Biometric Symbol Design for the Public - Case Studies in the United States and Four Asian Countries

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ABSTRACT

The use of biometric systems has been expanded beyond traditional law enforcement applications to other areas such as identity management, access control, e-commerce, and even healthcare. With the deployment of biometric systems on the rise, the user bases are also expanding from targeted users such as police to general computer users. This phenomenon challenges biometric researchers and developers to design systems with good usability. This paper evaluated a set of symbols intended for use in biometric systems to help users better understand biometric operations. Six studies with a total of 186 participants were conducted in the United States and in four Asian countries to investigate the cultural effects on people's perception and understanding of the symbols. Some symbols show culture-free results, while some have mixed results. The cross-cultural implications of the case studies are discussed and future research is recommended.

Keywords: Biometrics, Symbols, Usability, Cross-Cultural

INTRODUCTION

The application of biometric systems will become ubiquitous in the near future. Government and industry have a common challenge in today's global society to provide more robust tools and governance principles on how to deploy these tools intelligently to meet national and international needs (National Science and Technology Council Subcommittee (NSTC) on Biometrics, 2006). The NSTC specifically challenged technology developers and researchers to develop biometrics-enabled systems that are intuitive and usable to operators and end users.

Graphic design is a form of visual communication that uses visual elements such as image, color, form, shape, and typography as a unique type of language- visual language. The use of icons and symbols to facilitate communication has been pervasive in areas such as computing technology, mobile devices, appliances, etc. Visual representations can be used as interaction widgets on a user interface, status indicators, warning signals, or to provide graphical instructions. Similar application of icons and symbols will be implemented for biometric systems.

While Horton (1994) stated that one benefit of using icons is to reduce the needs of text translation when marketing products globally, other researchers noted that visual language can be problematic when it's used to communicate across cultures. Icons can be effective in one culture but offensive in another culture (Shirk and Smith, 1994). Graphical representations have been mainly designed and tested in the West, but often times they are targeted for international use. Plocher, Garg, and Wang (1999) reported findings on Chinese users' difficulties in recognizing application tool bar icons for process control workstations designed in the United States (U.S.) and in Australia. Choong and Salvendy (1998) examined the performance differences between American and Chinese users in recognizing icons presented in different modes. A combined presentation mode was found as the best choice since the performance with a combined mode was at least as good as or better than the performance with either alphanumeric or pictorial modes. Kurniawan, Goonetilleke, and Shih (2001) reported similar findings that bimodal (text and picture) icons provide the most appropriate and best meanings for Chinese.

With the rapid proliferation of biometric systems for use by the general public in the near future, users may be unfamiliar with particular implementations and they may not understand the local language in which instructions for use are described. It is important that the symbols used have consistent significance globally and do not cause offense. As many public biometric systems are used by foreign nationals, a consistent international standard set of symbols will reduce the difficulty that the wider community experiences in finding and using biometric systems.

The international biometrics community has recognized the need and importance of establishing standards to ensure a high priority and comprehensive approach to biometrics worldwide. A new subcommittee (SC37) of ISO JTC 1 was established in 2002 to accomplish this goal. In 2008, SC37 issued a call for contributions of

pictograms, icons and symbols for use within biometric systems. The National Institute of Standards and Technology (NIST) responded to the call by proposing a set of symbols for biometric systems that aims at enhancing the users' performance with these systems as well as the users' understanding of the use and goals of the systems. The objective was to help the general public understand the concepts and procedures for using electronic systems that collect and/or evaluate biometrics.

PROPOSED SYMBOLS AND PICTOGRAMS FOR BIOMETRIC USE

The proposed set of symbols are to be used to identify the biometric modality, provide instructions related to the scanning activities, display dynamic information related to the scanning process, and indicate the status of the biometric sensor.

Individual Symbols

The proposed symbols (Fig. 1) include concepts for directions and concepts for sensor activity or feedback. Some concepts have multiple variants that were evaluated to identify the best symbol for the corresponding concept.

