The recognition of 3D basic patterns and tactile icons for the blind

*Yu-Cheng Chen[1], Chun-Hsien Chiang[1], Huan-Chung Chiu[1]
[1]Department of Product Design, Transworld Institute of Technology, Taiwan

***ABSTRACT*:** Among disadvantaged minorities, due to the unique nature of their mental and physical situation, may experience more inconvenience and insecurity with the environment or certain products. If proper care is not given, their right to survival and basic dignity will be seriously undermined. Therefore, how to make exclusive plans for the disadvantaged minorities and progressively improve their living quality and welfares, according to their physical and mental characteristics, is believed to be an important issue for advanced nations.

The study focuses on blind people's ability to recognize three-dimensional patterns and tactile icons. Using the experimental facilities designed by the researcher, this case study is intended to clarify blind people's sensing and perceptual characteristics. In the experiments, the major findings are as follows: (1) Blind people's ability to recognize basic patterns is similar to sighted people's ability to visually recognize objects. (2) When blind people "touch-read" the tactile icons in basic patterns, dimensions of icons is the major factor that affects their recognition rate. (3) The subjects with adventitious blindness outperformed those with inborn blindness in the recognition of icons on stereo systems. (4) In the experiment with tactile icons in symbolic signs, it was found "providing hints" was the major factor affecting the blind subjects' recognition rate.

The study aims to progressively unveil the characteristics of the blind people's cognition of product interface and assist product designers to develop more products that are friendly to minority groups. Therefore, minority groups can also enjoy equal benefits and live with comfort and confidence as ordinary people.

KEYWORDS: disadvantaged minority, blind, tactile icons

1. INTRODUCTION

1.1 Motivation and background

Continuous development in human technologies and civilizations has always been connected with commercial behaviors. Although many technological industries are dedicated to development of everyday commodities, consideration of commercial interests has always directed planning and development of these commodities, only to satisfy market demands. New products are released to induce consumers' desire to purchase. The design focus of these products is usually placed on the appearance or playfulness rather than the importance of human-machine interface. Let alone the design of product interface for minority groups. This realistic situation has caused inconvenience and many challenges of life to minority groups that are more underprivileged in the society.

Visually impaired people may suffer more inconvenience in life than people with other types of disabilities. Rehabilitation or providing guidance is also relatively more difficult. Among the studies of people with visual impairments, most were published by scholars in special education, with focuses placed mainly on education and training. Studies of the mental and physical characteristics of visually impaired people are rare. Related information is also not sufficiently available for designers to improve the appropriateness of their designs. The researcher of this study has for long been dedicated to the research of the mental and physical characteristics of the visually impaired. Thus, through scientific research methods, the researcher attempts to open the black box of blind people, further clarity and define the information related to product development for blind people, and help them return to the society and get out of the darkness.

1.2 Research objectives

Even sighted people may feel frustrated when using electronic products from time to time; not to mention those with visual disabilities. A well-designed product can reduce the burden on learners in the initial operation, help users quickly exploit product performance, and decrease the odds of operational error. In other words, it achieves product performance and brings comfort to users after used (Treu, 1994). Blind people have visual impairments, so they cannot visually observe or judge how to operate a product as sighted people can. They rely on sensing and hearing abilities to explore the operation method of the product. It is easy to imagine how hard it may be for blind people to use product designed for the general public.

Through experimentation, this study aims to provide reference for designers to understand the needs and characteristics of the blind and further develop products compliant with their mental and physical characteristics. Developing friendly products for the blind can not only reduce inconvenience to them but also improve their living quality and ability to live autonomously.

