Running Title: Eye-tracking perspectives of students' learning trough MOOCs

Eye-tracking perspectives of students' learning trough MOOCs

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October 31, 2014

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Abstract [English]

Activating student knowledge (ASK) before receiving learning materials improves their learning outcome (Tormey and LeDuc (2014)). We implement ASK through priming by using two versions of the same pretest in a dual eye-tracking study in a MOOC context. We propose an additional activity, a collaborative concept-map, based on the MOOC lecture to enable the students to reflect on what they learnt. The priming affects the learning gain, individual and collaborative gaze patterns. Textual priming stands better than schema priming in terms of learning outcome. Finally, the pairs having participants with similar gaze to each other have more learning gain.

Keywords

Eye-tracking, Massive Open Online Courses, Student engagement, Dual eye-tracking, Priming

Abstract [French]

L'activation de la connaissance des étudiants (ASK en anglais) préalable à l'accès aux supports pédagogiques améliore leurs résultats (Tormey et LeDuc (2014)). Nous proposonsune ASK s'appuyant sur un amorçage basé sur deux versions du même pré-test, lors d'une étude en double eye-tracking dans le contexte des MOOCs. Nous proposons par ailleurs une activité additionnelle (une concept-map collaborative) basée sur un même MOOC afin de susciter chez les étudiants une réflexion sur leurs apprentissages. L'amorçage impacte les gains d'apprentissage, ainsi que les structures de regard individuels et collectifs. Il apparait qu'un amorçage textuel conduit à de meilleurs gains qu'un amorçage basé sur des schémas. De même, les paires de participants ayant des structures de regard similaires apparaissent avoir de meilleurs gains d'apprentissage.

Mots-clés

Eye-tracking, Massive Open Online Courses, Implication des étudiants, Double eye-tracking, Amorçage

Introduction

In the last two years millions of students worldwide have signed up for Massive Open Online Courses (MOOCs). The major issue for the MOOC researchers are: "how to develop efficient measures to capture the attention and engagement of the students?" and "how to make the learning process more efficient?" We address these two questions using a dual eye- tracking study based on a MOOC lecture and other add-on activities. Before the students attend to the MOOC lecture we use a pretest to prime them about the course content and after they have watched the video we ask them to collaboratively create a concept map based on what they learnt in the MOOC lecture.

We use the method of Activating Student Knowledge using pretest. We compare two versions of priming (Textual and Schema). We capture the attention and engagement of students during the video lecture and during the collaborative activity using eye-tracking. In the present decade, off the shelf eye-trackers have readily become available. Soon the eye-tracking will no more only be a sophisticated research tool.

In this article we present an empirical study that sheds some light on the gaze features of the MOOC learners and the effect of priming the students in two different ways. As we will see, the priming method impacts the learning gain of the students; and the gaze features we propose are efficient enough to highlight the differences between the good MOOC learners from the poor ones.

The rest of this paper is organised as follows. The second section presents the related work from collaborative eye-tracking research and from eye-tracking research in online learning. The third section presents the salient features and research questions from the present study. The fourth section explains the experiment and its variables. The fifth section presents the results. The sixth section discusses the implications of the results. Finally, the seventh section concludes the paper.

Related Work

In this seciton we review the previous work done in the related fields. First we present the findings in the field of eye-tracking and online collaboration. Second, we present the eye-tracking research outcomes from online learning environments.

Eye tracking for online collaboration

In previous studies Jermann, Nüssli, & Li, (2010), Nüssli, Jermann, Sangin, & Dillenbourg, (2009), Liu et al., (2009), Kraljic & Brennan, (2005) have shown that the gaze is predictive of the expertise and/or the task performance. In a collaborative Tetris task, Jermann et al., (2010) showed that the experts focus more on the stack than the novices. In a collaborative Raven and Bongard puzzle solving task, Nüssli et al., (2009) showed that the good performers switch more often between the problem figures and the solution figures than the bad performers. In a collaborative concept map task, Liu et al., (2009) used the gaze data to predict the expertise level of the pair. In a reference disambiguation task, Kraljic & Brennan, (2005) showed that the good performers spent less time on the ambiguous objects then the bad performers. In a collaborative concept map task, Molinari, Sangin, Nüssli, & Dillenbourg, (2008) showed that the gaze is predictive of the mutual modelling of knowledge in a pair. The participants used a knowledge awareness tool, to assess their partners' knowledge, to manipulate their own actions at the concept map. In a collaborative problem solving task, Schneider (2013) showed that the gaze features are predictive of the collaboration quality (a rating scheme proposed by (Meier, Spada, & Rummel, 2007).