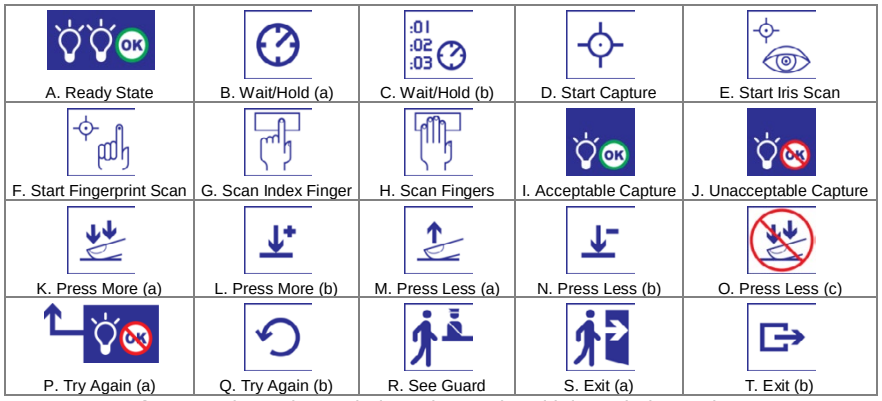

Figure 1 Biometric Symbols under Study, with intended meanings

Procedural Symbols

Although each individual symbol was designed for a concept, it is intended that the symbols be combined to fully illustrate the biometric scanning processes. For example in a customs or immigration environment, procedures constructed from the individual symbols can be presented as a series of posters while passengers are in the queue, or a series of transitional frames in a biometric booth. An example of this type of composite symbols was constructed and evaluated (Fig. 2).

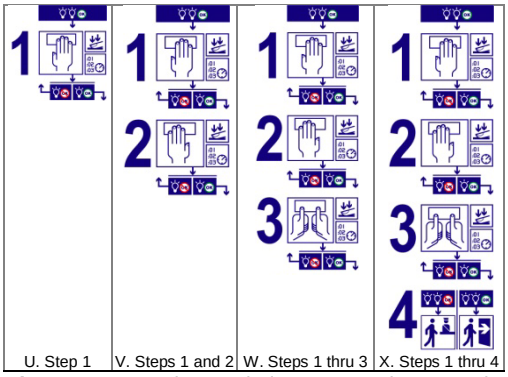

Figure 2 Composite Symbols Representing Steps in a Fingerprinting Procedure

METHOD

A study was designed to evaluate users' interpretation and comprehension against the intended meanings of the proposed symbols. The study was performed in the U.S. and, with collaboration from five research teams in Asia, was replicated in four countries, namely, China, Japan, South Korea (A), South Korea (B), and Taiwan.

PARTICIPANTS

A total of 186 participants from five countries participated in the study (Table 1). The recruitment of participants was cautioned to include only people who were born and resided in the country where the study was performed, with one exception in Korea (B) where one participant was born in Indonesia, had resided in Korea for years and was fluent in Korean. A majority of the participants had engineering or science backgrounds as the studies were conducted on campus where the research teams reside, except for the case of Korea (B) where two rounds of the study were conducted, one on campus and the other in the neighborhood where participants with various backgrounds (e.g. manager, housewife, or teacher) participated.

Table 1 Participant Demographics

Country	Number of Participants	Female (%)	Male (%)	Age Range	Age Average
China	15	53.3%	46.7%	21-29	23.6
Japan	12	0%	100%	20-23	21.2
South Korea (A)	14	50%	50%	21-36	27.5
South Korea (B)	100	49%	51%	19-58	27.8
Taiwan	30	50%	50%	20-36	25.7
U.S.	15	53.3%	46.7%	19-65	29.5

The genders of the participants were pretty balanced, except for the Japanese. The average age of participants from each team was comparable across all cultures.

APPARATUS

As stated earlier, ensuring the usability of biometric systems should be a high priority in product development as challenged by NSTC. Usability is defined as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." (ISO, 1999). To develop a usable system, the context in which the biometric system will be used should be considered from the early stages of the design lifecycle.

