Designing Course Material Using Interactive Authoring Software Application for Hard-of-Hearing Students

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Abstract. This paper reports on an eye-tracking study that focuses on the usage of interactive course material for designing e-learning course material that imposes the least cognitive burden on learners. We developed experimental course material using interactive authoring software for our students who have hearing difficulties. The material consists of an instruction pane displaying balloon instructions and demonstrations, and a workspace pane where the learners replicate the demonstrated operations. The students were supposed to comprehend the instructions and map their understanding of the operations in the workspace. 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 found that the hard-of-hearing students had difficulty using the e-learning system, probably due to their cognitive characteristics (e.g., difficulty processing the textual information used in the balloon instructions). We proposed an improved design of the e-learning course material that would be useful for hard-of-hearing students.

Introduction

E-learning is an ideal format for self-paced learning. Instructions and exercises are provided by the e-learning system, and the learner responds. Learning is a cognitive activity for acquiring knowledge that may be declarative (i.e., “know that”) or procedural (i.e., “know how”). An *interactive* e-learning system is promising for procedural knowledge, which is defined by a sequence of primitive operations for accomplishing a goal by demonstration. For example, instructions for enlarging a rectangle might be a sequence of such operations as *point to the left-bottom corner of the rectangle using the arrow pointer*, *drag the selected corner by holding down the mouse button*, and *release*. Such a system provides instructions by means of text in balloons and/or narration from the system or a “human” instructor. The timing of providing instructional texts is crucial for the use of an interactive e-learning system for procedural knowledge. Therefore, some classes that make use of e-learning systems have human instructors who can provide instructions for the next operation in a timely fashion by monitoring their students’ progress.

The first author teaches a class of students who have hearing problems. Since interactive e-learning is an ideal format for the class, she decided to develop course material using interactive authoring software. She followed what Debevc, Kosec, and Holzinger (2010) did, who pointed out that the use of images of sign language in e-learning materials should facilitate hard-of-hearing students’ learning because their primary language is not textual language. A majority of currently available e-learning contents focus primarily on language acquisition (Hilzensauer, 2010). However, the knowledge we need to teach at a class is procedural one, therefore it is critical to synchronize the presentation of learning contents with the reactions of the learners. The crucial issue is that it is not effective to present the demonstration of procedure at one place and its explanation in sign language at a different place: It is impossible for a learner to pay attention to both at the same time in order to comprehend the contents of the learning material. It is possible to locate the image of sign language next to the presentation of learning contents, however, but the image of sign language may hide the learning contents. Therefore, we decided to use textual explanation in place of sign language that is presented as the learner proceeds. However, in an interactive e-learning system for hard-of-hearing students, "instructions cannot be provided via audio, but only via text." Traditional interactive e-learning systems are not designed on the assumption that the learners cannot hear. The e-learning contents we will develop must be designed by considering the characteristics of hard-of-hearing students information literacy which would be related with the fact that they have hearing problems (Macio, 2009).

We aim to design an e-learning system that consists of an instruction pane demonstrating a sequence of operations to accomplish a task, and a workspace pane where students perform the operations according to their comprehension of the instructions. It is expected that the students can acquire the procedural knowledge needed to use the software by doing it themselves according to their comprehension of the instructions. The purpose of the e-learning material is to help students master the basic operations of a standard multimedia authoring application with minimal cognitive cost (e.g., the cost of comprehending the contents of the instruction pane, the cost of transferring the results of comprehension to the operations in the workspace pane, and the cost of verifying the result of operations by comparing it with what appears in the instruction pane). The students perform the processes of comprehending the instruction, creating a set of goals, and accomplishing the goals one by one in the workspace pane. These processes are not easy. According to the LInked model of Comprehension-based model of Action planning and Instruction taking (LICAI) model by Kitajima and Polson (1997), the user creates multiple task goals when reading and comprehending instructions, selects the most appropriate goal for the situation, and then selects an action to accomplish that goal. The LICAI model predicts that learners will interact with the e-learning system in a variety of ways. The representation of task goals depends on the learner's background knowledge, the result of the goal selection process depends on the learner's understanding of the task situation displayed in the workspace pane, and the result of action selection depends on the selected goal and on the learner's understanding of the task situation displayed in the workspace pane.

