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Effect Analysis of Playback Speed for Lecture Video Including Instructor Images

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The goal of this study is to clarify the effects of playback speed for lecture videos whose layouts consisted of slides together with instructor images. In our experiments, a lecture video that included images of instructors' faces was presented at speeds of 1×, 1.5×, and 2× to 59 university students. The results of comprehension tests and a questionnaire survey suggest the possibility that viewing videos at 1.5× speed is more effective for learning than viewing at normal speed. The results of eye-tracking tests to track the focus of 18 university students indicated that the majority of the students spend roughly 10% of the total duration of a lecture video with their eyes focused on instructor images regardless of video speed.

Keywords: High-speed presentation, Information-science education, Instructor images, Lecture video, Online learning

Intoroduction

As the popularity of massive open online courses (MOOCs) continues to grow worldwide in recent years, research efforts dedicated to studying the learning processes of course participants continue to advance. Breslow, Pritchard, Deboer, Stump, and Seaton (2013) studied learning in the MOOC context and showed that, among various modes of learning—including viewing lecture video, taking knowledge-retention quizzes, and participating in discussions on bulletin boards or related forums—the viewing of lecture video consumed the greatest amount of time. Kizilcec, Piech, and Schneuder (2013) showed that many course participants watched lecture video even if they did not take knowledge-retention quizzes or participate in bulletin-board discussions. These findings indicate the importance of the role played by lecture video in MOOC-based learning.

Studies of lecture video in online learning include the work of Guo, Kim, and Rubin (2014), who analyzed a dataset containing some 7 million instances of students watching lecture video on MOOCs. Their results indicated that the number of course participants paying attention to a lecture video begins to decrease significantly for videos of duration greater than 6 minutes, and that many participants prefer lecture videos consisting of both slides and instructor images to videos consisting of slides alone. These findings indicate that, when preparing lecture video, it is important to account for the audience's powers of concentration when determining the duration of the video, and, moreover, that the question of whether to incorporate images of instructors into lecture videos is an important one that requires careful consideration.

Laboratory studies on videos with regard to factors such as length have been conducted and some of these have focused on students' comprehension of high-speed videos (Foulke, 1968; Kurihara, 2012; Vemuri, Decamp, Bender, & Schmandt, 2004; Watamori & Sasanuma, 1974). Regarding the ability of course participants to concentrate on lecture video of various durations, Nagahama and Morita (2017) studied the efficacy of using variable-speed playback functionality to present video at high speed. The ability to play video at varying speeds is available, for example, in the well-known MOOC platform edX, which offers a choice of five playback speeds: 0.5×, 1×, 1.25×, 1.5×, and 2×. In experiments involving a group of 75 university students, a lecture video was presented at speeds of 1×, 1.5×, and 2×, and the corresponding effect on student learning was measured by comprehension tests given before and after the presentation. The results indicated that, under certain fixed conditions, video playback speed variations did not affect learning outcomes. This suggests the possibility that instruction time could be cut by half with no reduction in learning performance.

Meanwhile, studies of the design layout of lecture video for online learning include the work of Kizilcec, Papadopoulos, and Sritanyaratana (2014), who conducted eye-tracking experiment and found that students spent about 41% of their time watching the instructor image when it was shown in the video. They also suggested that students focused on the instructor image longer than on the slides but switched frequently between the two. Morita, Fujishima, Setozaki, and Iwasaki (2011) used augmented reality (AR) technology to test a system in which lecture video was presented on a head-mounted display to compare cases in which instructor images were or were not superposed over the video images. Analysis of the subjective evaluations of learners in both cases indicated that superposing instructor images atop educational video had the effect of significantly enhancing the interest and curiosity of students.

