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Graphical symbols

The effects of proximate context and educational background on recognition performance

Keywords: proximate context, graphical symbol, accuracy ratio, response time

This study evaluated the accuracy ratio and response time in recognizing graphical symbols, based on four classifications of proximate contexts: "direction + icon", "human + icon", "sign + icon", and "icon + icon". Participants were divided into a "design group" and a "general group". The performances of "direction + icon" and "human + icon" were better than the other classifications. The design group had a better accuracy ratio than did the general group. Additionally, three causes of errors were found: "failure to recognize an icon", "inability to make a connection among the icons", and "forming a concept other than the intended message".

Introduction

Background information

Graphical symbols convey information and are easily learned (Cairney & Sless, 1982, pp.91–97). Early researchers attempted the development of a universal pictogram system, such as ISOTYPE by Otto Neurath, to communicate information in a simple, non-verbal way (Kinross, 1981, pp.122–130). Though this goal has yet to be fulfilled, their efforts have laid an important foundation for visual communication design and are often reflected in our daily surroundings. For instance, the AIGA system, a set of passenger/pedestrian graphical symbols created by the US Department of Transportation and the American Institute of Graphic Arts, has been widely used in public spaces internationally since 1974. As an example of a modern pictogram system, it is frequently used as a source template for research into cognitive behaviors and performance evaluation (Zender, 2006, pp.177–206; Hsu & Lin, 2008, pp.87–105). Additionally, other pictogram systems have been developed as specific learning systems, such as the icon-based communication tools of Pictogram Ideogram Communication (PIC) or Picture Communication Symbols (PCS) for those with linguistic disabilities, which provide alternate communication options for visualization (Glennen & DeCoste, 1997, pp.283–333).

In visual communication studies, there are two approaches to exploring the recognition of graphical symbols. The first is abstraction, which deals with how well the intended message is portrayed by a graphical symbol made up of a single symbol object. The researcher's focus is to preserve the information represented by the object for identification and interpretation. In this tradition, Wang and Hsu (2006, pp.54-73) explored a series of techniques and theories of image abstraction, providing reference points for design methods and quality. After the design quality for the symbol objects within a

pictogram system is determined to be uniformly high, the researcher's focus progressively turns to the second approach: the information framework built upon multiple symbol objects, or the context of graphical symbols.

Context, broadly defined, is the sophisticated interaction between the graphical symbol and its surroundings in the recognition process. For example, Figure 1a, which depicts an airplane, might hold a different meaning in an airport than in a museum. This is a typical example of influence by environmental context. As a graphical symbol consists of multiple symbol objects, the interaction among those objects is another type of context. Horton (1994) declared that people tend to integrate the whole meaning of a graphical symbol by separating it into simple symbol objects. For example, people usually interpret Figure 1b, "drinking fountain", by separating it into three symbol objects: human, water spout, and fountain. Thus, Wang (1995, p.460) stated that the recognition performance of a graphical symbol would improve as its combination – the way the symbol objects were combined – better fitted people's logical reasoning. Zender (2006, pp.177–206) also indicated that an important variable in graphical symbol recognition within a system was the combination of symbol objects. Graphical symbols that were comprised of the same combination of symbols, such as Figure 1c, "barber shop", and 1d, "beauty salon", influenced people to use repetitive logic reasoning, a phenomenon he termed "proximate context".

Hsu and Lin (2009, pp.187–196) conducted a card sorting exercise which classified four type of proximate context: "direction + icon", "sign + icon", "human + icon", and "icon + icon". Each classification has its unique characteristics.

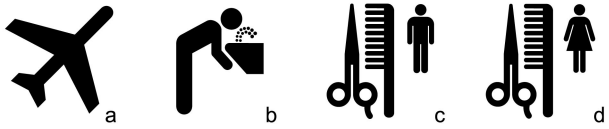

Figure 1. Examples of graphical symbols influenced by context.

