COGNITIVE CHARACTERISTICS OF HARD-OF-HEARING STUDENTS USING E-LEARNING MATERIAL

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ABSTRACT

This paper reports on experiments investigating how hard-of-hearing students use e-learning education material for procedure learning and suggests requirements of usable e-learning material for these students. For the experiment, we developed course material that consists of an instruction window displaying balloon instructions and demonstrations, and a workspace window where the learners replicate the demonstrated operations. We recorded the eye movements of 20 hard-of-hearing students and 20 normal-hearing students while they were using the experimental course material, and investigated their use of the balloon instructions. We transcribed their interaction in terms of 32 operations categorized in four classes: 1) eye movement without operation, 2) instruction reading, 3) instruction control, and 4) operation on the workspace. We found that even if they accomplished the course material objectives, hard-of-hearing students did not use the material as the designer intended, i.e., 1) observe demonstration, 2) read balloon instruction, 3) stop the movie, 4) reproduce the demonstration on the work window, 5) restart the material. Possible improvements include providing a list of procedures or stopping the material before proceeding to the next unit and having the students select "replay" or "proceed."

KEYWORDS

E-learning, Eye-tracking, Course material, Design, Hard-of-hearing.

1. INTRODUCTION

E-learning educational material is ideal for hard-of-hearing students because it can accommodate both textual information and visual information such as sign language. In addition, it enables hard-of-hearing students to replay the parts they could not understand because of the overload of visual information processing needed to process both the "natural" visual content and the visual substitutes for "natural" audio content. Learning includes procedure learning and fact learning. Hilzensauer (2010) argues the effectiveness of e-learning contents for language acquisition that emphasizes fact learning. However, there is little study on e-learning content of procedure learning for hard-of-hearing students. Procedure learning requires coordination of perception-cognition-motor processes, and therefore audio content plays a more important role than in fact learning. This study is about the development of e-learning material for procedure learning and the pilot test for evaluating its usability. Students with hearing problems use visual information as their primary source of information. Our previous studies demonstrated that they tend to rely more on image information than text information. This is probably because their primary language is "spatial" language such as sign language and gestures, and the primary language for hearing people, text language, is not counted as the primary but secondary. This is pointed out by Debevc, Kosec, and Holzinger (2010) who studied the effectiveness of communicating Web information by means of sign language. However, a disadvantage of using sign language in e-learning material for procedure learning is that it occupies a large area of the computer display. A typical application uses a 352 pixel by 240 pixel window for presenting sign language. E-learning material for procedure learning needs to display the explanation of the procedure next to its demonstration. It would be difficult to provide a window for displaying sign language without interfering with the demonstration. A compromise is to superimpose the explanation in text next to the demonstration, which we adopted for our e-

ISBN: 978-972-8939-38-0 © 2011 IADIS

learning content design. Macio (2009) suggested that, in order to develop effective e-learning material for hard-of-hearing students, their cognitive characteristics must be considered. In procedure learning, this is more of a challenge than in fact learning because we need to deal with content that represents the procedure.

We developed e-learning material for procedure learning that uses balloon instructions in text in place of audio instructions. The parameters that should influence its usability were the content of text instructions in balloons and the timing of when to display the balloons. In order to evaluate its usability, we conducted eye-tracking experiments and recorded the student eye-movements as well as mouse and keyboard operations. The participants were 20 hard-of-hearing university students and 20 hearing university students. In this paper, we report the results of preliminary analysis by using the data from two hard-of-hearing participants and one hearing participant who smoothly used the e-learning material. Namatame and Kitajima (2011) reported the results from the viewpoint of interaction times. This paper provides qualitative analysis for proposing an ideal way of using e-learning material for procedure learning by employing the previous quantitative analysis.