In a collaborative task the moments of joint attention are the most important. The moments of joint attention provide the basis of creating a shared understanding of the problem at hand. Making references is a key process to initiate a moment of joint attention. Jermann & Nüssli, (2012); Richardson & Dale, (2005) and Richardson, Dale, & Kirkham, (2007) showed in the different studies how the moments of joint attention affect the gaze of the collaborating partners. The cross-recurrence (the probability of looking at the same thing at the same time) was observed to be higher during the referencing moments than rest of the interaction (Richardson & Dale, 2005; Richardson et al., 2007). Moreover, Jermann & Nüssli, (2012) showed that the pairs with high quality of interaction have higher cross-recurrence during the moments of joint attention.

Apart from moments of joint attention there are many other episodes of interaction during a collaborative problem solving task. These episodes can be based on an underlying cognitive process (Aleven, Rau, & Rummel, 2012; Sharma, Jermann, Nüssli & Dillenbourg (2012)) or dialogues (Gergle & Clark, 2011). In a pair program comprehension study, Sharma, Jermann, Nüssli & Dillenbourg (2012) showed that gaze patterns of the pair can differentiate between the episodes of linear reading and episodes of understanding the data flow of the program. In a collaborative learning task Aleven et al. 2012) showed that the gaze patterns are indicative of the individual and collaborative learning strategies. In a pair programming task Sharma, Jermann, Nüssli & Dillenbourg (2012) and Sharma, Jermann, Nüssli & Dillenbourg (2013); Jermann & Nüssli (2012) showed that certain dialogue episodes correspond to the higher gaze proportions at certain area on the screen. In a collaborative elicitation task, Gergle & Clark, 2011) showed that the movement of mobile partners can help them as a coordination mechanism.

Eye-tracking for online education

Use of eye-tracking in online education has provided the researchers with insights about the students' learning processes and outcomes. Scheiter, Gerjets & Van Gog (2010) emphasises on the usefulness of the eye tracking methods as analytical tools in online education and collaborative problem solving. Sharma, Jermann & Dillenbourg (2014 a, 2014 b) proposed gaze measures to predict the learning outcome in MOOCs. Sharma, Jermann & Dillenbourg (2014 a) uses the low level gaze features (derived from the stimulus) to predict the learning outcome; while Sharma, Jermann & Dillenbourg (2014 b) used the fact that how closely the students follow the teachers' deictic and verbal references to predict the learning outcomes. van Gog & Scheiter (2010) used eye-tracking to analyse multimedia learning process and instruction design. Scheiter, Gerjets & Van Gog (2010) used eye-tracking data to differentiate between conceptual strategies in relation with different expertise levels in multimedia learning. Van Gog, Paas & Van Merriënboer (2005 a) used eye-tracking data to differentiate expertise levels in different phases of an electrical circuit troubleshooting problem and concludes that experts focus more on the problematic area than the novices.

Van Gog, Paas, & Van Merriënboer (2005 b) used eye-tracking data to provide feedback to the students about their action while troubleshooting an electrical circuit and found that the feedback improved the learning outcomes. Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, (2009) found that displaying an experts gaze during problem solving guides the novices to invest more mental effort than when no gaze is displayed. Amadieu, Van Gog, Paas, Tricot, & Mariné (2009) used eye-tracking data to find the affect of expertise, in a collaborative concept map task, on the cognitive load. The authors concluded that the average fixation duration was lower for the experts indicating more cognitive load on experts than novices. In an experiment, where the participants had to learn a game. Alkan & Cagiltay, (2007) found that the good learners focus more on the contraption ares of the game while they think about the possible solutions. Slykhuis, Wiebe, & Annetta, (2005) found that the students spend more time on the complementary pictures in a presentation, than a decorative picture.