1. Direction + icon
   Graphical symbols in this classification usually contained a direction symbol and one or more icon symbols. An arrow was used to indicate direction, and a simple graphic physically represented something for the icon. People interpreted the message by considering the icons as a subject, and associating that subject with the direction suggestion of the arrow. For instance, the meaning of Figure 2a, "stairs down", came from associating the icon of the stair with the direction message of the arrow.

2. Sign + icon
   Graphical symbols in this classification usually contained a sign symbol – an arbitrary graphic that has acquired a conventional significance – and one or more icons. People made sense of the message by correctly interpreting the common concept represented by the icons, and then associating it with the conventional significance of the sign. For instance, the meaning of Figure 2b, "lost and found", came from associating things commonly lost, the umbrella and gloves, with the idea of uncertainty, the conventional significance of a question mark.

3. Human + icon
   Graphical symbols in this classification usually contained a human symbol and one or more icons. It should be noted that the human symbol was in proportion with the other icon, in line with experience. People understood the message by correctly interpreting the interaction between the human symbol and the icons. For instance, the meaning of Figure 2c, "litter disposal", came from interpreting the interaction between the human symbol in the act of dropping and the icons for litter and trash can.

4. Icon + icon
   Graphical symbols in this classification contained multiple icons, excluding the human symbol. People understood the message by correctly interpreting the common concept drawn from the icons. For instance, the meaning of Figure 2d, "restaurant", came from the connection with tableware, the common concept of knives and forks.

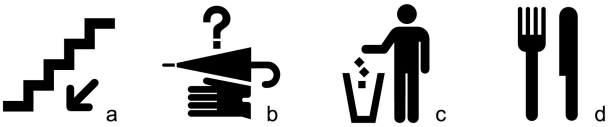

Figure 2. Examples of proximate contexts.

These four types of proximate context were accepted by both people from a design background and those from a general background, providing stabilizing support for the classifications (Hsu & Lin, 2009). This study used the classification system as a foundation for exploring further the effects of proximate context on design thinking in an information framework built upon multiple symbol objects.

Research questions

Once the proximate context had been classified, the next step was its performance evaluation.

Performance evaluation of graphical symbols has attracted considerable research in the visual communication field, and has proved useful for practical applications. One example of this is that the publication for public information symbols (ISOTC145/SCI) from the International Organization for Standardization, which addresses the need for analysis, development, and evaluation of graphical symbols, suggests a 67 percent accuracy ratio as reference for public usage (Zwaga & Easterby, 1984, pp.277–297). In graphic design studies, accuracy ratio and response time are common variables for recognition performance. For instance, Biederman (1998, pp.38–64) used accuracy ratio as a dependable variable in his recognition study, and Helbing et al. (1993) used response time as a variable to evaluate recognition. Therefore, this study used "accuracy ratio" and "response time" as the evaluation variables for the recognition performance of different proximate contexts.

Another important issue in visual communication studies is the comparison between design experts and the general public. Study participants are usually selected from people from both design and general backgrounds, respectively (Su, 2001; Lo & Lin, 2007, pp.1–20). It helps to clarify cognition and behaviors, and also provides a reference point for realizing the commonality and differences between designers and non-designers, avoiding blind spots in thinking. Therefore, this study built on the idea that recognition performance is influenced by proximate context (Zender, 2006, pp.177–206), and adopted the AIGA system as the stimuli source in order to clarify two questions regarding the context of graphical symbols:

1. Evaluating recognition performance from the two aspects of the proximate context and educational background.
2. Clarifying the causes of errors in proximate context recognition so that designers can communicate better with users.

Method

To evaluate the recognition performance of graphical symbols, two-way analyses of variance (ANOVAs) were conducted, taking "proximate context" and "educational background" as independent variables. The dependent variables were "accuracy ratio" and "response time". The framework of the experiment is shown in Figure 3.