Although these findings indicate the efficacy of design layouts for lecture video in which images of instructors appear together with educational slides, Tominaga and Kogo (2014) pointed out that, in lecture video layouts consisting of slides together with instructor images, the instructor images do not coincide with the slide's point of reference, thereby posing the risk that students will be unsure where to focus their attention. Although this point has been addressed by studies such as that of Sakamoto et al. (2008)—in which lecture imagery captured by video camera were analyzed to identify the image regions occupied by the instructor, which were then superposed atop PC slide images—to date, there have been essentially no studies of instructor images in high-speed playback of lecture video. Therefore, this study focused on the following research questions:

1. How does video speed influence students' learning when lecture videos whose layouts consisted of slides together with instructor images are played at the original speed and at speeds of 1.5× and 2×?
2. How do students' opinions about lecture videos differ according to video speed?
3. How do students watch lecture videos whose layouts consisted of slides together with instructor images when they are played at the original speed and at speeds of 1.5× and 2×?

Research Design & Methods

Creation of Video Images

Design layout of video images. Figure 1 shows the design layout of the video images used in our experiments. Following Guo et al. (2014), we have chosen a video layout consisting of instructor images and presentation slides. We used an interlaced format with a resolution of 1280×1080 and an aspect ratio of 16:9. The background color of the slide was black.

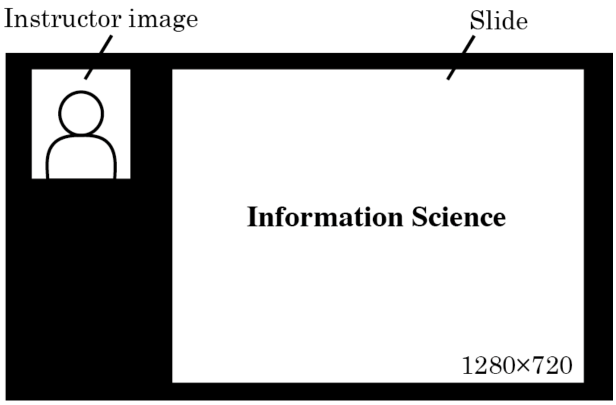

Figure 1. Design layout of the content images

Topics covered by video images. The topic of the lecture video used in our experiments was the network infrastructure of a high school information science department. We asked an information science teacher at a private high school in Japan to assume the instructor role.

We chose to record the lectures in a sound-insulated university lecture hall with good acoustics, which enabled us to prevent acoustic feedback. During lectures, the instructor used slides prepared in advance just as if he were delivering actual course materials to a class of students. The slides did not include animations or other such effects. In addition, the instructor did not use a pointer or other tool during the lectures.

To establish an appropriate speaking rate for the lectures, we familiarized our instructor with the rate of 358 mora/minute (Nagahama & Morita, 2017), which is a reference speaking rate determined on the basis of three types of lectures publicly available from the Japan MOOC (JMOOC). As a result, our instructor's actual speaking rate during our lectures was 336 mora/minute.

Based on the recorded images of these lectures, we prepared lecture videos at the original speed and at speeds of 1.5× and 2×. The times required to play back the three videos were 9 minutes and 12 seconds (9:12) for the original-speed video, 6:11 for the 1.5×-speed video, and 4:42 for the 2×-speed video. The slides and vocal audio used to prepare lecture video in this experiment were similar to those obtained by Nagahama and Morita (2017). Additionally, following Guo et al. (2014), we cropped the recorded images of lectures to include just the instructor's upper body.

Main Experiment

Comprehension tests. We used the comprehension tests of Nagahama and Morita (2017) to measure the educational effects of lecture videos. These comprehension tests consist of a total of 20 questions, including 11 playback questions regarding the form of playback tests and 9 application questions in the form of multiple-choice and yes-or-no questions. Tests were graded by assigning 1 point for each correct answer, for a maximum score of 20 points. The content of each test question was checked and verified in advance by our instructor, an information-science teacher at a high school.

Opinion questions. Table 1 shows the statements used for the opinion questions on the question sheet, subdivided by category. The subjective opinions of the test subjects regarding high-speed presentations and instructor images were surveyed using a five-point Likert scale of possible responses.

