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INFORMATION DELIVERY THROUGH VISUAL AND AUDITORY ICONS

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Abstract. *Icons are used in a variety of devices nowadays, since they are intuitive and easy to learn. Visual and auditory channels are mainly utilized for icons. These icons are usually supposed to deliver information, such as abstract concepts and emotional contents. In this study, we investigated the effects of visual and auditory icons on delivering information of abstract concepts in HCI contexts. We prepared a set of abstract concepts in HCI contexts, and visual and auditory icons that were well matched with each of abstract concepts. A total of 20 participants took part in the experiments, which were confirming the matches between icons and abstract concepts, and grouping the icons based on cognitive distances among icons. As a result of the experiments, it is concluded that associations among icons are not the same as those of meanings of abstract concepts. Thus, associations among icons should be considered when icons are selected to deliver information.*

Keywords: Visual icons, Auditory icons, Human-computer interaction, Abstract concepts

1. **Introduction.** Icons have been used in a variety of devices based on interaction channels of human senses to users who wish to gain information more efficiently [8,9]. Visual and auditory channels are mainly utilized as the interaction channels for icons. Visual icons based on graphics are relatively easier to use than text-based icons. Auditory icons using natural sounds have a potential advantage that in many contexts it does not require a long period of learning. Using icons has two advantages. First, icons are easy to deliver information. Second, icons are intuitive to use without learning. Information that icons can deliver includes abstract concepts and emotional contents. However, there were few studies that dealt with how to design intuitive icons to deliver information, such as abstract concepts emotional contents. Especially, guidelines are not enough for designing intuitive icons. This study aims to investigate the effects of visual and auditory icons on delivering abstract concepts in human-computer interaction (HCI) contexts. Specifically, based on the experiments, it is investigated whether the associations among icons are the same as those of meanings of abstract concepts, in order to draw guidelines for icons This paper is organized as follows. Related work in this section gives an overview of basic topics related to this study, followed by a description of research methods in Section 2. Sections 3 and 4 present the results of the experiments and discussion on the results with conclusions, respectively.

1.1. **Visual and auditory icons.** Icons are intuitive communication media between users and information in the interfaces [3]. Visual and auditory channels have been widely used as two main communication channels to users traditionally. For these reasons, visual icons and auditory icons were widely used in communication devices to deliver information. In order to design visual icons and auditory icons, Blattner et al. [6] suggested

design principles that can be applied to both visual and auditory icons. These icons can be classified into two types, such as representational icons and abstract icons. Representational visual icons are designed in a way of simplification of objects and hieroglyphic pictures, which are familiar to users as pictographic images, and representational auditory icons are designed by digitizing natural sounds sampled in the environment. In the meantime, abstract visual icons are designed by compounding geometric marks, and abstract auditory icons are designed by compounding single pitched or multiple pitched sounds, which are also called earcons. They summarized how to design icons as the tree model of compounding design elements, such as geometric marks or pitches, which consisted of combining, transforming and inheriting [6]. Representational icons and abstract icons can be evaluated according to variety and intuitiveness. Representational icons are intuitive because they are designed by taking the pictures and picking the sounds familiar to users, but they lack in variety. On the other hand, abstract icons have enough variety, but they are relatively less intuitive due to the design by compounding basic elements, and thus, users need to learn what they mean. This study focuses on representational icons for visual and auditory channels, since representational icons have the merits of intuitiveness that is closely related with this study.

1.2. **Typology of information in HCI context.** Icons are used to deliver information, such as abstract concepts and emotional contents [9]. Visual icons convey non-verbal messages in the form of symbols, including concepts and emotions. Auditory icons play the roles of evoking users' emotional responses and help improve our quality of life by helping users perceive concepts in emotionally optimized ways [1,7]. A variety of models have been suggested to investigate types of information that is properly delivered by icons. Emotional contents could be expressed using the Valence-Arousal (VA) model proposed by Russell [4]. According to this model, a variety of human emotions can be expressed in the arousal dimension, such as activation vs. deactivation, and in the valence dimension, such as pleasant vs. unpleasant. In the meantime, Lee and Hwang [2] proposed a typology to investigate the association among abstract concepts in HCI contexts. The typology consists of two dimensions, such as activity (static vs. dynamic) and priority (front of mind vs. back of mind). Based on experiments, 15 distinguishable abstract concepts in HCI contexts were successfully corresponded with the proposed typology. They concluded that these two axes (activity and priority) were good candidates for the typology of abstract concepts and the associations among abstract concepts based on the proposed typology would help design icons. This study focuses on abstract concepts in HCI contexts as information delivered to users, and comparing the associations among abstract concepts with those among icons.