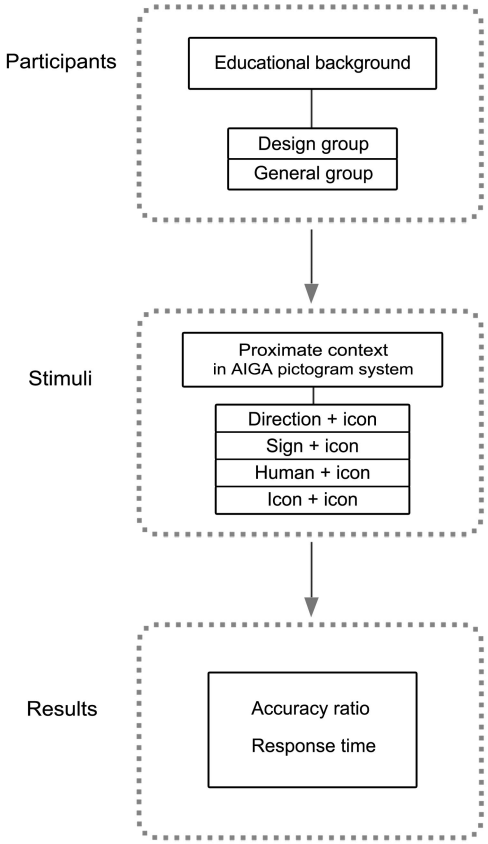

Figure 3. The framework of the experiment.

Variables

The definitions of the variables are as follows.

1. Independent variables:
   a. "Proximate context" refers to the combination of symbol objects within a graphical symbol. It allows people to follow and clarify the meaning of repetitions within a system. The stimuli of the four types – "direction + icon", "sign + icon", "human + icon", and "icon + icon" – were adopted from Hsu, Lin and Hou's (2009, pp. 187–196) classification study of proximate context, which used card sorting to identify typical samples based on the clustering priority (Table 1). It should be noted that the human symbol in "barber shop" and "beauty salon" was not in proportion to the other icons of scissors and comb. In these two stimuli, the human symbol was regarded as a sign symbol of "gender" rather than as an icon of "person". Thus, both were classified into "sign + icon", rather than "human + icon".
   b. "Educational background" refers to the participants' chosen major in college. The participants were divided into a "design group" and a "general group". The two groups were made up of 30 seniors in design-related courses and 30 seniors in non-design related courses, respectively, from Chung Yuan Christian University. All were 22 years old, and both groups were gender balanced.
2. Dependent variables:
   a. "Accuracy ratio" refers to the ratio of accurate recognition. The participants' answers were reviewed by three professionals, each of whom had more than six years' experience in graphic design. The reviewers assigned each answer to one of five options: "unanswered", "inaccurate", "partially accurate", "near accurate", or "accurate". An answer was considered accurate if it obtained an "accurate" or "near accurate" score from at least two professionals. The number of accurate answers divided by the total number of answered questions generated the accuracy ratio.
   b. "Response time" refers to the time taken by a participant in a recognition task. Each stimulus and its associated questions were on two separate pages in the questionnaire. The amount of time spent viewing a stimulus page was measured as the response time.

Table 1. The stimuli of four types of proximate context.

Proximate Context	Stimuli				
Direction + icon	 Stairs down	 Stairs up	 Elevator	 Escalator down	 Escalator up
Sign + icon	 Lost and found	 Barber shop	 Beauty salon	 Currency exchange	 Hotel information
Human + icon	 Litter disposal	 Escalator	 Drinking fountain	 Customs	 Immigration
Icon + icon	 Ground transportation	 Car rental	 Shops	 Baggage lockers	 Restaurant

Apparatus

The questionnaire was created using Adobe Authorware to display the questions and collect data for response times. Twenty questions, each divided into two pages, were arranged in random order. The former displayed a stimulus with an on-screen size of 10x10 cm^2 and the latter contained an open-ended question section to ascertain the meaning of the graphic symbol, and the reasons for the recognition results.