Another issue we must take into account when designing and evaluating applications for hard-of-hearing users is that the users are students with hearing problems. Our previous study on Web usability for hard-of-hearing users (Namatame, Nishioka, and Kitajima, 2006) demonstrated that they have difficulty processing textual information; therefore, it is difficult for them to perform tasks on Web pages where the objects are not easy to parse into semantically related groups. In other words, they have difficulty understanding the task they are instructed to accomplish. They tend to group objects based on visual features because they use different cognitive processes than hearing persons when examining visual information (Wilson and Emmorey, 1998), and they rely more heavily on visual representation than on textual representation when examining the contents of Web pages (Namatame and Kitajima, 2008; Namatame and Kitajima, 2009). However, in our previous study, it was not always useful to advance the task. Some pages did require semantically appropriate parsing to perform the tasks efficiently. We found that slight modifications (e.g., adding auxiliary lines to support semantically appropriate parsing and using easy-to-understand words) dramatically improved the hard-of-hearing participants' performance in terms of task completion time and number of errors, which was comparable with that of normal participants. Ideas regarding how to revise the original design came from detailed comparison between the performance of hard-of-hearing participants and that of normal-hearing participants by recording their eye movements and mouse operations while they were performing the tasks.

The purpose of this study was to design an interactive e-learning system for studying the procedural knowledge that is necessary for hard-of-hearing students to use interactive authoring software. Considering the potential diversity of the system's usage, we determined that a practical way to design a useful interactive e-learning system for procedural knowledge is iterative design (i.e., design a preliminary version of the system and examine its usability to obtain useful feedback for improvement). Our system uses text in balloons rather than audio to provide instructions. The usability of the system depends on the design of the balloon instructions (i.e., their contents and timing). Mouse and keyboard interaction logs are not sufficient for usability evaluation;

instead, interaction with the balloon instructions is an important source for evaluation. Therefore, we recorded participants' eye movements while they used the preliminary version of the system. Half of the participants were hard-of-hearing, and the other half were normal-hearing. This paper reports on an eye-tracking study for designing course material using interactive authoring software for hard-of-hearing students.

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.

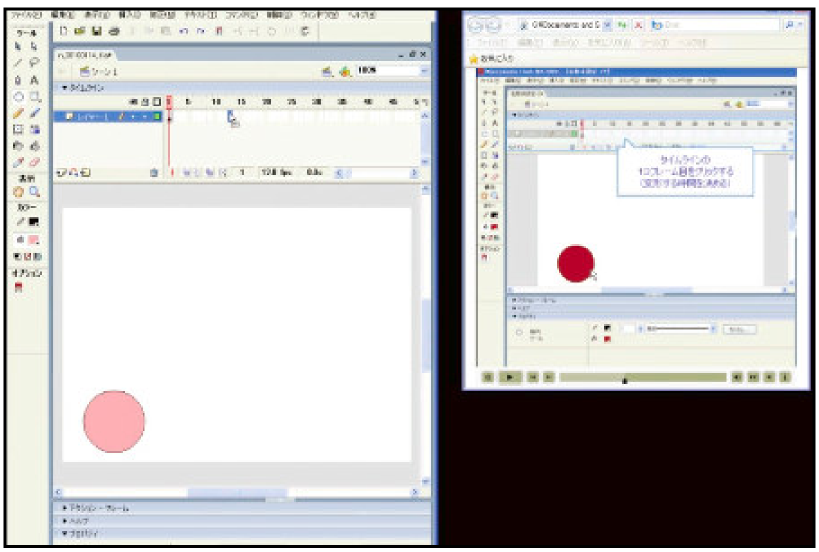

Fig. 1. Screenshot of the e-learning course material when the third balloon instruction, "Click the 13th frame on the timeline," is displayed on the instruction pane.

Table 1. Teaching units and balloon instructions.

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
Purpose	Draw a circle as in the figure before transformation.	Create a key frame to define the duration of the transformation.	Draw a rectangle as in the figure after the transformation.	Create an animation.	Verify the animation.
Balloon Instructions	1. Select the tool for drawing a circle. 2. Draw a circle by dragging the tool.	3. Click the 13th frame on the timeline. 4. Click on the "Insert" menu item and keep pressing. 5. Wait until the "Timeline" submenu appears. 6. Select "Blank	8. Click the 14th frame on the timeline. 9. Select the tool for drawing a rectangle. 10. Draw a rectangle by dragging the tool.	11. Select the frame to start the transformatio n. 12. Set "tween." 13. Select the "Shape" item.	14. Verify by means of "Onion Skin."

		Key Frame (B).” 7. Verify that 13 frames are created.			