Table 1

Statements Rated by the Course Participants

Category	Statement
Comprehension	1. I was able to understand the lesson. 2. The lesson was presented at a level appropriate for me.
Speaking style	3. The instructor's explanations were easy to follow. 4. The instructor's speaking style was easy to listen to.
Level of interest	5. I was interested in the content of the lesson. 6. I would like to learn more about the subject of the lesson.
Concentration	7. I was able to concentrate on the lecture. 8. My eyes got tired. 9. The flickering of the screen bothered me.
Ease of listening	10. I focused on the instructor's voice. 11. I found it difficult to understand the instructor's voice. 12. The audio quality made the instructor's voice easy to understand.
Ease of watching	13. I focused on visual information. 14. I found it difficult to follow the text in the lesson. 15. The images displayed were pleasant to view.
Whether students liked the speed and duration of the presentation	16. The content images were presented at a rapid speed. 17. At some places, I would have preferred a more leisurely pace of explanation. 18. The duration of the lecture video was appropriate. 19. I would choose the same presentation speed again.
Whether students liked the content	20. The design layout of the images was easy to understand. 21. The design layout of the images was clear. 22. The slides did not contain large quantities of text. 23. The slides contained many figures and tables. 24. I would prefer to see images of the instructor.

The questions comprised two questions concerning comprehension, two questions concerning speaking style, two questions concerning level of interest, three questions concerning concentration, three questions concerning ease of listening, three questions concerning ease of watching, four questions concerning whether students liked the speed and duration of the presentation, and five questions concerning whether students liked the video.

The five-point scale of responses consisted of the options strongly agree (assigned 5 points), agree (assigned 4 points), neither agree nor disagree (assigned 3 points), disagree (assigned 2 points), and strongly disagree (assigned 1 point).

Experimental procedure for the main experiment. We presented three lecture videos, differing in their speed of playback, to a group of test subjects comprising 59 university students. Each video was presented to a group of approximately 20 individuals. We arranged seating to ensure that no student was seated immediately adjacent to another student on either side. The lecture video was preloaded onto desktop computers, and all students began watching the video simultaneously upon receiving a signal to do so.

The test subjects participating in the experiment had not previously seen the instructor who appeared in the video. The experiment was conducted in a university computer laboratory equipped with multiple desktop computers of similar sizes and specifications, and in which we were able to ensure that the chairs, tables, headphones, and other elements used by course participants were all identical.

Figure 2 is a schematic depiction of our experiment. First, before presenting any lecture video, we give students a comprehension test (the pre-video test) to assess their pre-existing knowledge of the educational material in the lecture video. Next, we divided our class of 59 test subjects into three groups and presented our lecture video to 20 students at original speed, to 19 students at 1.5× speed, and to 20 students at 2× speed.

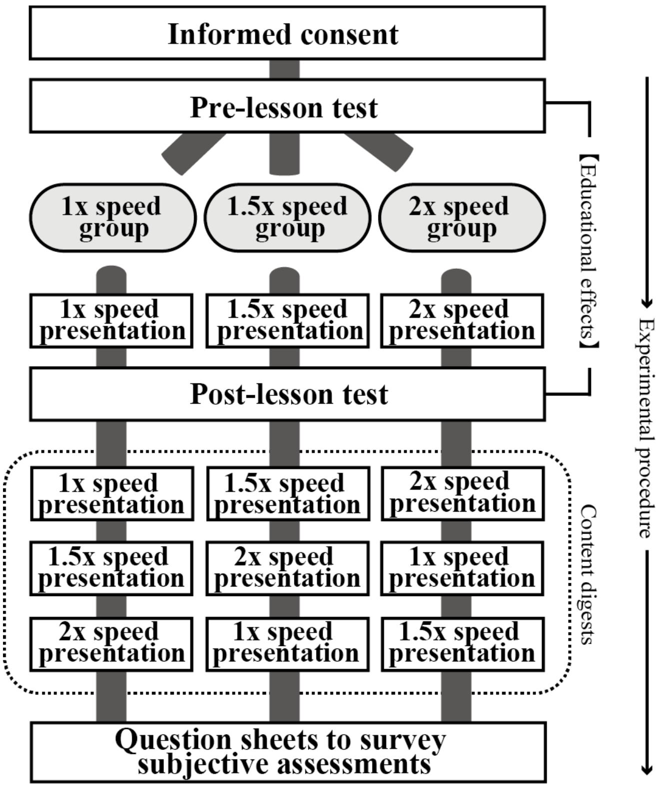

Figure 2. Schematic diagram of main experiment

Then, after viewing the lecture video at various speeds, each group of students was given a post-video test. Finally, all test subjects were shown condensed versions of their video (lecture video digests), extracted from the same location in each of the three speed-varying videos, and were asked to complete a sheet of questions. The Latin-square method was used to cancel any spurious effects due to the order in which procedures were carried out.