Mayer, (2010) summarised the major eye-tracking results on online learning with graphics and concluded that there was a strong relation between fixation durations and learning outcomes and visual signal guided students' visual attention. In a study to compare the affect of colour coded learning material Ozcelik, Karakus, Kursun, & Cagiltay, (2009) found that the learning gain and the average fixation duration were higher for the students who received the colour coded material than those who received the non colour coded material.

Present Study

We present a dual eye-tracking study where the participants attended a MOOC lecture individually and then a pair of participants collaborated to create the concept map about the learning material. We use the pretest to shape the understanding of the participants in a specific way (paying more attention to textual or schema elements in the video). This is called priming effect. One of the major hypotheses for the experiment was that the priming affects the learning process of the students specially their gaze patterns. An parallel (not alternate) hypothesis is that the there are two factors shaping the learning gain of the students: 1) how closely the students follow the teacher? and 2) how well they collaborate in the concept map task? The first factor is important because the more a student follows the teacher, the more (s)he could learn. The second factor is important because the better a student collaborates with the partner, the more the pair could discuss the learning material and have a better understanding. Through this study we explore the following research questions:

Question 1: How does the priming affect the learning outcome of the students?

Question 2: How does the priming affect the gaze patterns and other actions of students while watching video and during collaborative task?

Question 3: How do the gaze patterns and other actions during collaborative task affect the learning outcome of the students?

Experiment

In this section we present the detais about the experiment. First, we present the detaled procedure and tools used for the experiment. Second, we present the detailed description of the independent, dependent and process variables used in the study.

Participants and Procedure

98 students from École Polytechnique Fédérale de Lausanne, Switzerland participated in the present study. The participants were paid an equivalent of CHF 30 for their participation in the study. There were 49 participants in each of the priming condition (textual and schema). There were 16 pairs in each of TT and SS pair configurations while there were 17 pairs in ST pair configuration.

Upon their arrival in the laboratory, the participants signed a consent form. Then the participants took an individual pretest about the video content. Then the participants individually watched two videos about "resting membrane potential". Then they created a collaborative concept map using IHMC CMap tools 1. Finally, they took an individual posttest. The videos were taken from "Khan Academy"2 3. The total length of the videos was 17 minutes and 5 seconds. The participants came to the laboratory in pairs. While watching the videos, the participants had full control over the video player. The participants had no time constraint during the video-watching phase. The collaborative concept map phase was 10-12 minutes long. During the collaborative concept map phase the participants could talk to each other while their screens were synchronised, i.e., the participants in the pair was able to see what their partners' action. Both the pretest and the posttest were multiple-choice questions where the participants had to indicate whether a given statement was either true or false.

Independent variables and Conditions

As we mentioned previously, we wanted to observe the difference in the gaze patterns for different modes of priming. We used a pretest as a contextual priming method. We designed two versions of the pretest. The first version had usual textual questions. The second version had exactly the same questions as in the first version but they were depicted as a schema.

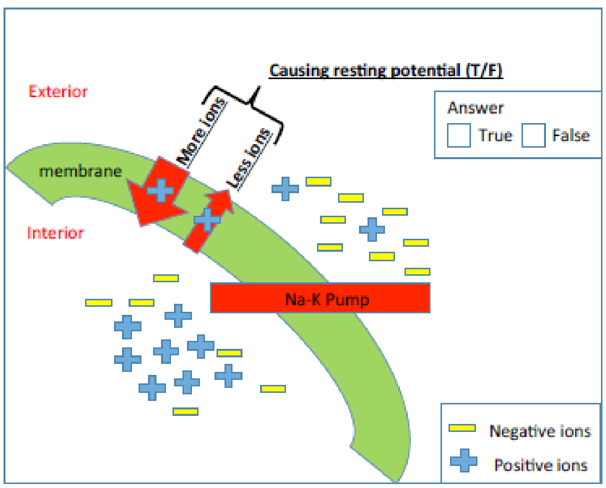

Figure : Example question from the schema version of the pretest.