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 course consists of five units containing two, five, three, three, or one balloon instruction. Table 1 indicates the purpose of each unit and the balloon instructions. 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. After completing the teaching units on the workspace pane, the learner continues to play the new teaching units.

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. The experiment procedures were approved by the internal review board of the Tsukuba University of Technology, and written informed consent was obtained from all participants prior to the experiment.

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.

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. Eye fixations were manually calibrated at the beginning of each session using a 9-point fixation procedure as implemented in the Tobii Studio software, and drift correction was performed for each trial.

Procedure. Before starting the experiment, the participants were asked to perform the practice task “move a circle,” to learn how to use the e-learning system. They 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. After they completed the practice task, the experimental e-learning course material was started by the Tobii Studio software (ver. 2.1.12, Tobii Technology, Stockholm, Sweden), and 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.

Results

Table 2 indicates the participants’ performance in terms of success/failure in completing the course material. Eleven hard-of-hearing participants and nine normal-hearing participants successfully completed the course material within 20min. Since the course was apparently difficult for everyone, it requires improvement. We assumed that the participants who completed the course smoothly would have an efficient strategy for learning the course material. One way to improve the course material would be to teach the specific efficient strategy, along with the contents of the course material, to the learners. For this purpose, we examined the performance records of the participants who completed the course and tried to understand their efficient strategy.

Table 2. Number of participants who could or could not complete the e-learning course material.

	Successfully completed the course		Failed to complete the course	
	Male	Female	Male	Female
Hard-of-Hearing	6	5	7	2
Normal Hearing	6	3	9	2

Figure 2 depicts how the participant who had the best performance used the e-learning course material as a sequence of 32 primitive actions, which were classified into four categories: visual actions to read instructions (Actions 1 and 2), manual actions to control instructions by using buttons (e.g., Stop or Play) (Actions 3 through 8), visual actions to observe the objects in the workspace pane (Actions 9 through 23), and manual actions to operate on the objects in the workspace pane (Actions 24 through 32). By carefully analyzing eye movement, we found that this participant efficiently used the course material by first reading the balloon instructions and observing the demonstration, and then performing the task in the workspace pane.

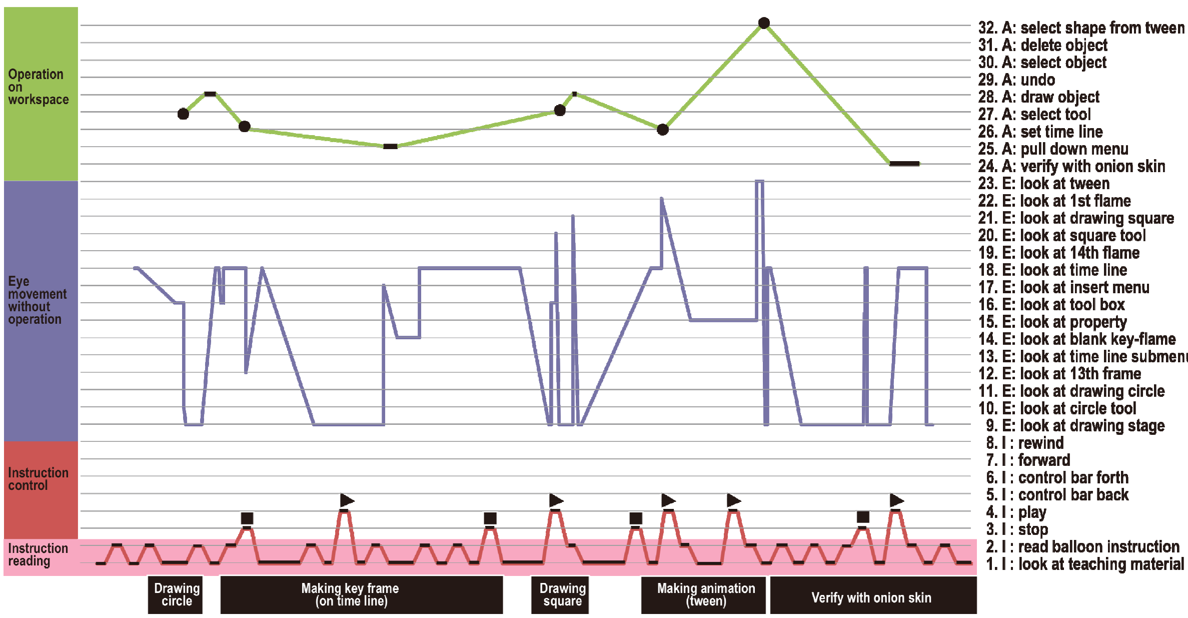

Fig. 2. Representation of the most successful participant's use of the course material with 32 primitive actions

Figure 3 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.