During our pilot runs before the study, we noticed that people would interpret the symbols more closely to the intended meanings if they had a visual reminder of the context. Some of the more abstract symbols were interpreted with meanings unrelated to biometrics when the context was forgotten. In order to assist our study participants in evaluating the symbols with reasonable background information, it was important to emphasize the intended operational context of the symbols. A mockup of a fingerprint sensor was developed (Fig. 3) as an example of the type of devices that would use the symbols. Each research team in Asia also received from NIST a fingerprint sensor mockup for use in their study.

Figure 3 Mockup of a Fingerprint Sensor

All test materials were developed in English by NIST in the U.S.. Before conducting the studies in Asia, all five Asian teams translated the test materials into their local languages. Peer reviews were performed to ensure the translation was valid and comparable to the original English version.

PROCEDURE

A detailed, step-by-step, test procedure and protocol was developed by NIST and disseminated to all research teams. This ensured that all studies were carried out in a similar fashion. The studies were conducted in two parts.

Part 1 Symbol Interpretation

Part 1 was performed as a one-on-one interview. The interviewer provided each participant with the background of the study, explaining that the symbols were designed to describe biometric processing such as fingerprinting and iris scanning in a multi-lingual environment. The interviewer also described the context of use of the symbols with the fingerprint sensor mockup as a reminder. The symbols (without the intended meanings) were printed on separate sheets of paper and presented in the same order for all participants. The interviewer asked participants to look at the symbols one at a time and provide their interpretation for each

symbol. The interviewer just took notes and did not provide feedback on participants' interpretations.

Once the participant had viewed and interpreted each individual symbol (Fig. 1), then the composite symbols were presented in incremental steps with one step added to the presentation each time (Fig. 2) [1]. Again each participant was asked to interpret the composite symbols intended to represent steps in a process.

Part 2 Meaning Matching

Each participant was presented with two pages of test materials. Each page contained a column of possible meanings (in Table 2) and a column of the proposed symbols (only the individual symbols in Fig. 1). Since all participants from part 1 also participated in part 2, the symbols in part 2 were randomized so that the presentation order was different from part 1 to eliminate any sequence effect. Based on what we learned from the pilot runs, words that can be possible interpretations, but not matching the intended meanings of some symbols were inserted intentionally to further investigate participants' perceptions of those symbols.

The interviewer asked each participant to examine the meaning choices and the symbols, and match the best meaning, if any, with each symbol. The participants were instructed that a meaning may be used for more than one symbol, not every meaning had to be used, and only one meaning could be chosen for each symbol.

[1]The team from Taiwan did not perform the study on the composite symbols due to time and resource constraints.

Table 2 Choices for Intended Meanings in Part 2

1.	Ready state	2.	Wait/Hold	3.	Start Capture	4.	Go in that direction
5.	Scan fingers	6.	Start biometric scan	7.	Start fingerprint scan	8.	Scan index finger
9.	Start iris scan	10.	Look here	11.	Move hand forward	12.	Press more
13.	Press less	14.	Do not press	15.	Give up	16.	Acceptable capture
17.	Unacceptable capture	18.	Try again	19.	Exit	20.	See guard
21.	Turn Around	22.	(none of the above)				

RESULTS AND DISCUSSION

A data analysis template was developed by NIST and disseminated to each Asian research team after each team finished the study in their country. All teams performed their data analyses independently. The Asian researchers also translated the data into English and sent the results to NIST for cross-cultural analysis.

PART 1 SYMBOL INTERPRETATION

A coding scheme was developed to investigate the participants' perceptions and understanding of the proposed symbols. Each interpretation was coded into one of the following categories: "Correct"- the interpretation matched the intended meaning; "Approximate"- the interpretation is related to the intended meaning or to a concept that can lead to the intended meaning, but not exact; and "Incorrect"- the

interpretation is totally unrelated to the intended meaning. Due to the subjective nature of the data, only one researcher from each team coded the data collected by his/her team so that the coding would be consistent. The correct interpretation rates are shown in Table 3, and the approximate interpretation rates and incorrect interpretation rates are shown in Table 4.