Verification experiment based on eye-tracking. As a verification experiment, we presented three lecture videos to 24 university students who were not involved in the main experiment and measured the line of sight of each as they watched the videos. The test subjects involved in this verification experiment had not previously seen the instructor appearing in the lecture video.

For eye-tracking, we used the Tobii Pro T60XL, which is a screen-based eye tracker. For data-collection purposes, we established areas of interest (AOIs) at two sites within the layout of our video images: one in the slide region and one centered on the image of the instructor. Then for each AOI, we computed the fractional visit duration and the mean value of the fixation duration.

After excluding from our analysis any test subject whose line of sight was focused on the presentation for less than 85% of the total duration of the presentation, our measurement dataset contained data from 6 test subjects for each of the three videos at speeds of 1×, 1.5×, and 2×, or 18 individuals in total. Line-of-sight data that deviated from the AOIs were excluded from our analysis.

Results & Discussion

Verifying Homogeneity

The Shapiro Wilk test indicated a normal distribution for the participants' scores on the pre-video test, $p>.05$. To test the homogeneity of the three groups of test subjects (original-, 1.5×-, and 2×-speed groups), we applied a one-way ANOVA to the data. The results indicated no significant difference between groups, $F(2, 56) = 2.16$, $p > .05$. This confirms that, before receiving the lecture videos, all three test subject groups had equal depth of pre-existing knowledge regarding the video.

Analysis of Comprehension Tests

We determined the overall score, the total score for playback questions (playback score), and the total score for application questions (application score). The Shapiro Wilk test indicated a normal distribution for all the data, $p > .05$. Then, we conducted a two-way mixed ANOVA using the presentation speed as one factor (speed factor) and pre-video vs. post-video as the second factor (pre/post factor). Table 2 shows the mean scores on pre-video and post-video comprehension tests together with the ANOVA results.

Table 2

Mean Value (SD) of Comprehension-test Score with ANOVA Results

	1.0x speed		1.5x speed		2x speed		*F values*		
	Pre	Post	Pre	Post	Pre	Post	Speed	Pre/post	Interaction
Overall score	2.45 (1.40)	9.15 (2.91)	3.42 (1.68)	11.05 (3.63)	3.35 (1.81)	9.90 (2.49)	2.65+	339.25**	0.79*ns*
Playback score	0.80 (0.89)	4.90 (2.20)	0.79 (0.79)	5.68 (1.60)	0.95 (1.05)	5.05 (1.91)	0.53*ns*	321.99**	1.17*ns*
Application score	1.65 (1.04)	4.25 (1.89)	2.63 (1.26)	5.37 (2.31)	2.40 (1.14)	4.85 (1.39)	4.10*	90.64**	0.09*ns*

Note. **: $p<.01$, *: $p<.05$, +: $p<.10$

First, we analyzed the overall scores. A significant interaction was not found, $F(2, 56) = 0.79$, $p > .05$. An analysis of main effects indicated a significant difference for the speed factor, $F(2, 56) = 2.65$, $p < .10$. The results of Bonferroni's post-hoc analysis indicated that the mean overall scores for the 1.5×-speed group were significantly higher than those for the 1×-speed group, $p < .05$. No significant difference was found between the 1×- and 2×-speed groups or between the 1.5×- and 2×-speed groups, $p>.05$. On the other hand, a significant difference was found for the pre/post factor, $F(1, 56) = 339.25$, $p < .01$.

Second, we analyzed playback scores. A significant interaction was not found, $F(2, 56) = 1.17$, $p > .05$. An analysis of main effects indicated no significant difference for the speed factor, $F(2, 56) = 0.53$, $p > .05$. On the other hand, a significant difference was found for the pre/post factor, $F(1, 56) = 321.99$, $p < .01$.

