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Gaze Analysis and Subjective Assessment of Learners Observing the Writing Process

Yasuhisa OKAZAKI [a*], Senju NOGUCHI [b] & Atsushi YOSHIKAWA [c]
[a] *Graduate School of Science and Engineering, Saga University, Japan*
[b] *Department of Information Science, Saga University, Japan*
[c] *Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, Japan*
* okaz@ai.is.saga-u.ac.jp

Abstract: We used subjective assessments from learners as well as eye trackers for gaze analysis to investigate and analyze differences between two cases: when learners were presented with a writing process, such as on a chalkboard, and when only the final results of writing were presented. The results indicate a relation between subjective learner assessment and gaze. More specifically, there were differences in gaze between learners who reported that watching the writing process was beneficial to learning and those who reported otherwise. We discuss the influences on understanding that result from showing the writing process and propose new ideas for presentation named "information push" and "information pull".

Keywords: gaze, eye tracker, writing process, chalkboard, slide

1. Introduction

As a method of presenting information in class, the slide presentation or chalkboard is often used. Although slides have many benefits, not a small number of teachers and learners prefer classes with traditional chalkboards in preference to presentation slides(Yanagisawa & Fukuda, 2008), and many teachers use their experience, knowledge, and teaching skill to determine how a variety of information should be presented to learners.

One of the predominant features of the traditional methods of presenting information on a chalkboard is that learners watch information presentation as it is being written(Brown, 2012; Jones, et al., 1994). Research is currently being performed that focuses on such features to examine the benefits of presentations that incorporate representations of the writing process(Bandoh et al., 2002; Kurihara, 2006).

We consider that chalkboard presentation represents a visualization of the thought process, and thus is far richer in educational information than simple presentation of final results. Presentation slide has advanced features such as animations, but these features are simply methods for drawing attention or mechanically creating sequential divisions, and do not reflect the structure or thought process behind the object being displayed. Showing this process has meaning with regard to understanding, and is different from presentation of completed forms or mechanical step-by-step presentations.

We focused on learners' gaze as fundamental data for elucidating the benefits of presenting the writing process(Okazaki et al., 2013). For presentation materials, we selected prime factorization and geometric proofs as topics for experimental problems where displaying the writing process can be examined in relation with comprehension of the topic. We used subjective assessments from learners as well as eye trackers (a system for following the path of a person's gaze) (Duchowski, 2007; Ohno, Mukawa & Yoshikawa, 2002) for gaze analysis to investigate differences between the case where learners are presented with the writing process, such as writing on a chalkboard, and the case where only the final results of the writing are presented.

2. Methods

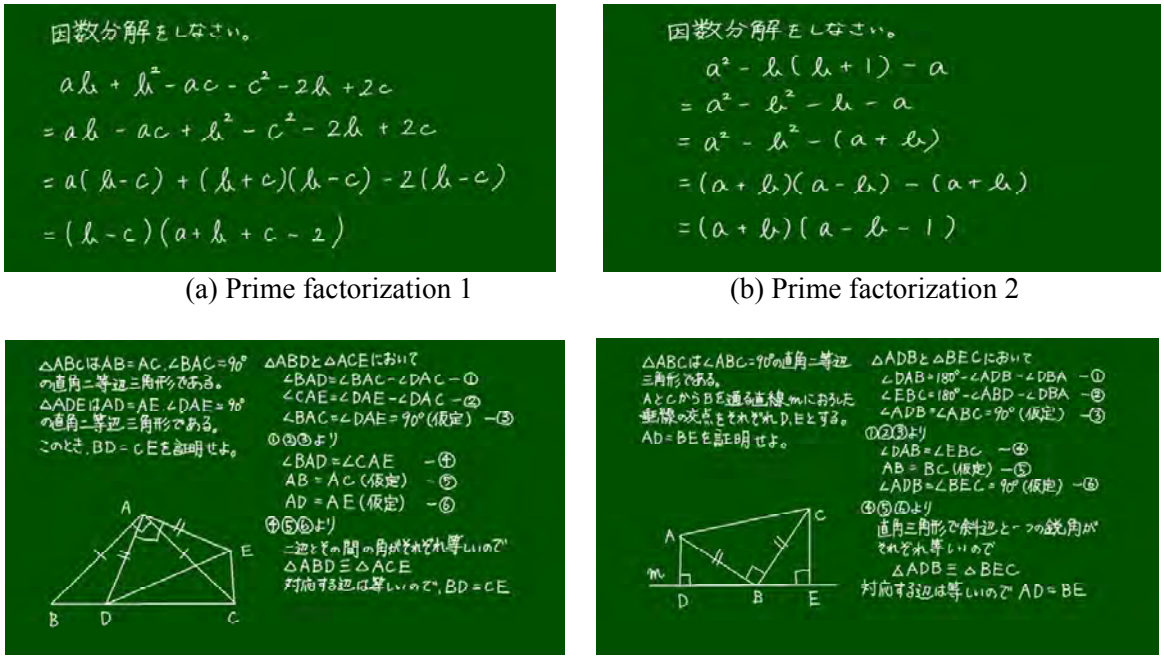
We used the following method to measure participants' gaze. Tobii T60 Eye Tracker was used to track gaze(Tobii T60 & T120 Eye Tracker, 2013). This eye tracing system is a standalone eye tracking unit integrated in a 17-inch TFT monitor. No sensors or other hardware elements are visible to distract the user. The system detects user's gaze by both bright and dark pupil tracking eye tracking technique with 60Hz data rate and typical 0.5 degrees accuracy.

