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How Learning-styles Influence Learning Experience with Lecture Video Played at Different Speeds

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The goal of this study was to clarify effects of students' learning styles on their learning experience with lecture videos played at different playback speeds. In our two experiments, participants' learning styles were categorized by Felder's index of learning styles. In the first experiment, lecture videos were presented to a group of 20 students with moderate or low visual preferences (Intermediate group) and a group of 21 students with strong visual learning preferences (Visual group) at different playback speeds (12 kinds of speed: 0.25× speed to 3.0× speed by 0.25×). In the second experiment, 35 students of IG and 40 students of VG learned about the network infrastructure with lecture videos played at original speed, 1.5× speed, and 2.0× speed. The results from both experiments imply that VG prefer watching the video at the original playback speed, while IG preferred watching the video at high-speeds like speed of 1.5x. Consequently, the possibility that students' learning experience could differ to their learning styles when they learn with hi-speed lecture videos was discussed.

Keywords: E-learning, Learning Experience, Learning Styles, Lecture Video, Playback Speed

Introduction

Background

In recent years, non-profit organizations, teachers, and individual learners as well as educational institutions have developed a considerable number of OERs (Open Educational Resources). With the spread of OERs, educational resources in a wide range of fields and aimed various learners are being shared on the Internet. MOOC (Massive Open Online Course) is one form of learning that utilizes OERs and allows any individual to participate in world-class courses on the Internet. Since the major MOOC platforms, such as Coursera, edX, or Udacity, were established in North America in 2012, the popularity of MOOC continues to grow all over the world. Waldrop (2013) reported that Coursera attracted 2.9 million students from more than 220 countries in its first year. In addition, Koller and Ng (2014) reported that Coursera reached seven million students with more than 600 online courses in its second year. In Japan, JMOOC (Japan Massive Open Online Education Promotion Council) was launched in 2013 and it attracted over 50,000 students in the first three months.

Over the past few years, a growing number of studies have been conducted on the learning-related records of MOOC learners. Hardesty's (2012) research of the first course offered on edX (6.002x) reported that approximately 155,000 students registered for the course and less than 5 percent of them received a certificate of completion. Breslow, Pritchard, Deboer, Stump, and Seaton (2013) analyzed the learning-related records of the students who got the certificates and reported that they spent the largest amount time watching lecture videos of the total time spent on the course. Kizilcec, Piech, and Schneuder (2013) analyzed the learning-related records of approximately 94,000 students who joined the courses on Coursera and found that many students watched lecture video even if they did not take comprehension quizzes and participate in online bulletin boards discussions. These findings indicate that lecture video plays a vital role in MOOC-based learning.

Guo, Kim, and Rubin (2014) identified issues with lecture videos in online learning. They analyzed a dataset containing some 7 million viewings of lecture video by students on edX. Their findings were that the number of students paying attention to a lecture video began to decrease dramatically when the lecture video exceeded 6 minutes in length and that students engaged more with lecture videos where instructors spoke faster- they reported that the lecture video where the instructor's speaking rate was 254 words per minute were popular among the students, even though some practitioners recommend 160 words per minute as the optimum speaking rate for presentation (Williams, 1998). These

findings suggest that one of the issues online learning faces is the need to prepare lecture video that takes into consideration for both video length and instructors' speaking rates.

Related Work

Previous studies on multimedia instruction regarding to factors such as length and speaking rates have been conducted. Foulke (1968) examined the relationship between comprehension and playback speed of English-language speech. He found that in the case where the speech was compressed beyond 275 words per minute, comprehension dropped precipitously, but below that level, comprehension levels did not change. Reid (1968) conducted the similar experiment with Foulke's and indicated that comprehension did not change until English-language speech was compressed beyond 325 words per minute when recordings of people reading scripts were played at high speed. In addition, some studies investigating the relationship between comprehension and playback speed of Japanese-language speech reported that even when speech was compressed to 50%, comprehension level were not influenced (Nagafushi & Marutake, 1973; Watamori & Sasanuma, 1974).

Several studies have examined relationship between visual information and high speed speech presentation. Vemuri, Decamp, Bender, and Schmandt (2004) conducted experiments comparing comprehension of time-compressed speech presented in synchrony with transcripts of varying qualities and presentation styles. They reported that participants were able to either save time or improve their understanding when reading error-laden speech-recognizer-generated transcripts in synchrony with time-compressed speech. Kurihara (2012) investigated high-speed reception of information in entertainment videos and reported that it may be possible to reduce viewing time by an average of 85.5% by controlling and changing the playback speeds.

Typical MOOC platforms implement variable-speed playback functionality and students can replay lecture videos at various speeds. Coursera provides 6 speeds, ranging 0.75x to 2.0x in 0.25 intervals, while edX provides 5 speeds: 0.5x, 1x, 1.25x, 1.5x, 2.0x. Nagahama and Morita (2017) studied the efficacy of using variable-speed playback functionality to present lecture video at high speed. In their experiment involving a group of 75 university students, a lecture video consisted of declarative knowledge of high-school-level information science was presented at speeds of 1x, 1.5x, and 2x. They reported that analysis of the comprehension test results indicated differences in the playback speeds did not impact learning effectiveness. They also reported that analysis of the subjective evaluations of the three playback speeds indicated while a playback speed of 1.5x was the most appropriate for studying with lecture video, the evaluations of the 2.0x playback speed were not positive. These findings suggest that while high speed presentation of lecture video may have increased the cognitive burden on students, actual learning effectiveness is not different among the playback speed of 1.0x, 1.5x, and 2.0x.