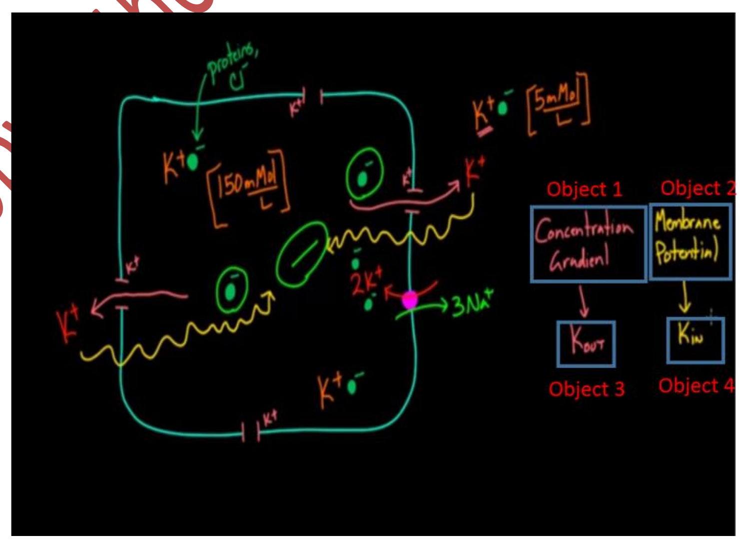

Figure : Example of areas of interest used in the experimental task.

<u>Priming</u>

Based on the two priming types we had two priming conditions for the individual video lecture task: 1) textual priming and 2) schema priming.

Pair composition

Based on the two priming types we had three pair compositions for the collaborative concept map task: 1) Both the participants received the textual pretest (TT); 2) Both the participants received the schema pretest (SS); 3) Both the participants received different pretests (ST).

Dependent variable : Learning gain

The learning gain was calculated simply as the difference be- tween the individual pretest and posttest scores. The miming and maximum for each test were 0 and 10, respectively.

Process variables

Time on video

We measure the total time spent on the video lecture by the participants. As the participants were allowed to interact with the video in any manner they wanted, the time spent on the video is an important variable to compare across the two priming conditions.

Gaze on text

The video lecture had a mix of textual and schema elements. The teacher drew some figures and charts during the lecture and he also made some tables and wrote some formulae. We categorised the tables, formulae and the sentences written by the teacher as the textual elements of the video; and the graphs, figures and charts were categorised as schema elements. We measured the time spent on the textual elements by the paricipants during the video lecture. This helps us verifying our hypothesis concerning the effect of priming on the gaze of the participants.

Gaze compensation index

The fact that the pariticipants in textual priming condition looks less at the textual elements of the video that their schema priming counterparts (see section Results), does not correctly reflect the compensation in the gaze patterns as the schema and textual elements do not appear in the same proportions on the screen throughout the video lecture. Initially, for a few minutes, the video contains only schema elements and later the teacher keeps adding the textual elements. This makes the proportions of schema and textual elements change over time. Hence, we need to take the change into account to compute the real compensation effect. We propose a gaze compensation index to be computed as follows :

$$Gaze\ Compensation\ Index = \sqrt{\sum \frac{\left(\frac{Gt}{Gs} - \frac{Pt}{Ps}\right)^2}{\frac{Pt}{Ps}}}$$

Where,

Gt := Gaze on textual elements in a given time window

Gs := Gaze on schema elements in a given time window

Pt := Percentage of screen covered with textual elements

Ps := Percentage of screen covered with schema elements

Similarity of gaze

The gaze similarity is the measure of how much the two participants in a pair were looking at the same thing at the same time (figure 3) or how similar their gaze patterns were during a short period of time. To compute the gaze similarity the whole interaction (during the collaborative concept map task) is divided into equal duration time windows. For each time window we compute a proportion vector, for each participant, containing the proportion of the window duration spent on each object of interest on the screen. Finally, the gaze similarity is computed as the scalar product of the proportion vector for the two participants in a pair. The gaze similarity is a similar measure as the cross-recurrence proposed by [36] but it is easier and faster to compute.