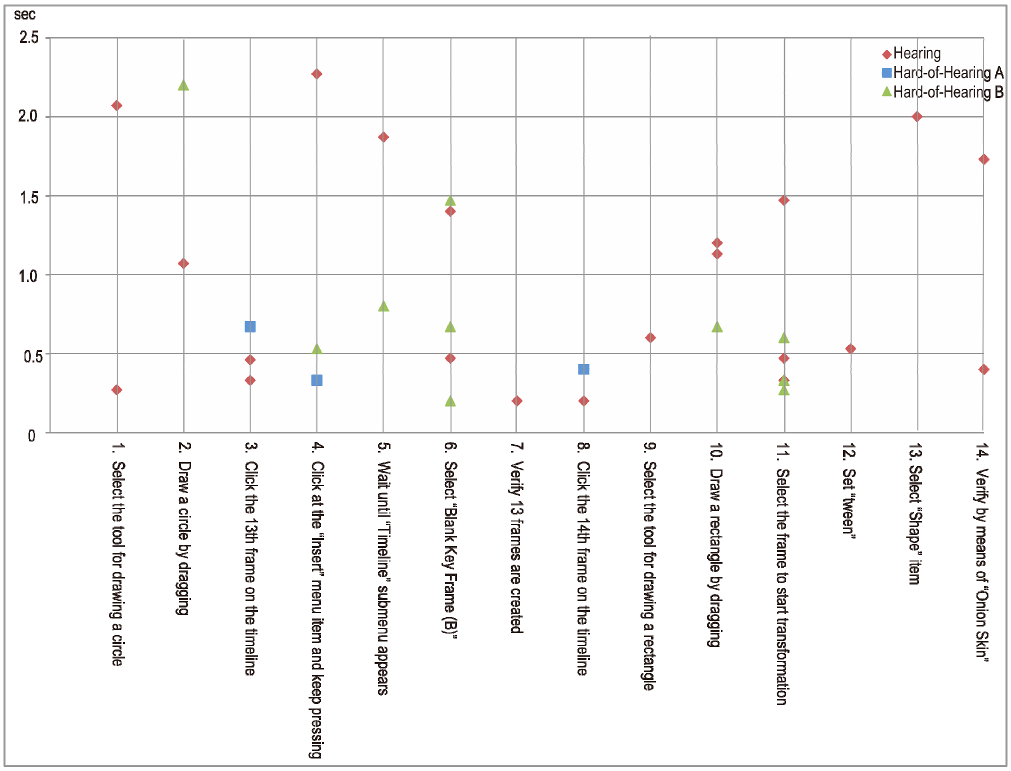

Fig. 3. Gaze time for reading balloon instructions.

Discussion and Conclusion

Although data analysis has just begun, it is clear that the results are consistent with those of our previous study on Web usability for hard-of-hearing users (Namatame, Nishioka, and Kitajima, 2006). The key finding was that hard-of-hearing users were not good at obtaining information necessary to perform a task from textual representation; instead, they tended to rely on graphical or image representation. With e-learning course material, hard-of-hearing participants tended to use demonstration, which is a form of image representation that has the same features as the sign language that they use in their daily communication. We expected our participants to adopt standard strategies when using an interactive e-learning system to learn procedural knowledge (i.e., read instruction and observe demonstration on the instruction pane, then replicate the demonstrated operations on the workspace pane). However, we found that even if the participants completed the e-learning course material, which might lead to a wrong conclusion that the system is successful, they did not follow the standard procedure that the course designer intended. Individuals with hearing problems may have difficulty following standard procedures but rely more heavily on *just* demonstration.

One way to improve an e-learning system for procedural knowledge for hard-of-hearing users would be to design a system without textual explanation. However, such a system would not efficiently teach them procedural knowledge that applies not only to the demonstrated case but also more widely to similar situations. Transfer of learned knowledge is important. Therefore, we need to design e-learning course material that takes into account the cognitive characteristics of hearing-impaired users. One possible solution is to force the user to read instruction by providing an appropriate cue, followed by a demonstration of what was instructed, and then prompt the user to replicate the procedure in the workspace pane. In other words, an improved system would combine the concept of self-paced learning, an important feature of an e-learning system, with that of system-paced learning.

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