On the other hand, Massa and Mayer (2006) suggests that people differ on learning style, which may lead to different learning outcomes. Keefe (1985) defined learning style as characteristic of the cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners interact with learning environments. Kraus, Reed, and Fitzgerald (2001) defined learning style as focus of a learner's preferred method for receiving information in a learning environment. Thus, we can say that learning style as a characteristic strength and preferences in the people learn (Cao & Nishihara, 2012).

Felder's index of learning styles (F-ILS: Felder & Henriques, 1995) has been used for researches which examine the relationship between learner characteristics and learning experience (Morita, Koen, Ma, Wu, & Johendran, 2005; Oyama, Murakami, Taguchi, & Matsushita, 2010). Cao and Nishihara (2012) reported that different viewing behavior of different learners with strong and intermediate visual learning preference and there was a possibility that students with intermediate visual learning preference paid more attention to instructor's voice source.

From both Nagahama and Morita's and Cao and Nishihara's viewpoints, one can say that the cognitive burden increased with high speed presentation of lecture video differs to individual students' learning styles. However, the question of how individual learning style influences student's learning experience while lecture video played at hi speeds remains unsettled. Therefore, the goal of this study was to clarify effects of students' learning styles on their learning experience with lecture videos played at different playback speeds. In order to achieve the goal, this study focused on the following research questions:

1. How do students' preference about lecture video's playback speed differ according to learning style? (RQ 1)
2. How does learning style influence students' learning effectiveness when lecture videos are played at speeds of 1.0x, 1.5x, and 2.0x? (RQ 2)
3. How does learning style influence students' opinions when lecture videos are played at speeds of 1.0x, 1.5x, and 2.0x? (RQ 3)

Research Design & Methods

Lecture Video

We conducted two experiments to investigate the effectiveness of student's learning styles on their learning experience with lecture videos played at different playback speeds. Through both experiment 1 and experiment 2, we presented the same lecture video as Nagahama and Morita (2017) used to the participants. The theme of the lecture video was the structure of networks, as taught in high school information science classes. All the knowledge conveyed in the video was declarative knowledge. An information science teacher currently teaching at a high school in Chiba prefecture was engaged to play the role of the instructor in the video. Animations were not used in the slides, and the instructor did not use a pointer or other tool during the lectures.

Table 1

Speech rate for the lecture video

Lecture video		Field	Course topic	Moras / minute
JMOOC	Course 1	Humanities	Law for Businesspeople	331
	Course 2	Science	Recent Research in Civil Engineering and Building Construction	411
	Course 3	Information science	Information Security	334
Nagahama and Morita (2017)'s lecture video		Information science	Structure of Networks	336

Note. Based on Nagahama and Morita (2017)

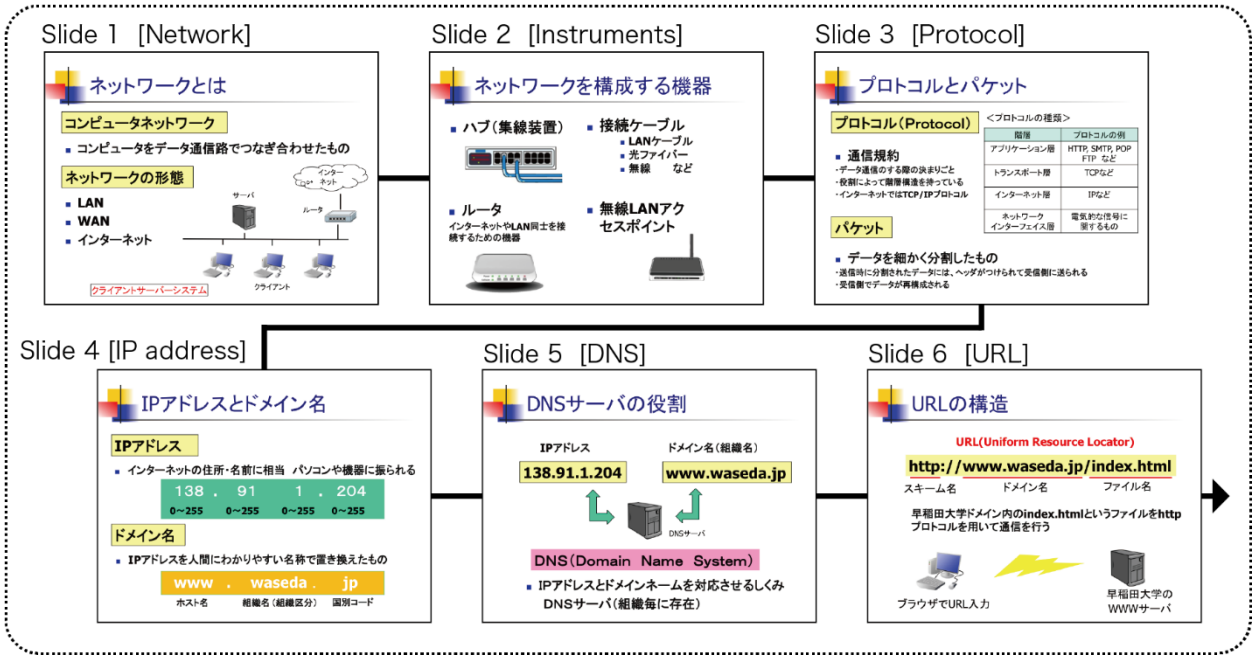

Figure 1. Design of the slides
Based on Nagahama & Morita (2017, pp. 300)