2. **Methods.** Two experiments were conducted consecutively. The first experiment was conducted to confirm whether the abstract concepts and the visual/auditory icons were well matched. The second experiment was conducted to measure cognitive distances among visual icons and among auditory icons, respectively.

2.1. **Participants.** During the two experiments, twenty participants took part in the experiments. Participants were 11 males and 9 females, and they were 25 years old on average, with a standard deviation of 1.58 years. Participants did not have any problem to hear and see in both ears and eyes. Two of participants wore glasses for vision correction.

2.2. **Procedure of experiment 1.** 15 distinguishable abstract concepts in HCI contexts were selected from Lee and Hwang [2]. These concepts are commonly used in interacting with PCs: Warning, click/selection, running/installation, completed execution, upload/download, delete, input/typing, double click/execution, switch window, backspace/cancel execution, exit/closing window, system down, reload, maximizing window, and

minimizing window. Visual and auditory icons based on each of 15 abstract concepts were selected by literature review and expert review. In the first experiment, each of twenty participants conducted two tasks. First, participants were asked to describe the meanings of icons when each of 15 visual icons and each of 15 auditory icons was presented. Second, participants were asked to sort 15 visual icons and 15 auditory icons corresponding to 15 abstract concepts. Based on the results of two tasks, we tried to select the best matches among abstract concepts, visual icons and auditory icons, in terms of consensus among participants.

2.3. **Procedure of experiment 2.** In the second experiment, each of twenty participants was asked to conduct cognitive grouping tasks with 15 visual icons and 15 auditory icons. First, a participant was asked to group icons into an arbitrary number of groups based on their similarity. Second, the participant was asked to group icons into 3, 6, and 9 groups separately, except for one number of groups closest to an arbitrary number of groups in the previous step [5]. The same procedure was applied to 15 visual icons and 15 auditory icons, separately. Based on the results of cognitive grouping, we calculated dissimilarity matrices for visual icons and auditory icons.

3. Results.

3.1. **Well matched 8 abstract concepts and icons.** As the results of experiment 1, we could select 8 visual icons and 8 auditory icons that were best matched with 8 abstract concepts in HCI contexts (see Tables 1, 2 and 3). These 8 visual icons, 8 auditory icons and 8 abstract concepts were selected based on consensus among experiment participants. Table 1 shows the selected 8 abstract concepts in HCI contexts and their definitions, and Tables 2 and 3 show 8 visual icons and 8 auditory icons that were matched with the selected 8 abstract concepts, respectively. In order to compare the results of experiment 2, the selected 8 abstract concepts were located in the typology of abstract concepts in HCI contexts [2], as shown in Table 4.

3.2. **Multidimensional scaling results for visual and auditory icons.** As the results of experiment 2, we could calculate dissimilarity matrices of visual icons and auditory icons. With these dissimilarity matrices, multidimensional scaling (MDS) was conducted to find dimensions that represent relative distances and locations of icons well. The results of MDS show that two dimensions are well fitted with data, and two dimensions can be interpreted as activity and priority in Lee and Hwang [2]. Figure 1 shows locations and relative distances among visual icons and auditory icons, according to activity (static vs. dynamic) and priority (front of mind vs. back of mind) dimensions. When

Table 1. Selected 8 abstract concepts in HCI contexts

ID	Concepts	Definitions in HCI contexts
A	Warning	Give messages or pop-up windows to users for an advance notice of something that will happen while using PC
B	Click/Selection	Press one of the buttons by which users point the cursor on an area of a computer screen in order to make something happen or selected
C	Completed execution	Give a signal that indicates execution has been completed
D	Input/Typing	Input the information through the input devices in PC
E	Double click/Execution	Press the button of mouse twice to execute by inputting the command users want to run
F	Exit/Closing window	Press the button to exit or dismiss the window from working
G	Maximizing window	Expand the window for a priority to work
H	Minimizing window	Descend the window for trying to work others