2. EYE-TRACKING EXPERIMENT

Material. We developed an experimental e-learning system for hard-of-hearing students, for use as course material for studying interactive authoring software. The system consists of an instruction pane providing instructions as demonstration in a balloon, and a workspace pane in which students perform the task at his or her pace, based on their understanding of the instructions (Fig. 1). The course material is regarded as a preliminary version and is improved through iterative design.

The course teaches basic procedures for creating a scene by using interactive authoring software application in which a circle is gradually changed to a rectangle. The learner is expected to play the course material, stopping it wherever he/she wants and replaying it if necessary to understand what he/she should perform on the workspace pane.

Participants. We recruited 20 congenitally hard-of-hearing Japanese people (13 males and 7 females; mean age = 21.7 years, standard deviation = 0.75) and 20 Japanese people with normal hearing function (15 males and 5 females; mean age = 24.6 years, standard deviation = 3.11). All the hard-of-hearing participants were undergraduate students at Tsukuba University of Technology, where one of the entrance criteria is hearing loss of 60dB or more. The hard-of-hearing participants typically used manually signed Japanese and/or lip-reading for communication.

Stimuli. The e-learning course material was displayed on a 17-inch LCD monitor and viewed at a distance of 55cm, subtending 20 degrees of visual angle (27cm) vertically and 36 degrees of visual angle (54cm) horizontally (Fig. 2).

Eye tracking. Eye movements were recorded at a sampling rate of 60Hz using a Tobii T-60 eye-tracker, which has an average gaze position error of 0.5degrees and near-linear output over the range of the monitor used. Only the dominant eye of each participant was tracked, although viewing was binocular.

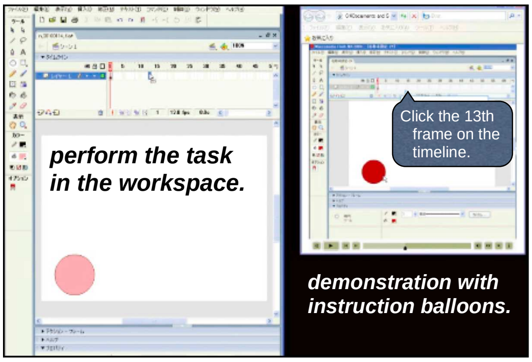

Figure 1. Screenshot of the e-learning course material

Figure 2. Snapshot of eye-tracking experiment

Procedure. The participants were required to understand the instructions displayed on the right instruction pane as a demonstration of instruction texts in balloons, and then perform the task in the left workspace pane, based on their understanding of the instructions. The participants freely controlled the system. The system recorded the participants' eye movements and mouse operations until they completed the course material or 20min had elapsed.

Contents. The task consisted of five study units, 1) Draw a circle as in the figure before transformation, 2) Create a key frame to define the duration of the transformation, 3) Draw a rectangle as in the figure after the transformation, 4) Create an animation, and 5) Verify the animation.

3. RESULTS

In order to understand how the participants actually used the e-learning material, we transcribed the participants' behavior as a sequence of 32 primitive operations that were categorized into the following four categories: 1) eye movement without operation, 2) instruction reading, 3) instruction control, and 4) operation on the workspace. Figure 3 depicts the operation sequence of the hearing participant who accomplished the task in the shortest time. The labels on the horizontal axis indicate the task unit along the elapsed time after starting the task. The labels on the vertical axis indicate the 32 operations arranged in the four primitive operation categories. This plot clearly demonstrates that this particular participant used the e-learning material as the designer intended. Namely, he used the material in the following sequence: 1) observe demonstration, 2) read balloon instruction, 3) stop the movie, 4) reproduce the demonstration on the work window, 5) restart the material.

Figure 4 plots the gaze times of this participant for each of the 14 balloon instructions (diamond-shaped symbols). This participant read some instructions twice, and the rest of the instructions once. The average gaze time per instruction was 1462msec. We considered the performance of this participant as the ideal performance for efficiently using this e-learning course material; it should be regarded as the reference to be compared with the performance of those who less efficiently but successfully used the e-learning course material.

