpful in recognizing the icon. For example, A1 has a telephone handset on a book which means “address book”. The meaning seems to be obvious to most respondents. A2 is an image of a partial note book with a telephone icon on it. The meaning is also obvious. The icon of telephone may be helpful in recognizing it. In addition, G1 and G3 use “number” to address that they are calendars.

However, the auxiliary elements may also cause difficulty in recognize meaning if it is too small. For example, A4 is an index file with a person’s photograph on it. However, the photo is so small that respondents might fail to see it. That may account for the low recognition rate. The same situation may also apply to B4 and I4.

**Ways of Presentations.** To use of partial image in icon design may cause difficulties in icon recognition. For example, G2, I2 and J2 use partial image of something to signify calendar, check list and notebook respectively. They may be stylish; however, details may be missing so that the meaning is lost. In addition, the effect of icons with background and icons in different style may not be obvious since some of those icons recognition rate are lower than ISO standard, whereas, some of them are quite high.

## 4.5 The Analysis of Confusing Matrix

**Icons with Similar Design that Represent Different Meanings.** Icon C2 and C3 mean “phone call records”. However, 55.9% and 59.3% respondents respectively recognize them mistakenly as “synchronize data”. On the contrary, 23.7% respondents misinterpret icon F2 as “phone call records” instead of “synchronize data”. This may be because their designs are too similar for to distinguish them from each other. They all use two arrows to represent data flows which may cause the confusion. Same thing happens with icon F3 that 27.1% respondents mistakenly recognize it similar to icon H5, “media player”.

**Icons with Different Design but Similar Wording.** Icon C4, “phone call records”, is mistakenly recognized as “address book” by 37.3% respondents. This may be because the wordings in Chinese for “phone call records” (tong-shuin-ji-lu) and “address book” (tong-shuin-lu) are very similar to each other.

**Misleading Icon Design.** Icon D4 means “setting”, however, its recognition rate is only 18.6%, the lowest among 42 icons. The design is a card with a list on it which seems misleading to recognize its real meaning.

**Icons with Wrong Hints.** Certain icons might include inadequate hints in their design which may cause confusion. For example, 35.6% respondents recognize icon B5 as “media player” instead of “message”. A music note and a photo are put in front of an envelope. Music note may hint that this relates to “media”. A pencil is placed on a ring book in icon G2. 17.0% respondents recognized it as “note book” in stead of “calendar”. The pencil may hint that this is a “note book”.

## 5 Conclusion

This study explored the relationship between the recognition rate and morphological elements based on the graphic icon design of three top-seller smart phones in Taiwan.



The icons were first categorized according to their morphological elements. The cognition rate was then calculated. Finally, the confusion matrix of icons and meanings were constructed to determine the cause of confusion. The study concludes:

**The Effects of Morphological Elements on the Icon Recognition.** It includes:

- Icons are better in expressing meaning.
- Conventional symbols have higher recognition rate.
- Particular symbols may be difficult to recognize.

**Gaps May Exist between Designers and Users.** The result of this study shows that the un-answered rate of the respondents without design background is significantly higher than the ones with design background. This suggests that gaps may exist between designers and users. Therefore, it is recommended that a designer designing icons should bear user in mind in order to minimize these gaps.

**Some Recommendations for Icon Design**

- “Icons” imitating real objects may be helpful in increasing the recognition rate.
- Conventional symbols have higher recognition rate.
- Proper use of auxiliary elements in icons may be helpful in increasing the recognition rate.
- A whole image may be better than a partial image in terms of recognition.

**Causes for Icon Confusion.** Causes for icon confusion determined through confusion matrix analysis are list below:

- Similar design
- Similar wording
- Not relevant to the meaning
- Wrong hints

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