An ACER Notebook (Pentium M Processor 740, 1024MB RAM, 17-inch screen) was used by participants to fill out the questionnaire.

An audio recorder was used during participants interviews about the recognition results.

Procedure

Pretests indicated each participant would require about 30 minutes, making it difficult to test all participants in a single day. Thus, the test was preceded by appointment, resulting in a two-step procedure.

1. Before the test, the researcher gave out the instructions and explained how to fill in the questionnaire. When there were no further questions, the test was begun without time limitation.
2. Upon completion of the test, the researcher registered response time data measured by Adobe Authorware. Additionally, an interview was conducted and recorded if the participant's reasons for their recognition results were ambiguous.

Analysis

Sixty valid questionnaires were obtained, and two-way ANOVAs were conducted to compare the difference in accuracy ratio and response time among each level of the independent variables. The data regarding the meaning and reasons for recognition were transcribed in an Excel file as a reference for error analysis.

Results

The mean and standard deviations of the accuracy ratio and response time, for each classification of the independent variables, were compiled in Table 2. A higher accuracy ratio represented greater effectiveness, while a lower response time pointed to better efficiency. Overall, the participants were best able to recognize "direction + icon", followed by "human + icon", and lastly "icon + icon" and "sign + icon". Additionally, the design group performed better than the general group. The significant difference between each classification of the dependent variables was determined by a two-way ANOVA. Results of the analysis of the accuracy ratio and response time were as follows.

Accuracy ratio

The two-way ANOVA analysis showed that the interaction between proximate context and educational background was not significant ($F_{(3, 174)} = 2.244$, $p = .085$) in terms of the accuracy ratio. Therefore, the difference should be measured by the main effect of the independent variables and the performances shown in Figure 4. The results indicated that educational background did cause a significant difference ($F_{(1, 58)} = 22.509$, $p = .000$). It signified that the design group (83.8%) performed better than the general group (69.0%) in the accuracy ratio of recognition. A significant difference ($F_{(3, 174)} = 56.330$, $p = .000$) was also registered for the proximate context. To confirm the accuracy ratio differences among the four classifications of proximate context in detail, a Least Significant Difference (LSD) post-comparison was conducted. From the analysis result, it indicated that "direction + icon" (93.7%) was superior, followed by "human + icon" (83.7%). Lastly, "sign + icon" (65.7%) and "icon + icon" (62.7%) showed the worst accuracy ratio with no significant difference ($MD = .030$, $p = .232$) between the two proximate contexts.

Table 2. Summary of mean and standard deviation for accuracy ratio and response time.

		Accuracy ratio		Response time	
Proximate context	Educational background	M	SD	M	SD
Direction + icon	Design group	.9800	.06103	1.2105	.63599
	General group	.8933	.25587	2.0304	1.45091
Sign + icon	Design group	.7333	.16884	3.6596	2.78075
	General group	.5800	.19896	4.8352	4.43994
Human + icon	Design group	.9000	.14622	1.8589	1.90116
	General group	.7733	.17207	2.4353	1.46732
Icon + icon	Design group	.7400	.18308	2.5759	1.59532
	General group	.5133	.18705	3.4035	2.38163

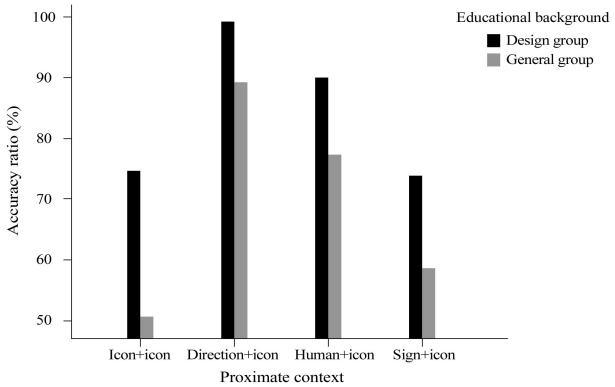

Figure 4. Accuracy ratio achieved by design and general groups for stimuli from four classifications of proximate contexts.