TABLE 2. Selected 8 visual icons

ID	Concepts	Visual icons	References
A	Warning		[11]
B	Click/Selection		
C	Completed execution		
D	Input/Typing		
E	Double click/Execution		
F	Exit/Closing window		
G	Maximizing window		[13]
H	Minimizing window		

TABLE 3. Selected 8 auditory icons

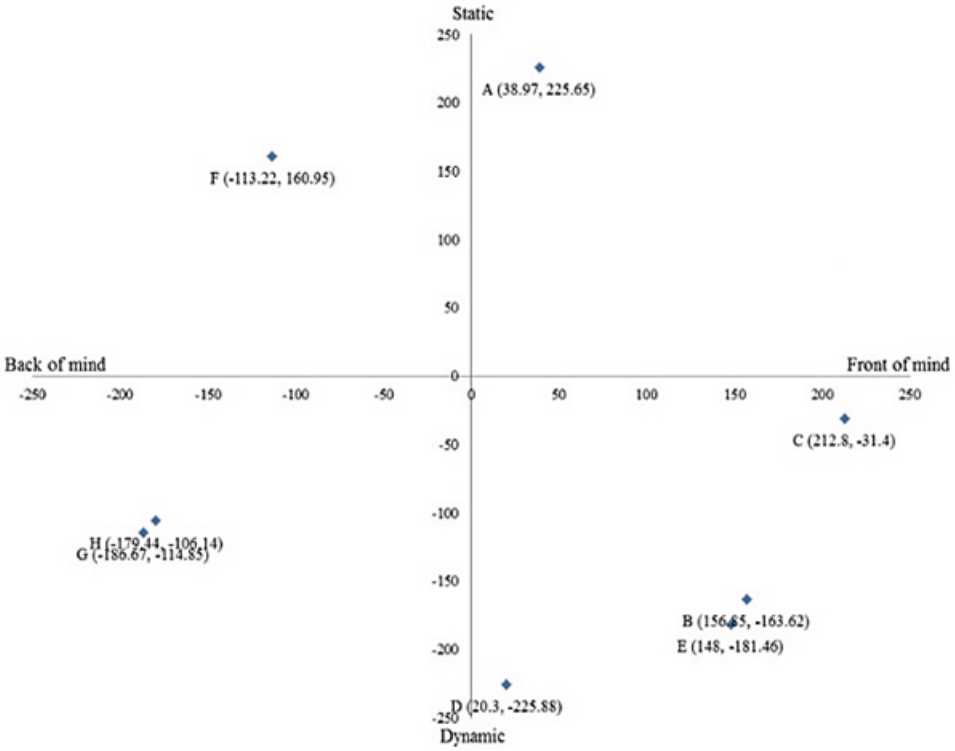
ID	Concepts	Auditory icons	References
A	Warning	Sound of blowing a whistle	[10]
B	Click/Selection	Sound of pressing a mouse	Collected by authors and selected by expert review
C	Completed execution	Sound of beeping continuously	[10]
D	Input/Typing	Sound of typing a keyboard	Collected by authors and selected by expert review
E	Double click/Execution	Sound of double pressing a mouse	
F	Exit/Closing window	Sound of closing a car door with key	[10]
G	Maximizing window	Sound of increasing pitches	[12]
H	Minimizing window	Sound of decreasing pitches	