Nagahama and Morita (2017) explained the lecture video was filmed in a university lecture hall with excellent soundproofing and sound collecting ability. The instructor was made aware of the standard speech rate of 358 moras (the minimal unit of measure in quantitative verse equivalent to the time of an average short syllable) per minute, which was a reference speaking rate determined on the basis of three types of lectures available from the JMOOC (Japan Massive Open Online Course). The single minute with the highest number of moras was selected as the point for measurement, in which the calculated speech rate was 336 moras per minute (Table 1).

Table 2

Length of time displayed (seconds)

	Introduction	Slide 1	Slide 2	Slide 3	Slide 4	Slide 5	Slide 6
1.0x	38	89	53	140	112	41	79
1.5x	29	59	35	94	74	27	53
2.0x	19	45	28	71	56	21	40

Table 3

Four dimensions of F-ILS

Dimension	Description
Active-Reflective	How the student prefers to process information • Active learners prefer to process information actively by doing something with learned material, for example, discussing, explaining, or testing it. • Reflective learners prefer to think about the material, work alone and check carefully.
Sensing-Intuitive	The abstraction level of learning material a student prefers • Sensing students like learning facts and needs more practical case studies. • Intuitive learners prefer to learn abstract material such as theories and their underlying meaning.
Visual-Verbal	Whether a student prefers auditory or visual documents • Visual learners remember best what they see pictures, diagrams, flow charts, time lines, films, and demonstrations. • Verbal learners get more out of words, written and spoken explanations, regardless whether they are spoken or written.
Sequential-Global	How a student progresses toward understanding • Sequential learners are more comfortable with details and they tend to gain understand ing step by step. • Global learners tend to learn in large jumps and grasp the whole picture.

Note. Based on Felder and Henriques (1995); Cao and Nishihara (2012)

When the lecture video was played back at 1.0x speed, it lasted 9 minutes 12 seconds; at 1.5x speed, it lasted 6 minutes 11 second; and at 2.0x speed, it lasted 4 minutes 42 seconds. The lecture video composed of 6 slides except for the introduction slide (Figure 1). Table 2 provide the length of time each slide displayed at the three different speeds.

Learning Style

In our two experiments, F-ILS was used to categorize participants' learning styles because of the following three reasons. First, Felder and Spurlin (2005) have tested the validation of F-ILS. Second, F-ILS has been used for researches which examine the relationship between learning styles and learning experience in various educational contexts (Morita, Koen, Ma, Wu, & Johendran, 2005; Oyama, Murakami, Taguchi, & Matsushita, 2010; Cao & Nishihara, 2012). Third, F-ILS is available on the Internet for free and easy to use. F-ILS assess individual learning preferences on four dimensions (Table 3): active-reflective, sensing-intuitive, visual-verbal, and sequential-global. We focused on visual-verbal dimension in this study using Cao and Nishihara (2012)'s findings as a reference.

Experiment 1

In the first experiment (experiment 1), the lecture video was presented to 41 participants at 12 different playback speeds: from 0.25x speed to 3.0x speed in 0.25x intervals. The participants were undergraduate students attending a private urban university, of which 27 were male and 14 were female. The average age was 21.1 years (SD = 1.58).

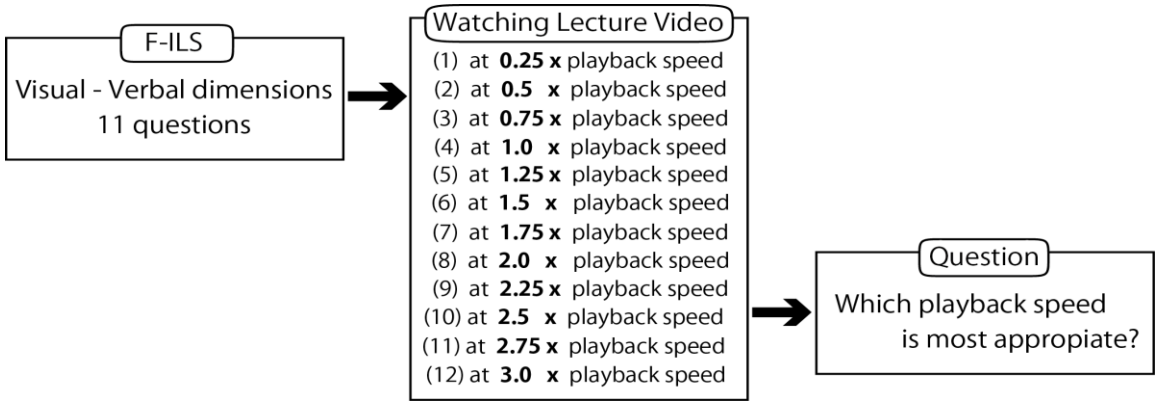

Figure 2. Procedure of experiment 1

Figure 2 shows the procedure of experiment 1. The participants supposed to answer the question "Which playback speed is most appropriate for you?" after they finished watching the lecture video at all different playback speeds. They continued viewing the lecture video at the same playback speed until they fully understood whether the playback speed was a match for themselves. Each participant spent approximately single minutes on average viewing the lecture video at one playback speed.