Third, we analyzed application scores. A significant interaction was not found, $F(2, 56) = 0.09$, $p > .05$. An analysis of main effects found a significant difference for the speed factor, $F(2, 56) = 4.10$, $p < .05$. The results of Bonferroni's post-hoc analysis indicated that mean application scores for the 1.5×-speed group were significantly higher than those for the 1×-speed group, $p < .05$. No significant difference was found between the 1×- and 2×-speed groups or between the 1.5×- and 2×-speed groups, $p > .05$. On the other hand, a significant difference was found for the pre/post factor, $F(1, 56) = 90.64$, $p < .01$.

To summarize, with respect to the speed factor we observed significant differences in overall scores and application scores. The results of a post-hoc test for overall scores and application scores indicated that mean scores for the 1.5×-speed group were significantly higher than those for the 1×-speed group. These findings indicate that, under our experimental conditions, presenting a lecture video at 1.5× speed may be more effective than presenting the video at its original speed.

For the pre/post factors, significant differences at the 1% level were found for all three test scores: overall, playback, and application. This demonstrates that the lecture video improved comprehension.

Analysis of Subjective Evaluations

We computed the mean scores for each category of questions. Figure 3 shows the mean responses for each category of the subjective evaluation questions. The Shapiro Wilk test indicated a normal distribution for all the data, $p > .05$. Then, we conducted a one-way ANOVA. Significant differences at the 1% level were found in five out of the eight categories. No significant differences were found in the categories of speaking style, level of interest, and whether students liked the video.

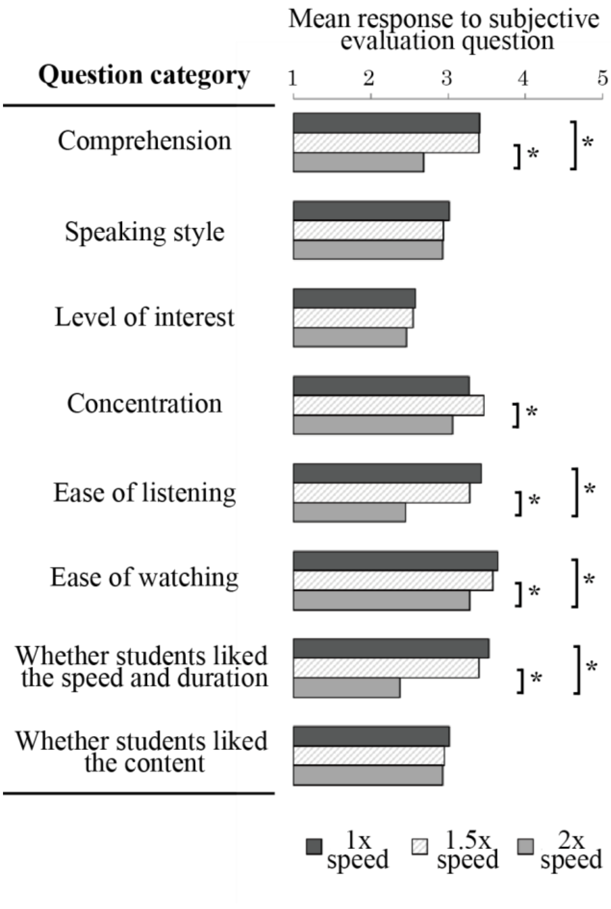

Figure 3. Mean responses to subjective evaluation questions
**: p<.01, *: p<.05, +: p<.10

In the comprehension category, significant differences were found, $F(2, 116) = 24.36$, $p < .01$. The results of Bonferroni's post-hoc analysis indicated that the mean values for the 1×- and 1.5×-speed groups were significantly higher than those for the 2×-speed group, $p < .05$. No significant difference was found between the 1×- and 1.5×-

speed groups, p > .05. This indicates that participants evaluated more favorably the 1× and 1.5× presentation speeds than the 2× presentation speed.

In the speaking style category, no significant differences were found, $F(2, 116) = 1.42$, $p > .05$. This indicates that the speed of presentation may not affect course participants' assessment of an instructor's speaking style.

In the level of interest category, no significant differences were found, $F(2, 116) = 1.39$, $p > .05$. This indicates that the speed of presentation may not affect course participants' level of interest in the material presented.