<u>Asymmetry of action</u>

This measure was first used by Jermann (2004) by the name "Sum of absolute differences". The action asymmetry varies between 0 and +1 and gives an indication about the overall asymmetry of tunings. A value of zero indicates that both subjects did exactly the same number of actions on same objects and a value of +1 indicates that all the actions were done by one subject. The action asymmetry can be calculated as follows:

$$Action\ Asymmetry = \frac{\sum_i |S_1O_i - S_2O_i|}{A_1 + A_2}$$

Where,

S_1O_i := Actions on Object i by participant 1

S_2O_i := Actions on Object i by participant 2

A_1 := Total number of actions by participant 1

A_2 := Total number of actions by participant 2

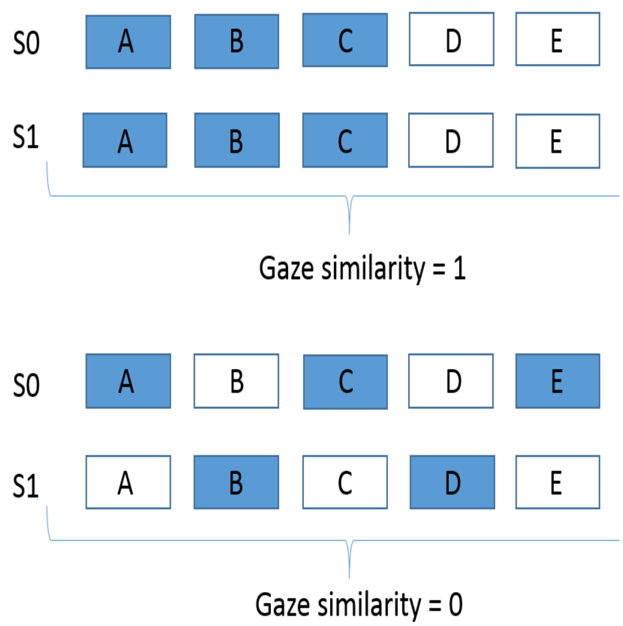

Figure 1: Typical cases while calculating gaze similarity. Filled rectangles show spent time on the object.

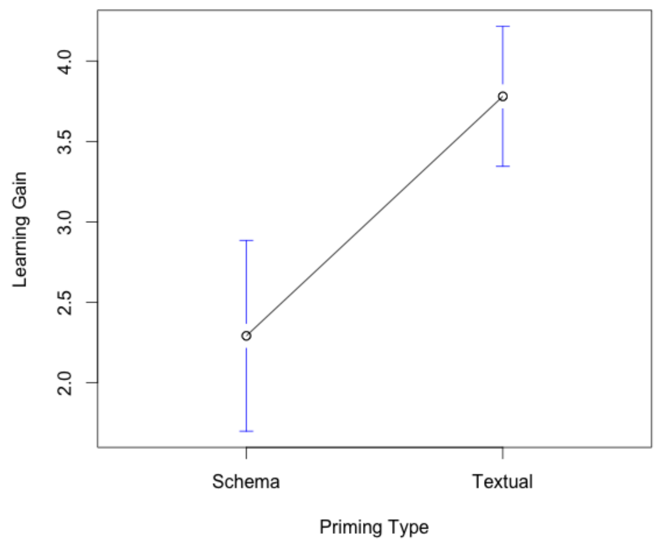

Figure 2: Learning gain for two priming conditions.

Results

In this section we present the relations among the indepandent, dependent and the process variables.

Priming vs learning gain

We observe a significant difference in the learning gain between the two priming conditions (figure 4). The learning gain for the participants in the textual priming condition is significantly higher than the learning gain for the participants in the schema priming condition ($F [1, 96] = 16.77$, $p < .01$).

Pair composition vs learning gain

We observe a significant difference in the learning gain between the three pair compositions (figure 5). The learning gain for the participants in the TT pairs is significantly higher than the learning gain for the participants in the other two pair composition ($F [2, 47] = 5.73, p < .01$).

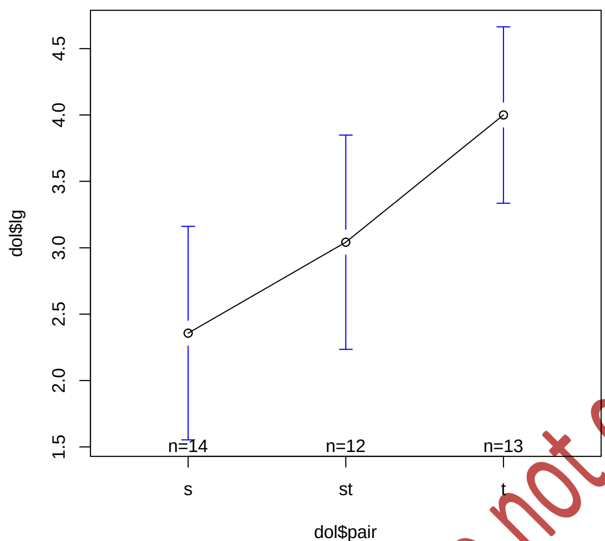

Figure 3: Learning gain for the three pair compositions.