Experiment 2

In the second experiment (experiment 2), the lecture video was presented to 75 participants, who did not join the experiment 1. The participants were undergraduate students attending the same private urban university as the experiment 1, of which 40 were male and 35 were female. The average age was 21.3 years (SD = 1.94).

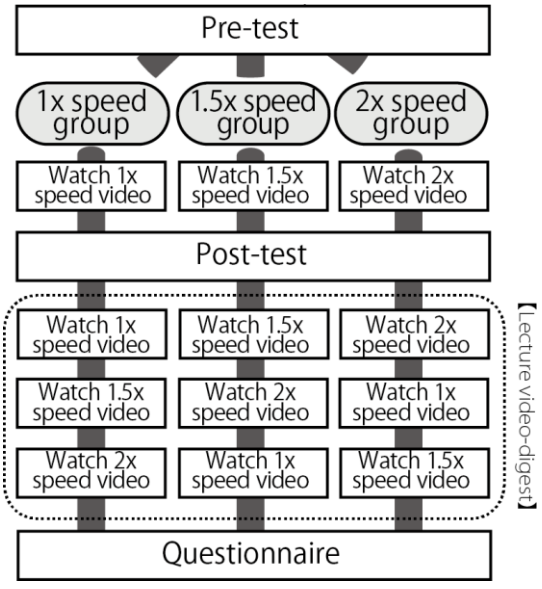

Figure 3. Procedure of experiment 2

Figure 3 shows the procedure of experiment 2. First, before watching the lecture videos, we gave a comprehension test (the pre-video test) to assess their pre-existing knowledge of the theme in the lecture video. Next, we divided 75 participants into three groups; (a) 1.0 group, who watched the lecture video at 1.0x speed; (b) 1.5 group, who watched the lecture video at 1.5x speed; (c) 2.0 group, who watched the lecture video at 2.0x speed. Next, each group of participants watched the lecture video. After that, the participants were given a post-video test to measure learning effectiveness. Finally, all participants were shown condensed versions of lecture video (lecture video digests) and were asked to complete a sheet of questions.

Comprehension tests. We used the comprehension tests of Nagahama and Morita (2017) to measure learning effectiveness. The comprehension test was administered as a pre-test and post-test before and after the participants

had watched the lecture video. The test consisted of 20 problems, 11 of which were playback problems intended to measure the quantity of information retained after watching the lecture video, and 9 of which were application problems intended to measure participants' ability to apply what they had learned to new problems. 11 playback problems were presented in the format of recall tests. 9 application problems included 1 multiple-choice problem, 5 short-answer problems, and 3 true-or-false problems. Tests were graded by assigning 1 point for each correct answer, for maximum score of 20 points (appendix). To assess reliability of the test, 40 undergraduate students attending the same private urban university as both the experiment 1 and the experiment 2 were asked to answer the problems. As a result, Cronbach's alpha was 0.81 for the 20 problems.

Table 4
Statements rated by the 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 length of the video	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 video	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.

Note. Based on Nagahama and Morita (2017)

Questionnaire. We used the questionnaire of Nagahama and Morita (2017) to collect subjective evaluations of the three different playback speeds. Table 4 shows the statements used for the questionnaire. The subjective evaluation questionnaire consisted of 24 five-point Likert scale questions, including questions on comprehension (2), instructor's speaking style (2), level of interest (2), concentration (2), ease of listening (3), ease of watching (3), whether students liked the playback speed and length of the video (4), Whether students liked the video (5). An average score was calculated for each question, with 5 points for responses of "I strongly agree," 4 points for "I agree," 3 points for "I can't decide," 2 points for "I disagree," and 1 points for "I strongly disagree."

Results & Discussion

Answer to Research Question 1

As a result of F-ILS, all the 41 participants in the experiment 1 were divided into 2 groups: a group of 21 participants with strong visual learning preferences (VG: Visual group) and a group of 20 participants with moderate or low visual learning preferences (IG: Intermediate group).

Table 5
Result of the Experiment 1

	Number of students				
	0.75×	1.0×	1.25×	1.50×	1.75×
Intermediate Visual Group	0	5	4	6	5
Visual Group	1	12	6	1	1

Table 5 shows the result of the experiment 1. There were no students who answered that the following playback speeds were appropriate for learning with the lecture video: 0.25×; 0.5×; 2.0×; 2.25×; 2.5×; 2.75×; 3.0×. The result of x2 test suggested that there was a significant difference between IG and VG about the preference of the playback speed, $x2(4) = 10.5$, $p < .05$. BH test suggested that the number of the students in VG who felt 1.0× playback speed was most appropriate was significantly more than the expected frequency, $z = 2.09$, $p < .05$, that the number of the students in IG felt 1.5× playback speed was most appropriate was significantly more than the expected frequency, $z = 2.15$, $p < .05$, and that the number of the students in IG felt 1.75× playback speed was most appropriate was significantly more than the expected frequency, $z = 1.83$, $p < .10$. These results suggest that VG preferred watching the lecture video at the original playback speed, while IG preferred watching the lecture video at 1.5 playback speed or 1.75 playback speed.

To summarize the above findings, there is the possibility that students' preference about lecture video's playback speed may differ according to the level of visual learning preferences (Answer to RQ 1).