In the concentration category, a significant difference was found, $F(2, 116) = 7.71$, $p < .01$. The results of Bonferroni's post-hoc analysis indicated that assessments for the 1.5×-speed group were significantly higher than those for the 2×-speed group, p<.05. No significant difference was found between the 1×- and 1.5×- or 2×-speed groups, $p > .05$. This indicates that test participants assessed the 1.5× presentation speed as being more conducive to concentration than the 2× presentation speed.

In the ease of listening category, a significant difference was found, $F(2, 116) = 30.82$, $p < .01$. The results of Bonferroni's post-hoc analysis indicated that mean values for the 1× and 1.5× speeds were significantly higher than for the 2×-speed group, $p < .05$. No significant difference was found between the 1×- and 1.5×-speed groups, $p > .05$. This indicates that participants did not have a favorable opinion of the ease of listening for the 2×-speed presentation.

In the ease of watching category, a significant difference was found, $F(2, 116) = 10.12$, $p < .01$. The results of Bonferroni's post-hoc analysis indicated that mean values for the 1× and 1.5× speeds were significantly higher than for the 2×-speed group, p<.05. No significant difference was found between the 1×- and 1.5×-speed groups, $p > .05$. This indicates that test participants did not have a favorable opinion of the ease of watching the 2×-speed presentation.

In the category of whether students liked the speed and duration of the presentation, s significant difference was found, $F(2, 116) = 43.54$, $p < .01$. The results of Bonferroni's post-hoc analysis indicated that mean values for the 1× and 1.5× speeds were significantly higher than for the 2×-speed group, p<.05. No significant difference was found between the 1×- and 1.5×-speed groups, $p > .05$. This indicates that participants did not have a favorable opinion of the speed and duration of the lecture video when the lecture video was presented at 2× speed.

In the category of whether students liked the video, no significant differences were found, $F(2, 116) = 1.42$, $p > .05$. In particular, no significant differences due to the speed factor were found in mean responses to the subjective opinion question on the statement "I would prefer to see images of the instructor", $F(2, 116)$=3.06, $p > .05$. This indicates that the speed factor may not affect course participants' assessment of the lecture video.

On the basis of these findings, we concluded that the subjective opinions of course participants regarding high-speed presentations and instructor images indicated support for the 1× and 1.5× presentation speeds, but an unfavorable disposition toward the 2 presentation speed.

Analysis of Eye-tracking

Table 3 shows the mean values and standard deviations (*SD*) of the test subjects' visit duration for each AOI, as observed in our verification experiments. The Shapiro Wilk test rejected the assumption of a normal distribution for the data, $p < .05$. Then, we conducted a Kruskal Wallis test. For the instructor AOI, the results of a Kruskal Wallis test indicated that there were no significant differences across the three groups, $p > .05$. For the slide AOI, the results of a Kruskal Wallis test also indicated that there were no significant differences across the three groups, $p > .05$. These findings indicate that, regarding the mean visit duration for each AOI, the students spent more time looking at slides than at instructor images, independent of presentation speed. More precisely, students spent approximately 10% to 15% of the total duration of the lecture video, irrespective of presentation speed, looking at instructor images.

Table 3

Mean Value (SD) of the Visit Duration for Each AOI (N=18)

Group	Instructor AOI	Slide AOI
1× speed	14.3 % (20.19)	82.8 % (21.10)
1.5× speed	14.5 % (15.88)	80.2 % (16.70)
2× speed	11.8 % (14.02)	84.5 % (19.32)

Figure 4 shows mean values of the course participants' fixation duration for each AOI. The Shapiro Wilk test indicated a normal distribution for the data, $p > .05$. Then, we conducted two-way mixed ANOVA with the first and second factors taken respectively to be the presentation speed (the speed factor) and the AOI (the AOI factor). The results of ANOVA indicated that no significant interaction was found, $F(2, 15) = 0.26, p > .05$. An analysis of main effects revealed no significant difference for the speed factor, $F(2, 15) = 0.09, p > .05$. On the other hand, for the AOI factor, a significant difference was found, $F(1, 15) = 20.77, p<.01$.