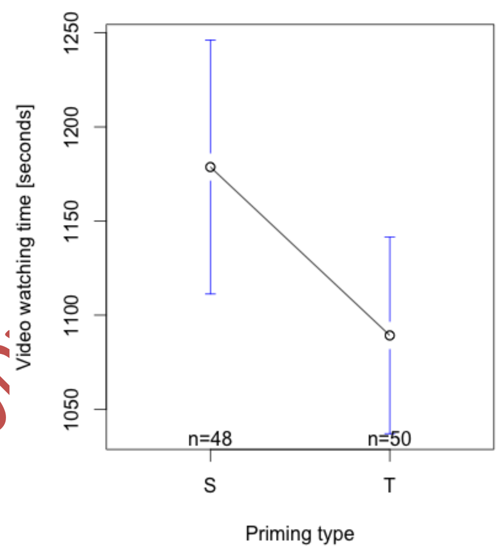

Figure 4: Video watching time (time on task) for the two priming conditions (S = schema priming, T = textual priming)

Priming vs time on video

We observe a significant difference in the time spent on video between the two priming conditions (figure 6). The time spent on video for the participants in the textual priming condition is significantly lower than the learning gain for the participants in the schema priming condition ($F [1, 96] = 4.49, p < .05$).

Priming vs time on text

We observe a significant difference in the time spent on textual elements in the video between the two priming conditions (figure 7). The time spent on video for the participants in the textual priming condition is significantly lower than the learning gain for the participants in the schema priming condition (F [1, 96] = 4.91, p < .05).

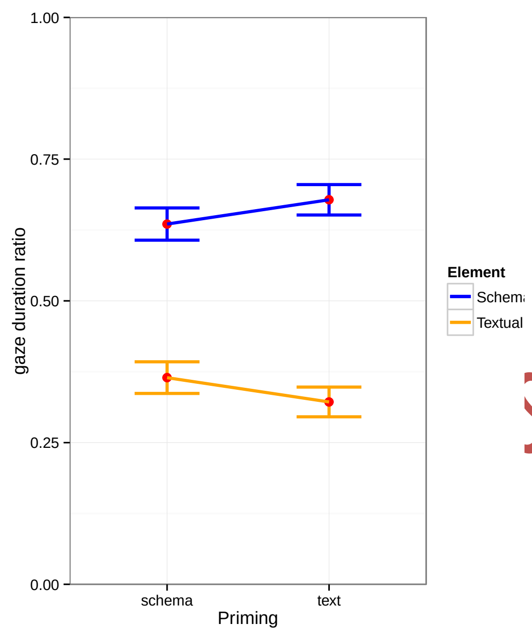

Figure 5: Gaze on different video elements for the two priming conditions.

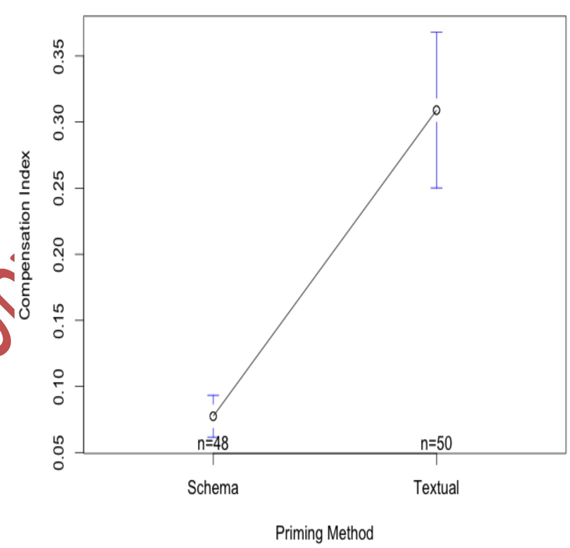

Figure 6: Gaze compensation index for the two priming conditions.