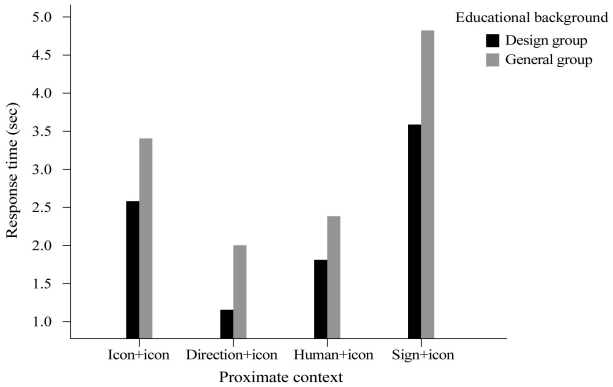

Figure 5. Response times achieved by design and general groups for stimuli from four classifications of proximate contexts.

Response time

In terms of response time, the two-way ANOVA revealed that the interaction between proximate context and educational background did not reach a significant state ($F_{(3, 174)} = .366$, $p = .778$). The performances are shown in Figure 5. Consequently, the main effects of the two independent variables indicated that the difference was insignificant ($F_{(1, 58)} = 3.064$, $p = .085$) between the design group (2.324 sec.) and the general group (3.176 sec.), while the proximate context caused a significant difference ($F_{(3, 174)} = 30.402$, $p = .000$).

The LSD post-comparison indicated that the difference reached a significant status between each classification of the proximate context. The response time of "direction + icon" (1.620 sec.) was the shortest, followed by "human + icon" (2.147 sec.), "icon + icon" (2.990 sec.), and lastly, "sign + icon" (4.242 sec.).

Discussion and conclusions

From the above results, neither accuracy ratio nor response time had a significant interaction with proximate context and educational background. It signified the absence of effect that one independent variable had on the other. Consequently, the performances should be discussed separately.

As regards proximate context, "direction + icon" was the best type in both accuracy ratio and response time, followed by "human + icon". "Icon + icon" performed better than "sign + icon" in terms of response time, but the difference in accuracy ratio was insignificant. It was determined that proximate context was an effective variable for recognition, as suggested by Zender (2006, pp.177–206). Overall, "direction + icon" and "human + icon" performed better than "icon + icon" and "sign + icon". According to the participant interviews, the interpretation of direction symbols was consistent in "direction + icon". Similarly, in "human + icon", the human object was considered the center in interpreting

the relationship among symbol objects. Thus, the benefit of recognition commonality reduced the interpretational uncertainty of graphical symbols, providing an explanation for the participants' excellent performances.

With regard to educational background, the difference in response time was insignificant between the design group and the general group; however, people with a design background performed better than those with a general background in terms of accuracy. This result agreed with the viewpoint that design training is an effective method for enhancing recognition ability (Su, 2001). It also indicated that improving effectiveness was a key point in reducing any performance differences between people from different educational backgrounds. Hence, in order to enhance communication, this study identified causes of errors for the graphical symbols with poor accuracy ratios to find recognition commonality.

Analysis of erroneous recognitions

Stimuli failing to reach the 67% accuracy ratio suggested for graphical symbols for public usage (Zwaga & Easterby, 1984, pp.277–297), are shown in Figure 6. The causes for errors are classified using the reasons given in the participant interviews.