Table 3 Part 1 Correct Interpretation Rates across Countries

Country	Symbols											
	A	B	C	D	E	F	G	H	I	J	K	L
China	20.00%	46.67%	46.67%	0.00%	53.33%	26.67%	53.33%	86.67%	53.33%	40.00%	66.67%	53.33%
Japan	16.67%	0.00%	0.00%	0.00%	33.33%	50.00%	0.00%	8.33%	8.33%	16.67%	8.33%	50.00%
South Korea (A)	42.86%	50.00%	64.29%	7.14%	35.71%	21.43%	92.86%	92.86%	85.71%	85.71%	57.14%	64.29%
South Korea (B)	7.00%	4.00%	7.00%	4.00%	25.00%	18.00%	13.00%	16.00%	18.00%	17.00%	21.00%	42.00%
Taiwan	16.67%	23.33%	60.00%	13.33%	36.67%	23.33%	73.33%	83.33%	80.00%	80.00%	46.67%	86.67%
U.S.	26.67%	40.00%	26.67%	20.00%	40.00%	53.33%	40.00%	86.67%	73.33%	86.67%	53.33%	33.33%

Country	Symbols											
	M	N	O	P	Q	R	S	T	U	V	W	X
China	13.33%	60.00%	26.67%	20.00%	20.00%	26.67%	60.00%	53.33%	46.67%	86.67%	93.33%	46.67%
Japan	0.00%	33.33%	16.67%	16.67%	25.00%	16.67%	41.67%	33.33%	8.33%	25.00%	8.33%	66.67%
South Korea (A)	0.00%	57.14%	35.71%	50.00%	50.00%	85.71%	57.14%	57.14%	57.14%	35.71%	50.00%	78.57%
South Korea (B)	0.00%	40.00%	13.00%	4.00%	9.00%	19.00%	22.00%	17.00%	12.00%	22.00%	21.00%	17.00%
Taiwan	3.33%	83.33%	36.67%	33.33%	40.00%	63.33%	60.00%	30.00%				
U.S.	6.67%	26.67%	26.67%	13.33%	80.00%	66.67%	66.67%	20.00%	33.33%	33.33%	33.33%	53.33%

The correct interpretation rates demonstrate great variations cross culturally. There are a few symbols (E, L, and N with green shadings) with higher than 25% correctness across all cultures. When the approximate interpretations were also considered, participants' interpretations were getting closer (above 50%) to the intended meanings for all countries on symbol E. Two symbols, D and M (with pink shadings), have interpretation rates lower than 20% across all cultures. Specifically, if approximate interpretations were counted, participants still had problems interpreting symbol M as they did not perceive the symbol with a concept that will lead to the intended meaning. Further examination of the data indicated that the majority of participants interpreted symbol M as "lift or remove your finger" (China 73%, Japan 75%, Korea (A) 100%, Korea (B) 68%, Taiwan 93%, U.S. 93%). For symbol D, some participants interpreted it as a "target" (Korea (A) 15%, Korea (B) 21%, Taiwan 17%, U.S. 33%), while 27% of Chinese participants thought it represented the "scan area" and 17% of Japanese participants thought that it directed users to "press the target".