Priming vs Gaze Compensation Index

We compared the gaze compensation index accros the two priming conditions (figure 8). The participants in the textual priming condition have higer compaensation index than the participants in the schema priming condition (F[1,96] = 56.198, p<.001).

Time on video vs similarity

We observe a significant negative correlation between the gaze similarity and the average time spent on the video by the pair ($r(39) = -0.39$, $p < .05$). The pairs having high gaze similarity have low average time on video.

Time on text vs similarity

We observe a significant negative correlation between the gaze similarity and the average time spent on the textual elements in the video by the pair ($r(39) = -0.32$, $p < .05$). The pairs having high gaze similarity spent less average time on textual elements in the video.

Pair vs similarity

We observe a significant difference in the gaze similarity between the three pair compositions (figure 9). The gaze similarity for TT pairs is the highest and the gaze similarity for SS pairs is the lowest ($F [1, 36] = 3.44$, $p < .05$).

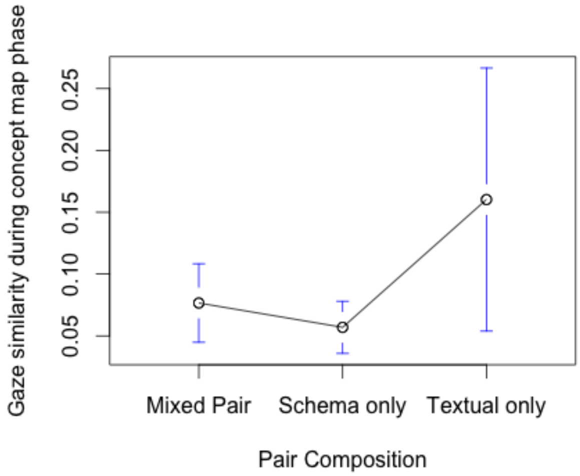

Figure 7: Gaze similarity during the collaborative concept map task for the three pair compositions.

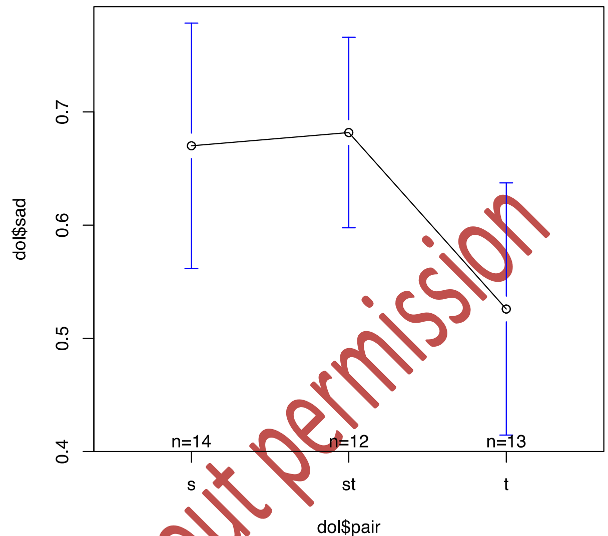

Figure 8: Action asymmetry for the three pair compositions.

Pair vs symmetry

We observe a significant difference in the action asymmetry between the three pair compositions (figure 10). The action asymmetry for TT pairs is significantly lower than the other two pair compositions ($F [1, 36] = 3.41$, $p < .05$).

Symmetry vs learning gain

We observe a significant negative correlation between the action asymmetry and the average larning gain for the pair ($r(39) = -0.39$, $p < .01$). The pairs having higher action asymmetry have lower average learning gain.

Similarity vs learning gain

We observe a significant negative correlation between the gaze similarity and the average larning gain for the pair ($r(39) = 0.39$, $p < .01$). The pairs having higher gaze similarity have higher average learning gain.

Discussion

The research questions we addressed through the present study were about the relationships among the priming, the learning gain, students' gaze patterns and time taken during the video and the pair's gaze similarity and action asymmetry during the collaborative concept map task. In this section we present the plausible explanations for the results presented in the previous section.