2. LITERATURE REVIEW

Of the visually impaired people, totally blind ones suffer more pains. Without visual senses, blind people can only explore and understand the outside world with remaining senses. It is said that “the hands are the eyes of the blind”. For blind people, the tactile sense is important. Through the tactile sense and the kinesthetic sense, blind people can feel the texture, shape, dimensions of an object. These sensitive sensing abilities are not naturally developed after one goes blind. They require constant practice and long-term familiarization. The sensory compensation theory was frequently discussed in the past. It was said that blind people develop better senses of touch and hearing than sighted people so as to compensate for their lack of vision. However, in recent years, more and more doubts have been cast on this theory, saying that blind people do not naturally have better senses to make up for their loss of vision. To clarify this myth, Prof. Lai conducted an experiment test of pure tone threshold on blind people and found that the pure tone threshold of their right ear is significantly higher than that of sighted people. This finding indicated that blind people do not have a better physical system that gives them better hearing than sighted people. In everyday life, blind people are indeed more sensitive to sounds due to their particular concentration on hearing. This is why blind people are considered to have superior hearing ability (Lai, H. H., Chen, Y. C., 2006). Through self-training, some blind people can even present extraordinary performance such as in music, memorization, and literature. This is the evidence that blind people have the potential to present outstanding and professional performance as long as proper training and guidance is given.

Owing to the visual impairment, blind people are confined in many aspects of life, separating them from the society of sighted people. Such interpersonal obstruction may deepen the general public's impression about blind people, believing that blind people must have incomplete physical, mental or personality characteristics. In fact, except for the constraint of visual ability, blind people do not significantly differ from normal people in other aspects. After entering adulthood, some blind people can even turn the frustration and difficulties they experienced before into an optimistic philosophy of life, and live a positive life thereafter.

Meyerson (1963) pointed out that visually impaired students are not much different from sighted ones in individual adaptation, but they are significantly inferior in social adaptation. This reveals visual impairment affects one's entire psychology and increase difficulty of adaptation. According to Warren (1977), blind children are not significantly different from sighted children in recognition of texture, weight, and sound, but they are significantly inferior to sighted children in pattern recognition and perceptual-motor integration. As a consequence, blind children find it difficult to learn mathematics that involves understanding of geometric meanings. Cahill et al. (1996) performed a study on amblyopic and blind students in Ireland and Belgium. They found geometric patterns, tables, and triangular functions were most difficult to the students. It can be inferred that comprehension of patterns is harder for blind children and may affect their performance in mathematics.

3. METHODOLOGY

This study aims to understand blind people's recognition of 3D basic patterns and tactile icons. Those who are born blind have no experience of visually recognizing object patterns. For them, using the tactile sense to identify object patterns involves a certain degree of difficulty. They may also be affected in learning and living. To verify this assumption, a series of experiments (Experiment I~III) are conducted on totally blind subjects using self-designed equipment. It is expected that the derived objective and quantitative results can help clarify recognizability of basic patterns and tactile icons for the blind.

3.1 Subjects

The search sample is composed of visually impaired participants and sighted participants. The visually impaired ones are required to join the first, second, and third experiments. From the junior high and senior high school departments of National Taichung School for the Visually Impaired, 16 (8 from each department) totally blind students with no multiple disabilities are selected. They are equally divided into two groups—"students with congenital blindness" and "students with adventitious blindness".

As it was not easy to recruit a large number of blind participants, the experiments were conducted on small samples. To ensure the robustness of the experimental results, non-parametric statistics was adopted. T-test was not applicable to comparison between two independent samples, so we applied Mann-Whitney U Test to find out if there was any significant difference between the two samples.

3.2 Experimental Procedure

3.2.1 Experiment I: Recognition of basic patterns of control rods

Bradley (1967) conducted a series of experiments using 10 different types of dials in a diameter of 2" (5cm). Considering the control characteristics of general users, all the experimental rods are designed with patterns within a diameter of 2" (5cm) too.

These patterns include “circle”, “triangle”, “square”, “pentagon”, and “hexagon”. All of these experimental rods are 3cm high as shown in Figure 1. Through this experiment, we hope to understand recognizability of these 3D basic patterns for blind people. Based on the experimental result, designers can also make use of the difference in rod styles to help visually impaired people distinguish the functions of control rods.