Table 4 Part 1 Approximate Interpretation Rates across Countries

Country	Symbols											
	A	B	C	D	E	F	G	H	I	J	K	L
China	13.33%	33.33%	26.67%	80.00%	40.00%	66.67%	33.33%	6.67%	13.33%	0.00%	26.67%	33.33%
Japan	8.33%	100.00%	66.67%	0.00%	41.67%	33.33%	50.00%	33.33%	8.33%	0.00%	66.67%	8.33%
South Korea (A)	7.14%	21.43%	28.57%	57.14%	50.00%	78.57%	7.14%	7.14%	14.29%	14.29%	28.57%	14.29%
South Korea (B)	16.00%	50.00%	28.00%	23.00%	26.00%	24.00%	45.00%	33.00%	7.00%	6.00%	48.00%	19.00%
Taiwan	13.33%	53.33%	23.33%	30.00%	13.33%	46.67%	20.00%	13.33%	6.67%	10.00%	46.67%	0.00%
U.S.	20.00%	40.00%	46.67%	46.67%	13.33%	33.33%	53.33%	13.33%	20.00%	6.67%	6.67%	6.67%

Country	Symbols											
	M	N	O	P	Q	R	S	T	U	V	W	X
China	0.00%	13.33%	33.33%	26.67%	0.00%	20.00%	13.33%	6.67%	40.00%	0.00%	6.67%	26.67%
Japan	0.00%	0.00%	75.00%	0.00%	0.00%	16.67%	41.67%	0.00%	25.00%	33.33%	58.33%	16.67%
South Korea (A)	0.00%	7.14%	42.86%	35.71%	14.29%	14.29%	35.71%	7.14%	42.86%	64.29%	50.00%	21.43%
South Korea (B)	1.00%	7.00%	52.00%	12.00%	27.00%	46.00%	39.00%	29.00%	12.00%	6.00%	11.00%	10.00%
Taiwan	0.00%	3.33%	40.00%	40.00%	13.33%	16.67%	26.67%	26.67%				
U.S.	0.00%	13.33%	20.00%	26.67%	0.00%	20.00%	26.67%	26.67%	53.33%	60.00%	60.00%	6.67%

For the composite symbols (U thru X) that represent procedural concepts, although there were no consistent interpretation results, interesting cultural differences were observed on how people described their impressions of these symbols. There are fundamental differences between East Asians and Westerners in how they perceive and think about the world. Westerners reason analytically, paying attention to objects and using logical rules to understand events, whereas East Asians reason holistically, focusing on objects in their surrounding field and the relationships among them (Nisbett, 2003). The East Asian participants in the studies tended to include relationships among objects and the field on the composite symbols during interpretation; whereas the U.S. participants tended to describe objects and their states on the symbols. For example, in interpreting symbol U, some interpretations from each culture are quoted: “First step, start when the upper two lights on. Put four fingers onto the area, press 3s. If not OK, do again; If OK, next step.” (China); “if two lights are on, touch it and press it. After several seconds, the light is on. If the light doesn't turn on, go inside.” (Japan); “When the light of the fingerprint scanner is turned on, scan the fingerprint during 3 seconds. If the green light is turned on, it has been completed successfully. If the red light is turned on, do it again.” (Korea (A)); “In the first step, the system will start if the two lights are on. If the one light is going on after you press the button for 3 seconds with the four fingers of your right hand, you can go to the next step. Otherwise, redo the first step.” (Korea (B)); “Light comes on to start. Put all 4 fingers down for 3 seconds. If not ok do it again, if ok move on” (U.S.).

PROMISING SYMBOLS

From the results of Part 1 and Part 2, seven symbols show promises that don't seem to be affected by cultures. When textual cues (part 2) are provided, majority (above