Participant gaze was measured by the following method. There were 16 participants (12 men and 4 women). Experiments were performed over 4 days: November 22, November 29, December 3, and December 10, 2013.

Figures 1 shows the presentation stimuli, which comprised two prime factorization problems and two geometric proofs. Each problem was presented in two ways—a presentation that included the writing process and another that showed only the final results of writing — for a total of eight presentation patterns.

Presenting the writing process provides students with a focal point that learners' gaze can follow. A presentation that includes the writing process reproduces the thought process during problem solving, which likely serves to support comprehension. We created presentation stimuli using a presentation tool, HPT(Handwriting Presentation Tool), currently in development at our laboratory(Hosoki et al., 2011). This tool allows for reproduction of the writing process such as when writing on a chalkboard.

We used Tobii Studio for analysis of gaze data(Tobii Studio, 2013). We used gaze plots for dynamic analysis, and heat maps for static analysis.



(a) Prime factorization 1 (b) Prime factorization 2

(c) Geometric proof 1 (d) Geometric proof 2

Figure 1. Presentation stimuli

3. Results

3.1 Comprehension check results

Figure 2 shows the ratio of correct answers for the comprehension check. Correct answer rates were higher when the writing process was shown for the prime factorization problem 2, but for the other cases, the rates were the same as or lower than when the writing process was not shown. Although we

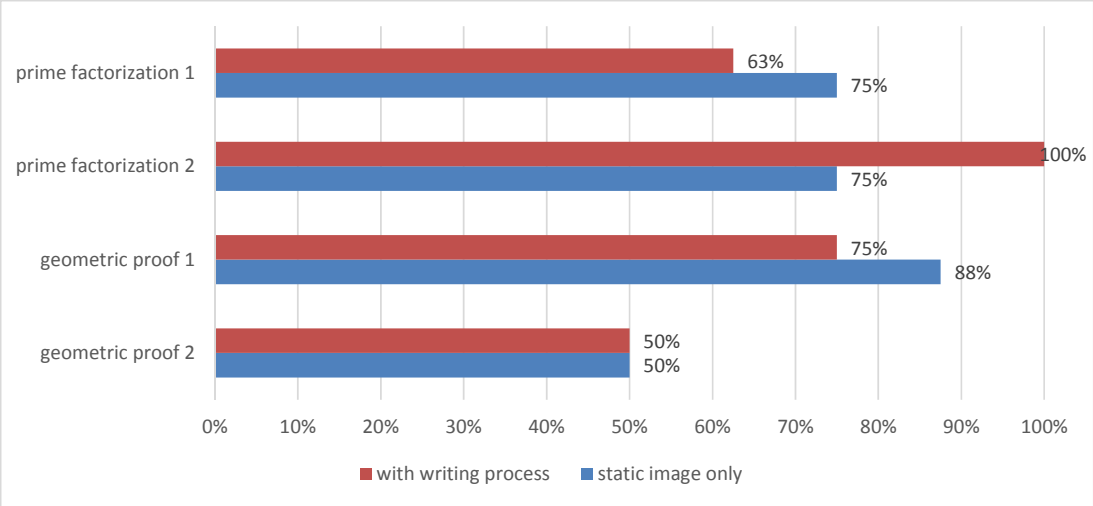


Figure 2. Ratio of correct answers for the comprehension check

Table 1: Questionnaire survey for subjective learner assessment

Writing process is helpful	prime factorization	geometric proof
Strongly agree	2	8
Agree	6	3
Neutral	4	1
Disagree	3	3
Strongly disagree	1	1

predicted that showing the writing process would support student learning, and that this result would be supported by a difference in comprehension check scores, we were unable to obtain data indicating this.