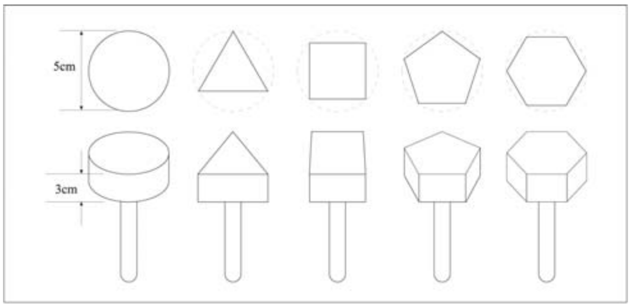

Figure 1 Specification of the control rod patterns

3.2.2 Experiment II: Recognition of tactile icons in basic patterns

In this experiment, the five basic patterns are converted into 3D icons that can be sensed with fingers. 2D patterns are output into 3D icons using rapid prototyping technique(as shown in Figure 2). In addition to the specification of the Braille system, we also refer to the finding provided by James and Gill (1975) in the design of dimension and height of the 3D icons. They found the optimal height of tactile icons is 0.7mm. According to Edman (1992), 3D icons should be designed to fit a dimension of 2 square inch for the best recognizability. However, considering the practical application of tactile icons in the future, we design the 3D icons in two dimensions, 13mm x 13mm and 6mm x 6mm, each with a height of 0.7mm(as shown in Figure 3).

Figure 2 Rapid prototyping Facility (FDM 200)

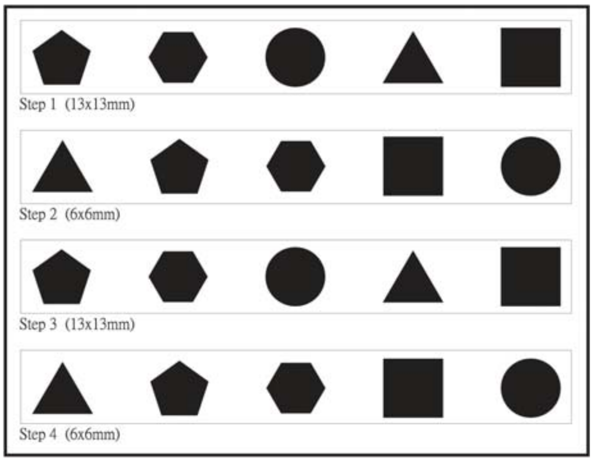

Figure 3 The order and dimension of tactile icons tested in Experiment II

3.2.3 Experiment III: Recognition of tactile icons in symbolic signs

Ten common symbolic signs are placed on a test board like the one used in Experiment II. Five symbols are selected from those used on mobile phones, including “message ”, “power ”, “phonebook ”, “end talk ”, and “start talk ”. The other five symbols are selected from those used on stereo systems, including “fast forward ”, “record ”, “next ”, “stop ”, and “play ” (see Figure 4). The dimension and height of these icons are the same as adopted in Experiment II (13mm x 13mm and 6mm x 6mm) and the height is fixed at 0.7mm. Through this experiment, we hope to understand blind people's ability to recognize symbolic icons generally designed for sighted people on stereo systems and mobile phones and provide a reference for designers to develop a proper human-machine interface for the blind.

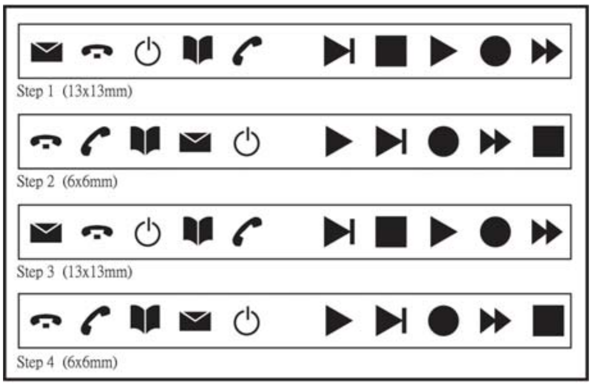

Figure 4 The order and dimension of tactile icons tested in Experiment III

4. RESULTS

4.1 Analysis of the result of recognition of control rods in basic patterns

In this Experiment I, the blind subjects were asked to "touch-read" five basic patterns, including "circle", "triangle", "square", "pentagon", and "hexagon", and identify them respectively. No matter if hints were given, they could correctly identify all patterns (100%). It can be concluded that, blind people, no matter born blind or not, can correctly identify 3-dimensional basic patterns if proper rehabilitative education is provided.