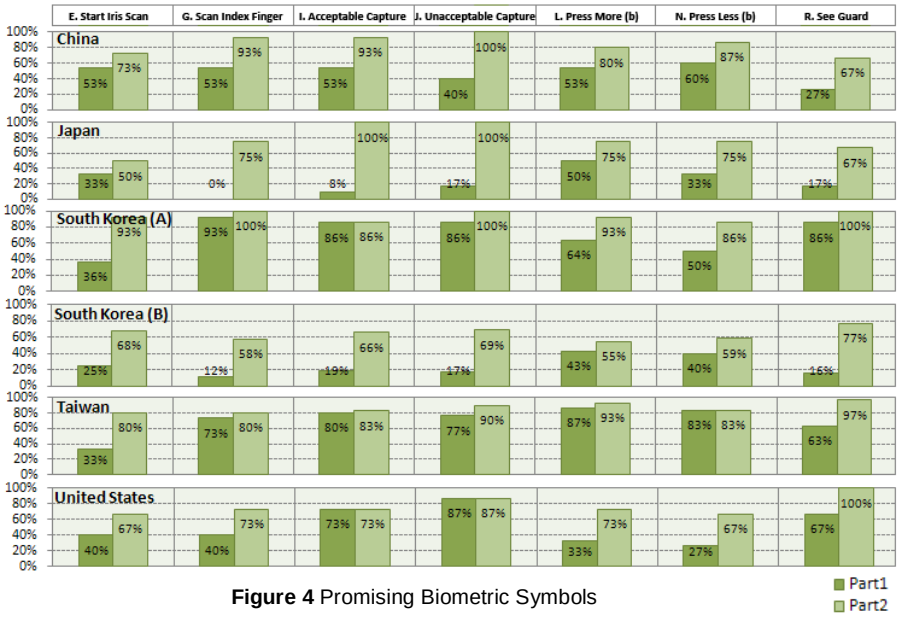

Figure 4 Promising Biometric Symbols

50%) participants were able to better recognize the symbols and their intended meanings (Fig. 4). Further improvements can be expected when the symbols are used operationally in biometric systems, e.g. as icons on a sensor.

SYMBOLS NEEDING DESIGN ALTERNATIVES

Four symbols (Fig. 5) caused confusion in participants from all cultures. With textual cues provided, results were not much better or even worse in some cases (below 50%). Design alternatives are needed for the concepts of "start scan" and "start fingerprint scan". For "Press Less," variants (a) and (c)

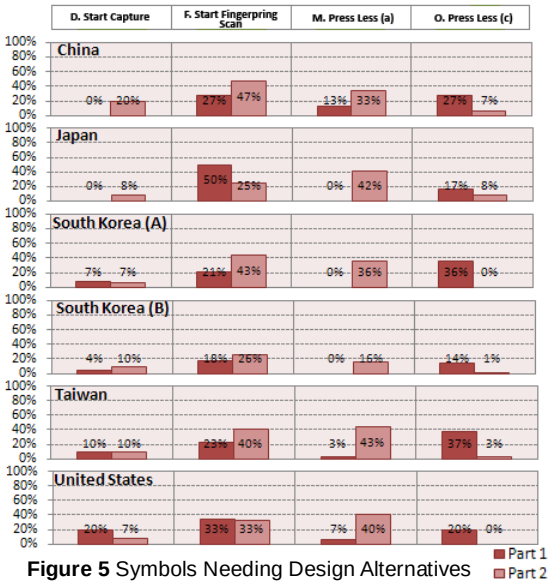

Figure 5 Symbols Needing Design Alternatives

(symbols M and O) should be further investigated and variant (b) (symbol N) is the best choice.

SYMBOLS WITH MIXED RESULTS

The remaining symbols (Fig. 6) show mixed results among cultures. With the textual cues, only U.S. participants (73%) could match the meaning to symbol A. For symbol H, the majority of participants could match it with the intended meaning except for Korea (B) with 29% participants choosing "Start fingerprint scan" as the meaning. Majority (more than 50%) of East Asian participants reached the intended meaning for symbol K while 47% of U.S. participants chose the same answer with