Answer to Research Question 2

As a result of F-ILS, all the 75 participants in the experiment 2 were divided into 2 groups: a group of 40 participants with strong visual learning preferences (VG: Visual group) and a group of 35 participants with moderate or low visual learning preferences (IG: Intermediate group). In order to confirm the homogeneity of the 2 groups, a one-way ANOVA was conducted for the pre-video test. As a result, no significant difference was found, $F(1, 73) = 0.48$, $p > .05$. This indicates that the two groups were homogeneous in their back ground knowledge about the theme of the lecture video.

Table 6
Result of comprehension test

	IG			VG			F-value		
	1.0×	1.5×	2.0×	1.0×	1.5×	2.0×	F-ILS	Speed	Interaction
Playback Problem Score	4.4 (1.84)	5.1 (2.53)	3.9 (2.49)	5.3 (2.02)	4.8 (1.60)	4.8 (2.05)	0.82 *ns*	0.53 *ns*	0.65 *ns*
Application Problem Score	3.0 (2.05)	3.8 (1.49)	3.9 (1.97)	3.3 (1.33)	2.9 (2.03)	3.8 (1.39)	0.32 *ns*	0.88 *ns*	0.59 *ns*

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

We determined the comprehension score and conducted a two-way ANOVA using the students' learning styles as the first factor (F-ILS factor) and the video playback speeds as the second factor (speed factor). Table 6 shows the result of the comprehension test. For the playback problems, the ANOVA result indicated no significant interaction, $F(2, 69) = 0.65$, $p > .05$. An analysis of main effects indicated no significant difference for the F-ILS factor, $F(1, 69) = 0.82$, $p > .05$ and for the playback speed factor, $F(2, 69) = 0.53$, $p > .05$. For the application problems, the ANOVA result indicated no significant interaction, $F(2, 69) = 0.59$, $p > .05$. An analysis of main effects indicated no significant difference for the F-ILS factor, $F(1, 69) = 0.88$, $p > .05$, and for the playback speed factor, $F(2, 69) = 0.32$, $p > .05$. These results suggest that no statistically significant difference was observed for both the F-ILS factor and the speed factor in the playback problem score and application problem score.

To summarize the above findings, under the conditions of this experiment, there is the possibility that learning style may not influence students' learning effectiveness when lecture videos are played at speeds of 1.0x, 1.5x, and 2.0x (Answer to RQ 2).