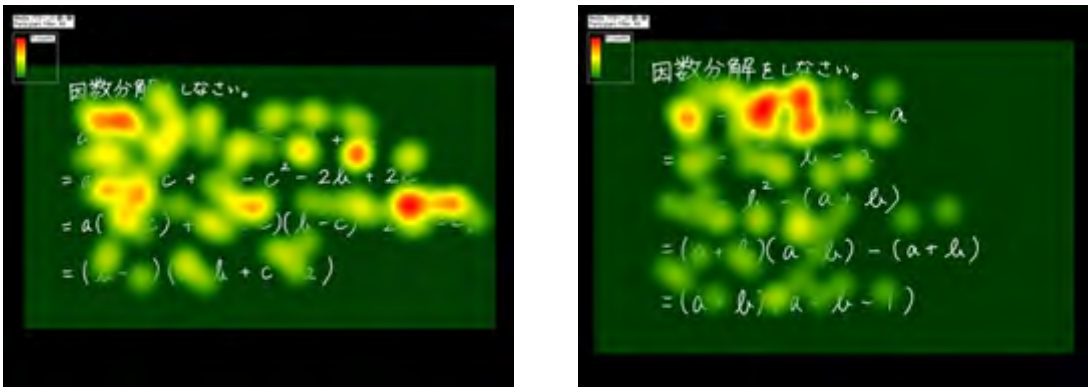
3.2 Subjective assessment

Table 1 lists items in the questionnaire survey used for subjective learner assessment. While no difference was seen in the correct answer rate for the examined problems, a difference was seen in responses to the questionnaire. For both the prime factorization problem and the geometric proof, participants reported that they preferred being shown the writing process. For the geometric proof problem in particular, half of the participants reported a strong preference for being shown the writing process, and when responses indicating a mild preference are included, approximately 70% of students preferred being shown the writing process. In contrast, only about half of the students indicated a preference for being shown the writing process for the prime factorization problem.

3.3 Gaze analysis

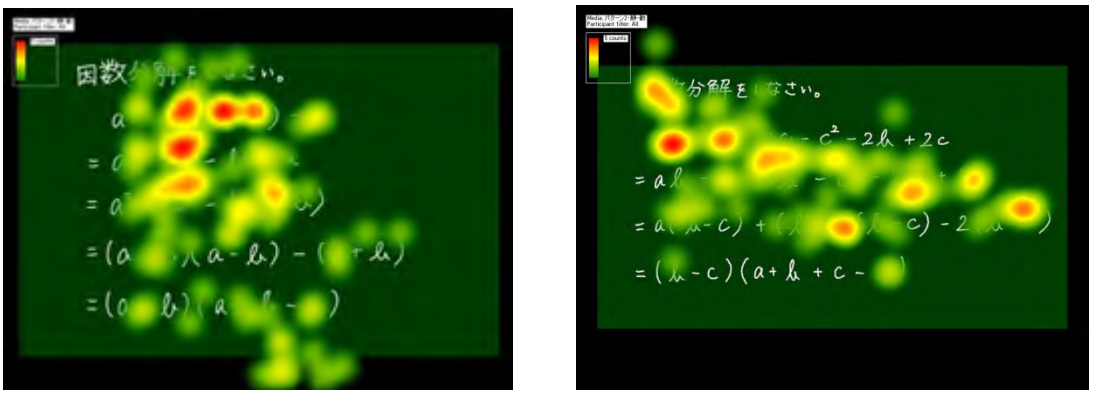
3.3.1. Participants for gaze analysis based on subjective assessment

As described in sections 3.1 and 3.2, we saw no difference in correct answer response rates between the cases where the writing process was or was not shown, but participants tended to prefer being shown the writing process. Upon investigating individual responses regarding this preference for being shown the writing process, we found 4 participants who reported a preference for being shown the writing process for one of the two problem types (prime factorization or geometric proof), but for not being shown the writing process for the other. We selected these 4 participants for a follow-up gaze analysis. We designated the 2 participants who reported a preference for being shown the writing process for prime



(a) The writing process is presented (b) The static image is presented

Figure 3. Heat map examples of participant A



(a) The writing process is presented (b) The static image is presented

Figure 4. Heat map examples of participant C

factorization but not for the geometric proof as A and B, and designated the 2 participants who indicated the opposite preference as C and D.

3.3.2. Gaze analysis for the prime factorization problem

A gaze plot for participants A and B revealed that they followed the writing process when it was shown, but that eye movement was faster and less time was spent examining the presentation when the writing process was not shown. In contrast, the eye movements of participants C and D were slower in both cases, following the presentation when the writing process was shown and reading the presentation more carefully when it was not.