As the first step of iterative design, we chose two hard-of-hearing participants who completed the course material within the time limit and compared their performance with the ideal one. Since we were interested in the design of balloon instructions, our analysis focused on gaze times on the balloon instructions. Figure 3 plots the gaze time for hard-of-hearing participants A (squares) and B (triangles). Participant A briefly dropped her gaze on balloon instructions 3, 4, and 8, with an average gaze time of 468msec per instruction. Participant B looked at instructions 2, 4, 5, 6, 10, and 11 with the average gaze time of 1335msec per instruction. Participant A looked at only a fraction of the entire series of balloon instructions with much shorter reading times than the most successful hearing participant. Participant B looked at only half of the instructions with shorter reading times than the most successful hearing participant. The performance of the most successful participant confirmed that use of the balloon instructions was possible. However, the less efficient hard-of-hearing participants did not use the balloon instructions as expected. They simply seemed to replicate what they had seen in the demonstration without making full use of the textual information explaining the demonstration.

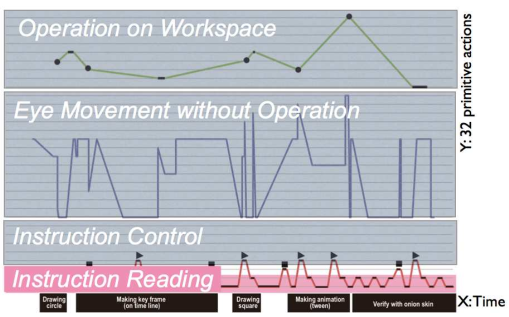

Figure 3. Actions of the best performance .

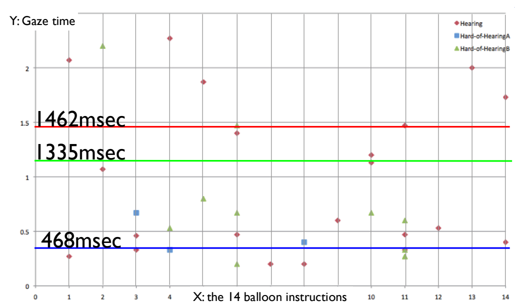

Figure 4. Gaze time for reading balloon instructions.

4. DISCUSSION AND CONCLUSION

The two hard-of-hearing students accomplished the course material objective. However, they did not use the material as we intended. We designed the material on the assumption that the students first observe a study unit that consists of demonstration accompanied with balloon instructions then replay the demonstration on the workspace window. Their interaction did not match this scenario. They seemed to just observe the demonstration to remember and try to reproduce it by resorting to memory. They didn't utilize the balloon instructions much and failed to stop the material in a timely manner. Eventually, they stopped the material at places where they could not recall the material. This tendency was observed in our previous study on Web usability (Namatame, Nishioka, and Kitajima, 2006).

The experiment results are useful for improving the material. It seems that it was difficult for the hard-of-hearing students to control the progress of the material by themselves. Therefore, the e-learning material must provide explicit cues for them to be able to stop the material where appropriate. Solutions include providing a list of procedures or stopping the material before proceeding to the next unit and having the students to select "replay" or "proceed." However, it should be noted that the results were from the analysis of three participants who smoothly accomplished the course material objective; he remaining 20 participants there were 40 participants, could not accomplish it for several reasons.

However, the primary reason for the failure of participants with hearing problems is that they could not follow the standard method of using e-learning course material. In addition, the analysis provided in this paper did not consider the degree of difficulty of operations. For example, the standard procedure of drawing a circle was a kind of acquired operation, and therefore there is no need for providing detailed instructions. In contrast, a "new" operation such as preparing a timeline requires detailed instructions. These improvements have to be made while remembering that some students can accomplish the task without following the standard method for using e-learning course material.

ACKNOWLEDGEMENT

This research is supported in part by JSPS Grants-in-Aid Scientific Research (0034440, 21300301).

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