Table 7
Mean score (SD) with ANOVA results

	IG			VG			F-value		
	1.0×	1.5×	2.0×	1.0×	1.5×	2.0×	F-ILS	Speed	Interaction
Q1. I was able to understand the lesson.	3.8 (0.92)	3.9 (1.00)	2.8 (1.21)	4.1 (0.86)	4.0 (0.86)	2.7 (1.33)	0.13 *ns*	59.1 **	1.01 *ns*
Q2. The lesson was presented at a level appropriate for me.	3.4 (1.22)	3.5 (1.09)	3.0 (1.26)	3.7 (1.00)	3.5 (1.09)	2.9 (1.13)	0.21 *ns*	20.38 **	1.24 *ns*
Q3. The instructor's explanations were easy to follow.	3.9 (1.03)	4.1 (1.00)	3.1 (1.30)	4.1 (0.71)	3.8 (0.88)	2.6 (1.22)	1.22 *ns*	47.34 **	2.25 *ns*
Q4. The instructor's speaking style was easy to listen to.	3.7 (1.27)	4.3 (0.89)	2.9 (1.26)	3.8 (1.01)	3.9 (0.88)	2.1 (1.22)	3.98 *	57.56 **	3.55 *
Q5. I was interested in the content of the lesson.	2.8 (1.52)	3.0 (1.44)	2.8 (1.59)	3.0 (1.29)	3.0 (1.29)	2.7 (1.26)	0.01 *ns*	6.41 **	1.26 *ns*
Q6. I would like to learn more about the subject of the lesson.	2.8 (1.24)	3.0 (1.24)	2.7 (1.24)	3.0 (1.15)	3.1 (1.18)	2.7 (1.20)	0.24 *ns*	15.07 **	0.89 *ns*
Q7. I was able to concentrate on the lecture.	3.1 (1.08)	4.2 (3.93)	3.3 (1.27)	3.1 (1.09)	3.9 (0.97)	2.7 (1.21)	2.70 *ns*	24.56 **	2.05 *ns*
Q8. My eyes got tired.	2.3 (1.26)	2.1 (0.99)	2.71 (1.30)	2.4 (1.10)	2.3 (1.06)	2.88 (1.28)	0.28 *ns*	10.75 **	0.80 *ns*
Q9. The flickering of the screen bothered me.	2.1 (1.06)	2.1 (1.05)	2.6 (1.42)	1.9 (0.97)	1.9 (0.98)	2.3 (1.27)	1.29 *ns*	11.3 **	0.14 *ns*
Q10. I focused on the instructor's voice.	2.7 (1.1)	3.4 (0.98)	3.26 (1.56)	2.8 (1.10)	3.2 (1.07)	2.7 (1.31)	1.93 *ns*	4.67 *	1.68 *ns*
Q11. I found it difficult to understand the instructor's voice.	1.9 (1.21)	2.1 (0.96)	3.7 (1.12)	1.8 (1.08)	2.4 (1.17)	4.3 (0.97)	2.35 *ns*	100.3 **	2.40 +
Q12. The audio quality made the instructor's voice easy to understand.	3.9 (1.29)	4.0 (0.79)	2.4 (1.26)	3.7 (1.18)	3.6 (0.95)	2.0 (1.13)	4.66 *	51.8 **	0.33 *ns*
Q13. I focused on visual information.	3.8 (1.21)	3.8 (0.94)	3.7 (0.93)	3.4 (0.98)	3.7 (1.16)	3.8 (1.29)	0.12 *ns*	1.60 *ns*	0.87 *ns*
Q14. I found it difficult to follow the text in the lesson.	2.0 (0.87)	2.2 (0.94)	3.1 (1.28)	2.0 (0.92)	2.3 (1.11)	2.9 (1.45)	0.04 *ns*	28.66 **	0.63 *ns*
Q15. The images displayed were pleasant to view.	4.3 (0.80)	4.2 (0.61)	3.5 (1.20)	4.2 (0.60)	4.0 (0.89)	3.9 (0.92)	0.01 *ns*	14.35 **	5.26 **
Q16. The content images were presented at a rapid speed.	1.3 (0.57)	2.2 (1.06)	4.1 (1.00)	1.4 (0.67)	2.6 (1.20)	4.5 (0.78)	2.92 +	322.6 **	0.67 *ns*
Q17. At some places, I would have preferred a more leisurely pace of explanation.	1.5 (0.89)	2.6 (1.12)	3.9 (1.17)	1.7 (1.09)	3.1 (1.24)	4.5 (0.82)	4.28 *	188.1 **	1.35 *ns*
Q18. The duration of the lecture video was appropriate.	3.0 (1.20)	4.1 (0.73)	3.3 (1.18)	3.1 (1.20)	4.0 (0.90)	3.1 (1.24)	0.22 *ns*	21.43 **	0.43 *ns*
Q19. I would choose the same presentation speed again.	2.5 (1.20)	4.3 (0.94)	2.4 (1.46)	2.9 (1.31)	4.2 (0.87)	2.1 (1.38)	0.1 *ns*	51.19 **	1.11 *ns*
Q20. The design layout of the images was easy to understand.	3.8 (1.03)	4.2 (0.72)	3.4 (1.20)	3.8 (1.03)	3.9 (1.12)	3.4 (1.35)	0.44 *ns*	14.89 **	1.24 *ns*
Q21. The design layout of the images was clear.	2.2 (1.07)	2.3 (1.16)	2.2 (1.11)	2.1 (0.97)	2.2 (1.03)	2.1 (0.94)	0.4 *ns*	2.96 +	0.42 *ns*
Q22. The slides did not contain large quantities of text.	2.7 (1.12)	2.5 (0.98)	2.4 (0.98)	2.8 (0.95)	2.6 (0.93)	2.6 (1.00)	0.26 *ns*	3.66 *	0.61 *ns*
Q23. The slides contained many figures and tables.	2.4 (1.03)	2.5 (0.98)	2.4 (0.94)	2.8 (1.12)	2.8 (1.15)	3.0 (1.18)	3.39 +	1.35 *ns*	3.42 *
Q24. I would prefer to see images of the instructor.	2.4 (1.24)	2.3 (1.26)	2.2 (1.18)	3.1 (1.36)	3.1 (1.38)	2.9 (1.34)	6.16 **	3.21 +	0.02 *ns*

Answer to Research Question 3

We computed the mean scores for each question and conducted a two-way mixed ANOVA using the students' learning styles as the first factor (F-ILS factor) and the video playback speeds as the second factor (speed factor). Table 7 shows the mean scores with the ANOVA results.

Analysis of interactions. Significant interactions were found in four out of 24 questions. For the Q4 "The instructor's speaking style was easy to listen", a significant interaction between the F-ILS factor and the speed factor was found, $F(2, 146) = 3.55$, $p < .05$. An analysis of simple main effects indicated significant differences for the F-ILS factor and the speed factor. For the F-ILS factor, the Bonferroni test indicated that IG gave significantly higher scores to 1.5× speed than original speed, $p < .10$, and original speed than 2.0× speed, $p < .05$. On the other hand, VG gave significantly higher scores to original speed and 1.5× speed than 2.0× speed, $p < .05$. For the speed factor, the Bonferroni test indicated that IG' scores for 1.5× speed and 2.0× speed were significantly higher than VG's, $p < .05$.

For the Q11 "I found it difficult to understand the instructor's voice", a significant interaction between the F-ILS factor and the speed factor was found, $F(2, 146) = 2.40$, $p < .10$. An analysis of simple main effects indicated significant differences for the F-ILS factor and the speed factor. For the F-ILS factor, the Bonferroni test indicated that IG gave significantly higher scores to 2.0× speed than original speed and 1.5× speed, $p < .05$. On the other hand, VG gave significantly higher scores to 2.0× speed than 1.5× speed, $p < .05$, and 1.5× speed than original speed, $p < .05$. For the speed factor, the Bonferroni test indicated that VG' scores for 2.0× speed were significantly higher than IG's, $p < .05$.

For the Q15 "The images displayed were pleasant to view", a significant interaction between the F-ILS factor was found, $F(2, 146) = 5.26$, $p < .05$. An analysis of simple main effects indicated significant differences for the F-ILS factor and the speed factor. For the F-ILS factor, the Bonferroni test indicated that IG gave significantly higher scores to original speed and 1.5× speed than 2.0× speed, $p < .05$. On the other hand, VG gave significantly higher scores to original speed than 1.5× speed, $p < .10$.