This difference can be seen in the heat maps shown in Figure 3. The heat maps of participants A and B differed between the cases where the writing process was or was not shown. When the writing process was shown the participants were able to focus on the process, and many focal points were seen (Fig. 3(a)). When the writing process was not shown, there was a tendency to quickly scan the entire presentation, indicating that less attention was paid (Fig. 3(b)). In contrast, participants C and D paid close attention to the presentation regardless of whether the writing process was shown, so there was little difference in their heat maps between the two cases(Fig. 4(a)(b)).

3.3.3. Gaze analysis for the geometric proof

No difference in the gaze was seen between participants C and D, who reported a preference for being shown the writing process for the geometric proofs, and participants A and B, who reported a preference for not being shown the writing process for those problems. Analysis of the gaze plots for each of the 4 participants did not show differences in their gazes, but some similar features were observed.

4. Discussion

As discussed above, a difference was seen between participants A and B with respect to their understanding of the process of manipulating the equations for the prime factorization problem. This difference depended on whether they had been shown the writing process, which promoted attention toward the process of manipulating the equation, resulting in differences in eye movement. This might have led to differences in subjective evaluation.

In contrast, participants C and D placed less of a priority on seeing the writing process when manipulating equations for the prime factorization problems, and they showed similar focus even when the writing process was not shown. These indicate that presenting the writing process promoted an attention effect, and that there was an effect of attention neglect when only a static image was presented.

In the case of the geometric proofs as well, when the writing process was presented to show the characters and symbols representing the geometric elements (angles and sides), participants looked at the associated parts in the figure, which might have provided a trigger promoting verification of the relation between the elements in the figure.

In the solution process to the right of the geometric proofs, there were cases where a participant's gaze did not follow the equation manipulation, despite the writing process being shown. This was possibly because the process of equation manipulation was somewhat difficult and proceeded while learners were thinking and making verifications. In other words, it is possible that the presentation of the writing process was too fast, resulting in a loss of effectiveness.

In contrast, when a static image was shown we saw participants looking at the associated parts of the figure after viewing the equations or after looking at several equation manipulations, indicating that they were confirming the summary of what had occurred.

From gaze analysis, we suggest that presenting the writing process provided a focal point for attention and that the speed and timing of that focal point was important. For those participants who indicated a preference for not being shown the writing process, it is possible that the speed and timing of the presentation was not well suited to them.

Showing the writing process allowed for showing the procedures, relations, and ways of grasping the diagram. It also provided focal points, likely providing a mechanism for focusing attention on the process. When the final results were summarized through presentation of a static image, learners shown this information were able to interpret information obtained on their own.

We call the first case, where information including processes is actively provided, "information push", and the second case, in which the recipients (i.e. learners) derive information themselves, "information pull." Showing the writing process is a form of information push, promoting attention and providing explicit information about individual elements and their relations. In this case, the speed and timing of presentation are important, and care must be taken to tailor the presentation to learners. Showing final results as a static image is a form of information pull, and requires that learners derive for themselves the individual elements and their relations. Information pull does not provide attention focuses or processes, but allows for a higher degree of freedom in interpretation. The appropriateness of providing such a degree of freedom likely varies with individual learners.

Information pull is appropriate for learners who can read problems and independently discover their meaning and identify important problem elements and relations. Information push, with appropriate speed and timing, is best suited for learners who require support in making such discoveries.

In courses where instructors write on a chalkboard, the instructors can monitor student responses and thereby adjust the speed and timing of the presentation. We believe that this makes information push effective, thereby leading to an easier-to-understand class.

5. Conclusions and future topics

We have used subjective assessments from learners as well as eye trackers for gaze analysis to investigate and analyze differences between two cases: when learners are presented with a writing process and when they are not. Some participants reported that presentation of the writing process was effective, although others reported that it was not. Differences in gaze were seen between these groups, and we found the possibility that presentation of the writing process can lead to better ease-of-understanding under certain conditions.

Presentation of the writing process provided learners with focal points for attention and let them see how to grasp the subject matter and relations within it. Those who preferred being presented with the writing process were likely those who needed support in understanding the presented information. Conversely, those who preferred not to be presented with such an active display of information were likely those who found it to be a restriction on their free interpretation.

In cases of high readiness for the displayed information, information pull (presenting the final results) is more appropriate due to the freedom of interpretation it provides. In other cases, information push (presenting the writing process) with appropriate speed and timing may be preferable.

In future research, we will investigate in more detail the cases in which information push and information pull methods of information presentation are more effective. We will also perform actual experiments to investigate these differences, thereby revealing how these two methods of information presentation should be implemented.

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