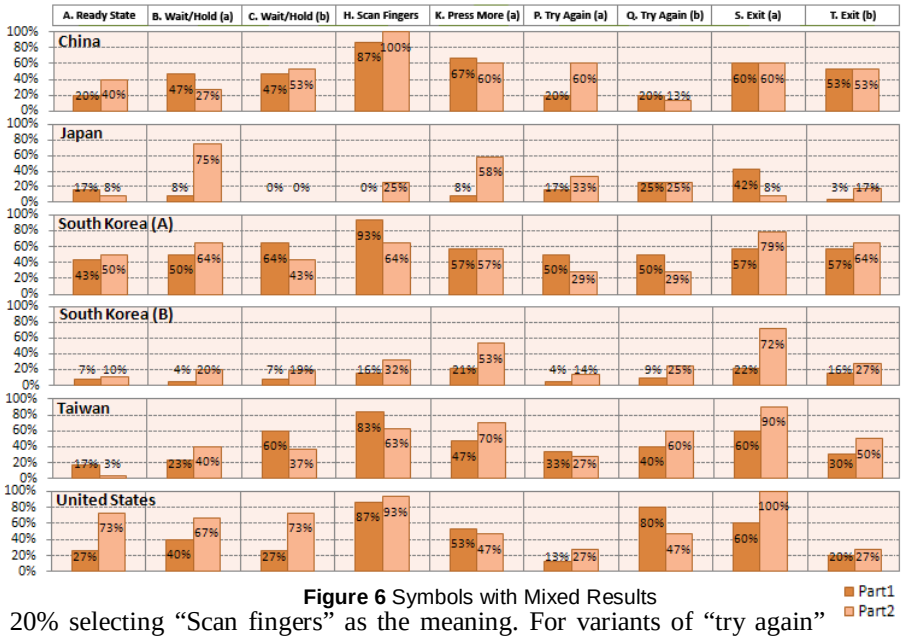

Figure 6 Symbols with Mixed Results

20% selecting "Scan fingers" as the meaning. For variants of "try again" (symbols P and Q), 60% of the Chinese found symbol P closer to the meaning, whereas 60% of the Taiwanese found symbol Q closer to the meaning, and participants from other cultures did not find either variant good for the intended meaning. For symbol S representing "Exit," the majority of participants found it plausible except for the Japanese with 75% choosing "Go in that direction" as the answer. These symbols will require further investigation to determine their feasibility of representing the intended meanings.

CONCLUSIONS

Researchers and developers of biometric technologies will soon be faced with

significant challenges to provide reliable and usable systems for operators and end users who may have different cultural backgrounds. NIST has proposed a set of symbols intended to be used in biometric systems with the goals to facilitate user performance and improve usability. The symbols were evaluated in six case studies in four Asian countries and in the U.S.. Seven symbols show great promise to be culture free, four symbols did not work well, and nine symbols require further investigation to determine their utility.

While the numbers of participants of those case studies were not substantial (except for Korea (B)) for drawing statistical inferences, the results of the studies provide great insights for future research. The findings will serve well when future research is performed to investigate those symbols in operational settings for reaching the ultimate goal of an international standard set of biometric symbols.

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REFERENCES

Choong, Y.Y., & Salvendy, G. (1998). ''Design of icons for use by Chinese in Mainland China.'' *Interacting with Computers,* 9, 417-430.

Horton, W. (1994). *The icon book: visual symbols for computer systems and documentation*. New York: John Wiley & Sons, Inc.

ISO 13401:1999. *Human-centered design process for interactive systems*.

Kurniawan, S. H., Goonetilleke, R. S., & Shih, H. M. (2001). ''Involving Chinese users in analyzing the effects of languages and modalities on computer icons.'' In C. Stephanidis (Ed.), *Universal Access in HCI: Towards an Information Society for All* (pp. 491-495), Proceedings of the HCI International Conference August 5-10 2001, volume 3, Mahwah, New Jersey: LEA.

National Science and Technology Council Subcommittee on Biometrics. (2006), *The National Biometrics Challenge*, August, 2006, retrieved from http://www.biometrics.gov/NSTC/Publications.aspx.

Nisbett, R.E. (2003). *The geography of thought: why we think the way we do.* Free Press.

Plocher, T.A., Garg, C., and Wang, C.S. (1999). *Use of colors, symbols, and icons*

in Honeywell process control workstations in China. Joint technical report prepared with Tianjin University, December 1999.

Shirk, H. N., & Smith, H. T. (1994). ''Some issues influencing computer icon design.'' *Technical Communication*, Fourth Quarter, 680-689.