For the Q23 "The slides contained many figures and tables", a significant interaction between the F-ILS factor and the speed factor was found, $F(2, 146) = 3.42$, $p < .05$. An analysis of simple main effects indicated significant differences for the F-ILS factor and the speed factor. For the F-ILS factor, the Bonferroni test indicated that VG gave significantly higher scores to 2.0× speed than original speed, $p < .10$. For the speed factor, the Bonferroni test indicated that VG' scores for 2.0× speed were significantly higher than IG's, $p < .05$.

Analysis of main effects. As for the main effects for the F-ILS factor, significant differences were found in four out of 24 questions. For the Q12 "The audio quality made the instructor's voice easy to understand", a significant difference was found, $F(2, 146) = 4.66$, $p < .05$. The result of Bonferroni's test indicated that IG gave significantly higher scores than VG, $p < .05$. For the Q16 "The content images were presented at a rapid speed", a significant difference was found, $F(2, 146) = 2.92$, $p < .10$. The result of Bonferroni's test indicated that VG gave significantly higher scores than IG, $p < .05$. For the Q17 "At some places, I would have preferred a more leisurely pace of explanation", a significant difference was found, $F(2, 146) = 4.28$, $p < .05$. The result of Bonferroni's test indicated that VG gave significantly higher scores than IG, $p < .05$. For the Q24 "I would prefer to see images of the instructor", a significant difference was found, $F(2, 146) = 6.16$, $p < .01$. The result of Bonferroni's test indicated that VG gave significantly higher scores than VG, $p < .05$.

As for the main effects for the speed factor, significant differences were found in 19 out of 24 questions and the results were consistent with the findings of Nagahama and Morita (2017).

Summary of subjective evaluation. The above findings indicated three tendencies. The first tendency apparent in the results of Q4, Q12, and Q15 was that IG's evaluations about faster playback speed, especially about the speed of 1.5x, were higher than VG's. This suggests that students with moderate or low visual learning preference may feel more comfortable when they watch lecture video at high-speeds, like speed of 1.5x (Answer 1 to RQ3).

The second tendency apparent in the results of Q11, Q16, Q17, and Q23 was that VG's evaluations about both the speed of 1.5x and the speed of 2.0x were less positive than IG's. This suggests that students with strong visual learning preference may have increased cognitive burden when they watch lecture videos at faster playback speeds (Answer 2 to RQ3).

Third tendency apparent in the result of Q24 was that VG preferred to see images of the instructor more strongly

than IG. This suggests that preference about the lecture video production may differ to their learning styles (Answer 3 to RQ3).

Discussion of Results

The main findings of this study showed that learning experience with lecture videos played at different playback speed differed according to the student's level of visual learning preferences. The results from of experiment 2 were consistent with the findings of experiment 1, which imply that VG prefer watching the video at the original playback speed, while IG preferred watching the video at high-speeds like speed of 1.5x. A possible contributor to this finding might be differences in the auditory channel-capacity to process auditory information among the two groups.

Mayer (2009) proposes a model, well known as the CTML (Cognitive Theory of Multimedia Learning), which assumes three assumptions: Dual channel assumption, Limited capacity assumption, Active processing assumption. First, the dual channel assumption is that human possess separate channels for processing visual and auditory information. Second, the limited capacity assumption is that humans are limited in the amount of information that they can process in each channel at one time. Third, the active processing assumption is that humans engage in active learning by attending to relevant incoming information, organizing selected information into coherent mental representations, and integrating mental representations with other knowledge (Mayer, 2009). Based on the viewpoints of CTML, one can suppose that VG can be characterized by a higher degree of use of the visual channel when they deal with the multimedia information.

Nagahama and Morita (2017) revealed the possibility that watching hi speed lecture videos highly increases the amount of auditory cognitive loads. This means that when additional auditory cognitive loads increased by the faster playback speed is presented, it competes with the original auditory information for limited capacity in the auditory channel. Considering this, we can say that the cause of the VG's less compatibility with the faster playback speed is the malfunction of the auditory channel due to the excessive amount of auditory information in the auditory channel. Consequently, a following suggestion is discussed: Lecture video should be presented at the original speed or moderate speeds to students with strong visual learning preference for the sake of avoiding overrunning in their auditory channel.

Conclusion

In this research, we conducted two experiments to investigate the effects of students' learning styles on their learning experience with lecture videos played at different playback speeds. In these experiments, students' learning styles were categorized by Felder's index of learning styles.

In the first experiment, lecture videos were presented to a group of 20 students with moderate or low visual preferences (IG: Intermediate group) and a group of 21 students with strong visual learning preferences (VG: Visual group) at different playback speeds (12 kinds of speed: 0.25x speed to 3.0x speed in 0.25x intervals). The result of x2 test suggests that there was a significant difference between IG and VG about the preference of the playback speed. This finding indicates that there is the possibility that students' preference about lecture video's playback speed may differ according to the level of visual learning preferences.