4.2 Analysis of the result of recognition of tactile icons in basic patterns

The Experiment II was designed to test blind people's recognition of tactile icons in basic patterns. As shown in Figure 5, icons in dimensions of 13mm x 13mm, due to the fact that larger icons can be more easily recognized, were better recognizable. No matter if hints on patterns were given, the subjects presented higher recognition rates for icons sized 13mm x 13mm (93.8%, 100%). From the Mann-Whitney U Test result shown in Table 1, it can be discovered that recognizability of icons in dimensions of 13mm x 13mm is higher than that of icons in dimensions of 6mm x 6mm. Therefore, tactile icons designed in a proper size can be easily recognized by blind users with their tactile sense.

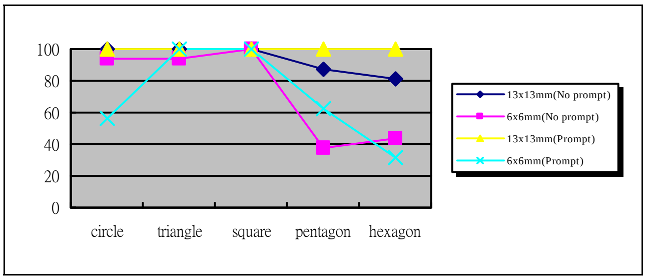

Figure 5 Blind subjects' recognition rates for basic patterns

Table 1 Mann-Whitney U Test between icon size and recognition of tactile icons in basic patterns

Exp. II	Mean Rank(n=32)		Mann-Whitney U	Z Test
	13*13 (16)	6*6 (16)		
No hint	20.72	12.28	60.50	**-2.86****
Hints	22.00	11.00	40.00	**-3.98*****

*p<.05 **p<.01 ***p<.001

4.3 Analysis of the result of recognition of tactile icons in symbolic signs

This experiment (Experiment III) and the Experiment II were similar. The difference between the two experiments lay in the test of common functional icons on mobile phones and stereo systems. The result is shown in Figure 6. It can be discovered that the recognizability of these functional icons was generally low to blind people. The recognition rate for the "start talk" icon on mobile phones, the most easily recognizable among all icons, was only 23.4%. The lowest recognition rate was observed in the test of the "message" icon on mobile phones, with an average rate of 4.7%.

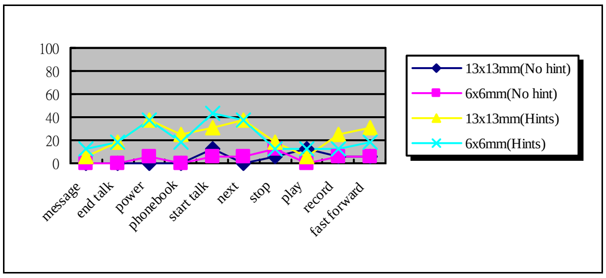

Figure 6 Blind subjects' recognition rates for symbolic signs

In the test of the effect of congenital blindness and adventitious blindness, the average recognition rate of the students with congenital blindness was 8.45%, and that of the students with adventitious blindness was 19.1%. The Mann-Whitney U Test result (Table 2) indicates that the students with adventitious blindness have a significantly better ability to recognize icons on stereo systems than those with congenital blindness.