The first question concerns the effectiveness of priming on the learning gain of the participants (figures 4 and 5). The learning gain of the participants in textual priming condition is significantly higher than that for the participants in the schema priming condition. Our explanation for this effect is based on the theory of Tormey & LeDuc (2014) about Activating Student Knowledge (ASK) using priming methods. Tormey & LeDuc (2014) compared the students' learning gain with and without the priming in a history lecture. The priming method used in the study was a pretest. We extend the concept by using two different versions of pretest (textual and schema based). The textual method for ASK stands better than the schema method. The reason for the effect on learning gain is that the textual version gives more exact terms to look forward for in the lecture than the schema version of the pretest.

The second question explores the affect of priming on individual gaze patterns during the video lecture and collaborative gaze patterns during the collaborative concept map task. We found that the participants in textual priming condition look more at the schema elements of the video and the participants in schema priming condition look more at the textual elements of the video (figure 6). This is a compensation effect of the priming. We also computed the gaze compensation effect based on the ratio of the textual and schema elements present on the screen and the ratio of the gaze on them respectively (figure 8). The participants in the schema priming condition under-compensate for the priming they received in the video phase and hence they miss some of the key concepts. This can have a detrimental effect on their learning gains.

Moreover, during the collaborative concept map task, the pairs with both the participants from the textual priming (TT) condition have higher gaze similarity than the pairs in other two configurations (ST and SS pairs). Once again, we can expect a better priming effect in textual priming condition than in the schema priming condition. The participants in the TT condition had better priming and they had better compensation for the key concepts from the lecture. This enables them to reflect together on the concepts in the collaborative concept map task and hence they had higher gaze similarity (figure 9).

The second question also considers the individual and collaborative action patterns during the video-watching and collaborative concept map tasks respectively. We found that the students in the schema priming condition spent significantly more time on the video than the students in textual priming condition (figure 7); and the TT pairs have significantly less action asymmetry than SS and ST pairs (figure 10). Having spent more time on the video without a high gaze compensation on the different elements in the video also effects the understanding of the students from the schema priming condition. Moreover, since the students from schema priming condition do not have enough knowledge on the key concepts from the video lecture, they tend to have a poor shared understanding with their partners in the collaborative task as well. This results in a higher action asymmetry and lower gaze similarity during the collaborative concept map task involving at least one student from schema based priming method. On the other hand, the TT pairs had a very clear view on the concepts from video lecture they had better shared understanding during the concept map task and hence they had higher gaze similarity and lower action asymmetry during the collaborative task.

The third question inquires about the effect of the gaze similarity during the collaborative concept map task on the learning gain. The pairs with high gaze similarity also have high average learning gain. This can be explained using the fact that the high gaze similarity indicates a good shared understanding on the concerned topic. Hence, a similar pair (in terms of gaze) discusses the lecture points in a better manner than the pair with low gaze similarity. More specifically, the pair with high gaze similarity works on the same part of the concept map given a time period; hence they develop better shared understanding about the concerned topic. Whereas, the pair with low gaze similarity work on less similar parts of the concept map and hence they fail to have a shared understanding. The fact that having better shared understanding helps reflect on the course content, this also results in a higher learning gain.

Conclusion

We present a dual eye-tracking study in MOOC context. There are two salient features of the study. First, we propose to activate the key knowledge points in the lecture before the lecture using two different priming methods (schema and textual priming). Second, once the students have watched the video, we propose to have them collaborate on a concept map based on what they learnt from the video lecture. We compare the gaze patterns during the video lecture across the two priming conditions and the gaze patterns during the collaborative concept map across the three pair compositions (TT, TS and SS).

We propose a new gaze measure for comparing the gaze patterns on the video lecture as gaze compensation index. This measure tells us that how much the students compensate for their activated knowledge through priming. We found that the students in the textual priming condition has more compensation than the students from the schema priming. This has a detrimental effect on the learning gains of the students.

We also found that the gaze similarity also effects the learning gain of the students in a positive way. Gaze similarity is a measure of how much the students spend time in creating and maintaining a shared understanding while collaborating on the similar parts of the concept map. This shared understaning in tern improves the learning gain of students. However, more research is required to arrive at any causal research as we report only correaltions.

In a nutshell, the results from the study are encouraging enough for continuing research in the direction of prior knowledge activation of MOOC students and having addon activities. The future work for us is to compare the results with a very simple study with no priming and no add on activity in the same setting. Moreover, a gaze-aware feedback system can also help the students better compensate for their prior knowledge activation in a video lecture.

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