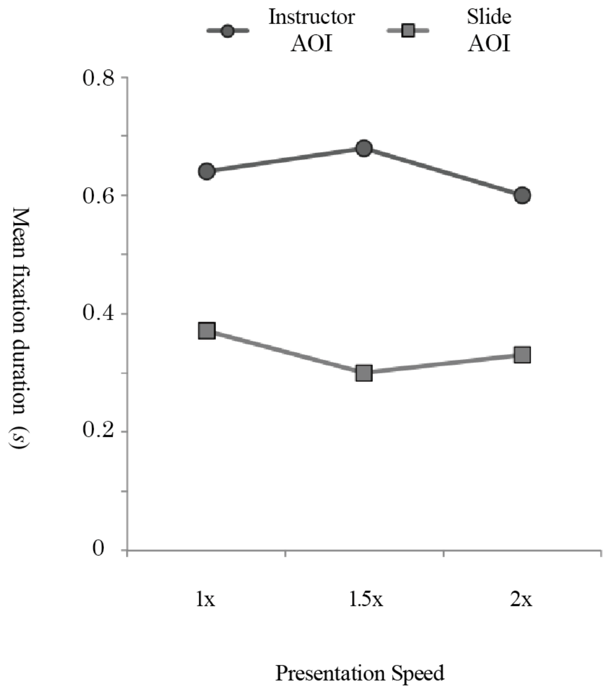

Figure 4. Average of fixation duration in AOIs

These findings indicate that, regarding the mean fixation duration for each AOI, the length of the intervals over which students' line of sight remained focused on instructor images was significantly longer than the length of the intervals for which the students' line of sight was focused on slides, independent of presentation speed. This finding shows that the duration of line-of-sight fixation may differ depending on whether the focus of the fixation is an instructor image or a slide.

These results indicate that, given a video layout consisting of instructor images and slides, the majority of subjects, notwithstanding differences in the nature of line-of-sight fixation, spend roughly 10% of the total duration of watching a lecture video with their eyes focused on instructor images.

Conclusion

In this study, based on the three research questions, we investigated the effects of playback speed for lecture videos whose layouts consisted of slides together with instructor images. In our main experiment, we presented a lecture video, which included instructor images, at three speeds—original, 1.5×, and 2×—to a group of test subjects comprising 59 university students. We used student scores on comprehension tests conducted before and after the video to assess educational effectiveness. We also distributed a question sheet to survey the students' subjective opinions of high-speed presentations and instructor images. Finally, we conducted verification experiments based on eye tracking on a test group of 24 university students.

With respect to the speed factor, an analysis of comprehension test results indicated significant differences in overall scores and application scores. Results of Bonferroni's post-hoc analysis for overall scores and application scores found that mean scores for the 1.5×-speed group were significantly higher than those for the 1×-speed group. This indicates that, under our experimental conditions, presenting lecture video at 1.5× speed may be more effective than presenting the video at its original speed.

Furthermore, the students' responses to the question sheet that we distributed to assess subjective opinions regarding high-speed presentations and instructor images indicated that students were supportive of the original- and 1.5×-speed presentations, but were not favorably disposed toward the 2×-speed presentation.

The results of verification experiments based on eye-tracking revealed that, whereas the course participants' line of sight was focused for a greater total length of time for each AOI on the slide portion of the presentation than on the instructor-image portion, the mean duration of the individual intervals over which the students directed their line of sight was longer for the instructor images than for the slides.

These findings indicate that, for high-speed presentation of lecture video incorporating instructor images under the conditions of our experiment, course participants more favorably received a 1.5× presentation speed. Moreover, although the course participants did not have a favorable subjective opinion of the 2×-speed presentation, its educational effectiveness was equivalent to that of the 1×-speed presentation. These findings agree with the observations of Nagahama and Morita (2017).

On the other hand, although the results of subjective evaluations regarding instructor images did not differ significantly with presentation speed, the results of verification experiments based on eye-tracking suggest the possibility that students look at instructors and slides in different ways. These observations indicate that a fruitful topic for future work might be to analyze the relationship between educational effectiveness and the design layout of lecture videos, including the presence of instructor images, and investigate the connections to the insights obtained in this study.

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