Table 2 Mann-Whitney U Test between vision loss time and recognition of tactile icons in symbolic signs

Exp. III	Mean Rank(n=16)		Mann-Whitney U	Z Test
	Con.(8)	Adv.(8)		
step1-1	7.5	9.5	24.00	-1.46
step1-2	7.5	9.5	24.00	-1.46
step2-1	7.5	9.5	24.00	-1.46
step2-2	7	10	20.00	-1.85
step3-1	8.38	8.63	31.00	-0.11
step3-2	6.81	10.19	18.50	-1.53
step4-1	7.69	9.13	25.50	-0.73
step4-2	5.44	11.56	7.50	**-2.80****

*p<.05 **p<.01 ***p<.001

In the test of the effect of providing hints on recognition rates, the Mann-Whitney U Test result (Table 3) supports that the recognition rate is significantly higher in any condition if hints are provided.

Table 3 Mann-Whitney U Test between providing hints and recognition of tactile icons in symbolic signs

Exp. III	Mean Rank(n=32)		Mann-Whitney U	Z Test
	Hints(16)	No hint(16)		
Mobile phone				
13*13	20.4	10.6	39.00	**-3.41****
6*6	20.83	10.17	32.50	**-3.66****
Stereo				
13*13	20.23	10.77	41.50	**-3.25*****
6*6	19.37	11.63	54.50	**-2.67****

*p<.05 **p<.01 ***p<.001

5. CONCLUSIONS & SUGGESTIONS

This study was designed to explore the blind's recognition of basic patterns and tactile icons. A series of experiments were conducted to test their recognition of control rods in basic patterns, tactile icons in basic patterns, and tactile icons in symbolic signs to further induce the blind's acceptance of product interface. The experimental results were later analyzed using non-parametric Mann-Whitney U Test. The major findings are as follows:

(1) Blind people's ability to recognize basic patterns is similar to sighted people's ability to visually recognize objects, because they can make use of their tactile sense to correctly identify 3D basic patterns. This finding allows us to understand the blind's recognition of 3D basic patterns and tells designers that they can make use of various patterns to prompt the function of controls in the design of control buttons or control rods.

(2) When blind people "touch-read" the tactile icons in basic patterns, dimensions of icons is the major factor that affects their recognition rate. It was found in our experiment that icons in dimensions of 13mm x 13mm were significantly more recognizable than those in dimensions of 6mm x 6mm. It can be concluded that blind people can also identify tactile icons in basic

patterns at a considerable accuracy rate, as long as these icons are designed in proper dimensions. This finding is important for future design of tactile maps or tactile icons.

(3) The subjects with adventitious blindness outperformed those with inborn blindness in the recognition of icons on stereo systems. This result can be explained by the visual experience of the subjects with adventitious blindness. Most of the blind subjects were unfamiliar with functional icons on electronic devices, but those with adventitious blindness still have some visual impression about these icons. This is probably the reason why people with adventitious blindness could better recognize functional icons on stereo systems.

(4) In the experiment with tactile icons in symbolic signs, it was found "providing hints" was the major factor affecting the blind subjects' recognition rate. This implies that blind people's lack of visual experience about functional icons and providing hints on the symbolic signs can help them identify the meaning of each icon.

In two experiments on recognition of basic patterns, it was found that no matter born blind or not, the blind subjects showed a considerably high recognition rate for basic patterns. As long as these patterns were not too small in dimensions, they could be correctly identified by the blind subjects using their tactile sense. This reveals that special education of graphic training for the blind students has been very successful. Through the use of adequate materials and instructions, they could completely recognize and understand the characteristics of these basic patterns. This finding can be applied to the design of various control interfaces. Based on the blind students' recognition of basic patterns, more training can be given to help them learn other complicated patterns and develop spatial cognition.

Although the blind subjects could successfully identify various basic patterns, they were relatively unfamiliar with functional icons on common electronic devices. Some of these icons are concrete symbols, but some are abstract ones. For blind people, no matter born blind or not, these symbols were not easy to recognize. Even sighted people were unable to fully understand all kinds of functional icons on electronic products. This finding indicates that more importance should be attached to the appropriateness and standardization of the design of functional icons. Only when functional icons are properly designed and standardized can they be used on tactile icons for the blind. According to the blind's accuracy in touch-reading, if proper explanation and time for training is given, blind people can also identify various functional icons with their tactile sense. Therefore, the future product designs can also comply with the "Universal design" principle.

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