TABLE 4. Typology of selected 8 abstract concepts

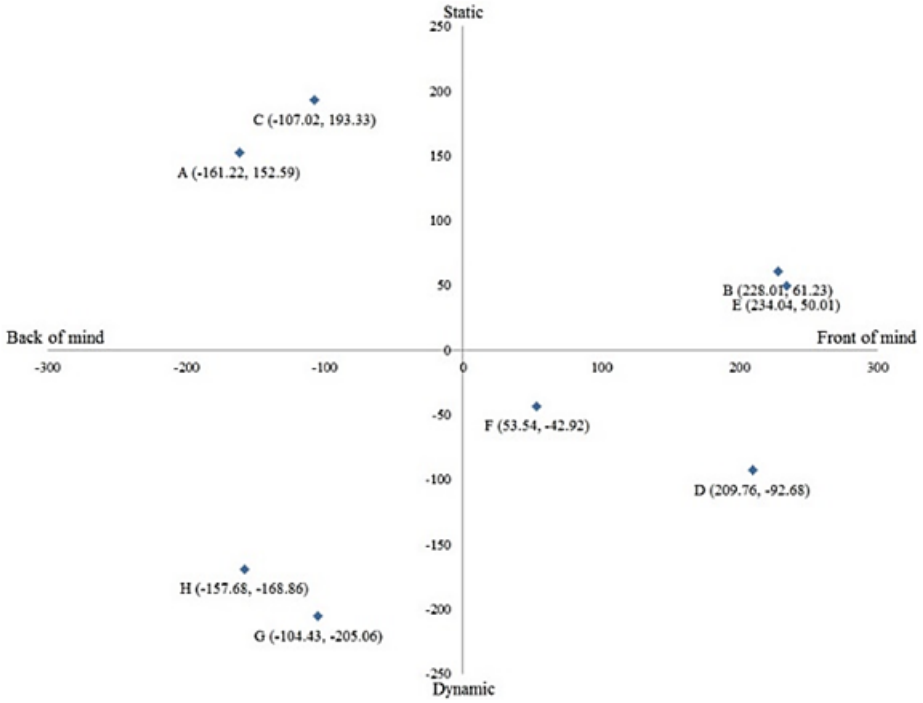
	Back of mind	Front of mind
Static	Completed execution (C) Exit/Closing window (F)	Warning (A) Click/Selection (B)
Dynamic	Maximizing window (G) Minimizing window (H)	Input/Typing (D) Double click/Execution (E)

MDS results are compared with the typology of 8 abstract concepts, 'click/selection' (B) and 'completed execution' (C) as visual icons in Figure 1(a) are not well matched with the typology of 8 abstract concepts in Table 4, in terms of dimension (see Table 5). In addition, 'warning' (A), 'double click/execution' (E) and 'exit/closing window' (F) as auditory icons in Figure 1(b) are not well matched with the typology of 8 abstract concepts in Table 4, in terms of dimension (see Table 5). Other icons except for these 5 icons are well matched with the typology of 8 abstract concepts (see Table 5).

4. **Conclusions and Discussion.** Based on the results of two experiments, we can compare the associations among abstract concepts in HCI contexts with those among visual and auditory icons. It is concluded that the associations among abstract concepts in HCI contexts are not the same as those among visual and auditory icons, even though each of visual and auditory icons are well matched with each of abstract concepts. For example, the abstract concept of 'click/selection' belongs to 'static (activity) and front of mind (priority)', but the visual icon of 'click/selection' is located in 'dynamic (activity)



(a) Visual icons



(b) Auditory icons

FIGURE 1. MDS results for visual icons and auditory icons

and front of mind (priority)', even though the abstract concept of 'click/selection' is well matched with the visual icon of 'click/selection'. It is presumably because the visual icon of 'click/selection' is cognitively very close to the visual icon of 'double click/execution', which is located in 'dynamic (activity) and front of mind (priority)'. It can be interpreted that the meaning of 'click/selection' is 'static (activity) and front of mind (priority)',

TABLE 5. Comparison between MDS results and typology of abstract concepts

Icons	Well matched	Mismatched
Visual icons	Warning (A) Input/Typing (D) Double click/Execution (E) Exit/Closing window (F) Maximizing window (G) Minimizing window (H)	Click/Selection (B) Completed execution (C)
Auditory icons	Click/Selection (B) Completed execution (C) Input/Typing (D) Maximizing window (G) Minimizing window(H)	Warning (A) Double click/Execution (E) Exit/Closing window (F)

but users recognize the visual icon of 'click/selection' as a relatively similar object to the visual icon of 'double click/execution'. Therefore, when we design an icon, we do not need to only examine whether the newly designed icon is well matched with the abstract concept that it aims to represent, but also investigate the cognitive association of the newly designed icon with other existing icons based on visual or auditory characteristics.

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