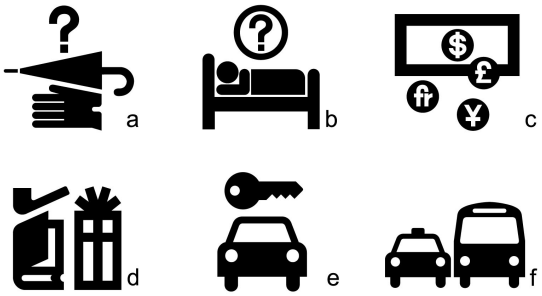

Figure 6. Graphical symbols below the 67% accuracy ratio.

1. Failure to recognize an icon.
   (1) Sign + icon: In Figure 6a, "lost and found", the glove icon was incorrectly considered to be a hand by 33.3% of participants. In Figure 6b, "hotel information", the sign for information was mistaken as a question mark by 30% of participants. Additionally, Figure 6c, "currency exchange", which was comprised of four currency signs, had a failure rate of 31.7% due to the unfamiliarity of participants with the currency signs.
2. Inability to make a connection among the icons, even though they were successfully recognized.
   (1) Sign + icon: Instead of inferring the common concept "lost items" from the umbrella and the glove icons in Figure 6a, "lost & found", 28.3% of participants merely stated the names of the icons. Interviews revealed that the relatively low use of gloves in Taiwan resulted in problems associating the icon with the concept of a lost item. A similar error also occurred for Figure 6b, "hotel information".
   (2) Icon + icon: Figure 6d, "shops", registered a 48.3% error response because participants failed to infer the common concept "gifts" from the icons of a smoking pipe, an open book, and a gift. Consequently, they could only write the names of the icons for the answers. The same thing occurred for Figure 6e, "car rental", and Figure 6f, "ground transportation".
3. Forming a concept other than the intended message from the relationship of the icons.
   (1) Sign + icon: In Figure 6c, "currency exchange", 43.3% of participants deviated from the intended inference of the relationship between various currencies and the trading area. They arrived at explanations such as "cash withdrawal" or "safety deposit box".

(2) Icon + icon: For Figure 6e, "car rental", 26.7% of participants inferred different conclusions, such as "car locking" or "valet parking". Additionally, Figure 6f, "ground transportation", also drew erroneous interpretations, such as "temporary parking area" or "restricted usage lanes".

Variations occur in the interpretation of graphical symbols comprised of unrecognizable icons or sign objects (Hsu & Lin, 2008, pp.87-105). Of the three causes, "failure to recognize an icon" had the lowest number of errors, revealing that variation in icon identity was effectively lessened by the uniformly high design quality of the abstractions. Thus, interpreting the relationship of the symbol objects was the crucial point for proximate context. Errors of "inability to make a connection among the icons" and "forming a concept other than the intended message" resulted in uncertain interpretations, especially for "sign + icon" and "icon + icon". Therefore, in order to reduce uncertainty, "direction + icon" and "human + icon" are recommended as the better proximate context options for design thinking in an information framework built upon multiple symbol objects.

Conclusions

Based on the idea that graphical symbol recognition is influenced by proximate context, this study took the AIGA system as the stimuli source to evaluate recognition performance. It clarified the accuracy ratio as a key point to reduce performance differences for people from different backgrounds. It also exposed the graphical symbols with poor performance, and discovered recognition commonality by error analysis. The findings could enable designers to enhance users' performance and experience in visual communication. Summarising these discussions leads to several conclusions and suggestions:

1. When the design quality is the same, "direction + icon" and "human + icon" are better options than "sign + icon" and "icon + icon" in applying the proximate context concept in visual communication. This is shown by participants' excellent performances in terms of accuracy ratio and response time.
2. People from a design background have a higher accuracy ratio than those from a general background. However, there is no significant difference between their response times. In order to properly apply proximate context to targeted groups of users, it is suggested that the influence of individual differences be explored in a further study.
3. Recognition errors are classified into three types: (1) failure to recognize an icon; (2) inability to make a connection among the icons; (3) forming a concept other than the intended message. To improve recognition performance, these error commonalities should be considered in depth for design thinking.

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