In the second experiment, 35 students of IG and 40 students of VG learned about the network infrastructure with lecture videos played at 1.0x speed, 1.5x speed, and 2.0x speed. The comprehension test results indicated that the video playback speeds and the students' learning styles did not influence the comprehension test scores in this experiment condition. The subjective evaluation results indicated that students with moderate or low visual learning preference may feel more comfortable when they watch lecture video at high-speeds, that students with strong visual learning preference may have increased cognitive burden when they watch lecture videos at faster playback speeds, and that preference about the lecture video production may differ to their learning styles.

Consequently, the possibility that students' learning experience could differ to their learning styles when they learn with hi-speed lecture videos was discussed. This study advances the multimedia learning literature by proposing strategy for individual learners who have different learning styles regarding the effective ways of hi speed lecture video presentation.

However, it must be noted that regarding to the classification of dominant preference among visual-verbal, we used gentler threshold as Cao and Nishihara (2012) did. That was because we did not find a sufficient number of verbal learners in our two experiments likewise Cao and Nishihara's research. The results are therefore limited to in this research, and they need to be replicated in future research where a sufficient number of verbal learners participate.

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Appendix

Overview of the slides presented and the test problems

	Textual information on slide [*number of units / characters*]	Comprehension test questions for each slide
Slide 1	What is a network? / Computer networks / Connecting computers via data transmission channels / Types of network / LAN / WAN / Internet / Servers / Client / Router / Internet / Client server system [*12 units /98 characters*]	Q1. Fill in the blanks in the following sentences describing computer networks. (3 recall questions) -deleted- Networks at the classroom or building scale are called (1). Networks that are slightly larger than (1), about the size that connents buildings, are called (2). The global-scale network that interconnects (1) and (2) is called (3).
Slide 2	Devices that make up a network / Hub (multiplexer) / Connector cable / LAN cable / Fiber optic cable / Wireless, etc / Router / A device for connecting multiple Internet or LAN networks / Wireless LAN access point [*9 units /83 characters*]	Q4. Select all the devices in the following list that are used to connect to the Internet. Use the corresponding letters to answer. (1 multiple choice question) (a) router (b) connector cable (c) USB (d) wireless LAN access point (e) scanner (f) hub (g) RGB cable (h) SSD (i) display port
Slide 3	Protocols and packets / Protocols / Communications protocols / Standard procedures for data communication / Depending on the role, it may have a hierarchical structure / For the Internet, it is called TCP/IP protocol / Packets / Finely split data / Packets created using data that have been split when sending are sent to the recipient / Data is reconstructed on the recipient end / Types of protocol / Level / Examples of protocols / Application level / HTTP, SMTP, POP, FTP, etc. / Transport level / TCP, etc. / Internet level / IP, etc. / Network interface level / Protocols related to electrical signals, etc. [*21 units /240 characters*]	Q2. Fill in the blanks in the following sentences describing the hierarchial structure of protocols. (5 recall questions) -deleted- (1) refer to standard physical or electrical procedures such as cable terminal shapes or electrical signals. Next, the Internet level determines the channels etc. for exchanging data on networks. A typical protocol for this level is (2). Above that, the (3) level determines standards for delivering data with greater certainty, and includes the TCP protocol. Next, the application level determines standards for using various types of application software. For example, the (4) protocol is used when viewing web pages, and the (5) of POP protocols are used when sending email. Q3-1. Answer the following question. (1 recall question) When information is sent from a sender to a recipient on the Internet, the data is first finely split on the sender's side. What is this finely split data called? Q6-2. Read the following sentence. Draw a circle if it is true, or an X if it is false. (1 true-or-false question) The protocol used for sending data to a recipient through the Internet with a high level of certainty is called TCP.
Slide 4	IP addresses and domains / IP addresses / Equivalent to a name and address on the internet. Allocated to computers and devices. / 138.91.1.204 / 0-255 0-255 0-255 0-255 / Domain name / A substitute name for the IP address that is easy for humans to understand / www.waseda.jp / Host name / Organization name (demarcation) / Country code [*11 units /143 characters*]	Q3-3. Answer the following question. (1 recall question) What do we call the numerical address which is the Internet equivalent of a street address and which is assigned to computers and devices? Q6-3. Read the following sentence. Draw a circle if it is true, or an X if it is false. (1 true-or-false question) IP addresses are written using the numbers 1-256, separated by 4 dots.
Slide 5	Role of the DNS server / IP address / Domain name (organization name) / 138.91.1.204 / www.waseda.jp / DNS server / DNS (Domain Name System) / A system for linking IP addresses and domain names / DNS server (exists for every organization) [*9 units /114 characters*]	Q6-1. Read the following sentence. Draw a circle if it is true, or an X if it is false. (1 true-or-false question) Servers that manage the information that corresponds, on the Internet, to a URL, such as "133. 11.200.31" and that respond to external inquireies are called IP servers.
Slide 6	Structure of a URL / URL (Uniform Resource Locator) / http://www.waseda.jp/index.html / File name / Transmits "index.html" a file within Waseda University's domain, using http protocol. / Enter URL into browser / Waseda University's WWW server [*9 units /149 characters*]	Q3-2. Answer the following question. (1 recall question) What do we call the address we specify when using a browser to display data from a WEB server on the Internet? Q5. Answer the following question. (5 short answer questions) 1. In the following URL, what do the numbers (1) - (3) represent? http://www.hs.p.u-tokyo.ac.jp/index.html (1) (2) (3) 2. In the above URL, what do "ac" and "jp" express? ac → (4) jp → (5)

Note. Based on Nagahama and Morita (2017)