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EMPIRICAL ARTICLE

The Impact of Lecture Fluency and Technology Fluency on Students' Online Learning and Evaluations of Instructors

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Given the increasing popularity of online courses, it is important to explore how factors inherent to online lectures influence students' learning and metacognition. We evaluated how lecture fluency (via instructor delivery style) and technology fluency (via visual quality) influence students' learning, perceptions of learning, and evaluations of the instructor. Students watched an online lecture that was delivered in a fluent or disfluent manner (Experiments 1 and 2) presented with good or poor visual quality (Experiment 2). Next, students judged their learning, answered evaluation questions, and completed a test over the lecture. Although lecture fluency did not impact learning, students who watched a fluent lecture reported learning more and rated the instructor as more effective than did students who watched the disfluent lecture. Technology fluency did not impact any outcome. Thus, lecture fluency (but not technology fluency) can influence students' perceptions, but not their actual learning, in an online context.

General Audience Summary

Advances in technology in recent years have led to changes in students' experiences in college courses. Students can take classes, and even complete degrees, entirely online. As such, it is important to explore how students learn from online lectures and how various factors influence students' experiences. The goal of the present study was to investigate how two factors influence students' online learning. First, when watching a lecture, the instructor can vary in how fluently they present the information. Some instructors present information in a fluent manner where they speak clearly and confidently. Other instructors present information in a disfluent manner, where they speak less confidently and stumble over their words. Second, in an online context, technology quality can vary depending on the students' internet connection and computer graphics. Thus, technology fluency (e.g., visual quality) may be high for some students and low for others. We explored how these two factors—lecture fluency and technology fluency—impacted students' learning, perceptions of their learning, and evaluations of the instructor. Students watched an online lecture that was delivered in a fluent or disfluent manner and that was presented with good visual quality or poor visual quality. After watching the lecture, they rated the instructor and their learning and completed a test. Students' learning was unaffected by lecture fluency or technology fluency. However, students who watched the fluent lecture thought that they learned the material better and rated the instructor as more effective compared to students who watched the disfluent lecture. Thus, although lecture fluency does not impact students' actual learning in an online context, it can bias their perceptions of their learning and their evaluations of their instructor.

Keywords: instructor fluency, online learning, student evaluations of teaching, visual quality, metacognition

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The increasing availability of technology has led to changes in how classes are delivered and to students' learning experiences (e.g., Goddard, 2002; Hughes, 2003; Martin et al., 2011). Students can take classes, and even complete entire degrees, online. In a recent survey, 58.3% of students reported taking online classes at least occasionally (Witherby & Tauber, 2019). Though online education brings advantages in the form of increased accessibility, it also raises questions about effective ways of teaching and learning. Much of what we know about learning comes from research conducted in supervised environments such as laboratories and classrooms. We know much less about how students approach learning within the unsupervised context of online courses.

Success in online courses requires students to have good metacognition—the ability to evaluate and regulate their own learning. Unfortunately, students' metacognition is generally poor. When asked to evaluate how well they have learned something, students' subjective impressions of their learning are often higher than their actual learning. This overconfidence is common, and several factors can bolster it even more (e.g., Rhodes & Castel, 2008, 2009 for a review, see Finn & Tauber, 2015). In particular, learning experiences that involve effort and difficulty are often perceived by students as less effective for learning, when really these are key ingredients of successful learning (for reviews, see Bjork et al., 2013; Carpenter, Endres, et al., 2020; Carpenter, Witherby, et al., 2020).

Among the things that can make learning feel difficult, one example is the clarity of an instructor's speech. To illustrate, Sanchez and Khan (2016) had students watch one of two video-recorded lectures. The lectures were identical in length and content and no instructor was present; the only difference was that the voice presenting the lecture was either of a native English speaker or a nonnative English speaker with an accent. After watching the lecture, students completed a test and evaluated the instructor. Although actual learning did not differ between the two groups, students rated the native English instructor as easier to understand and as a more effective teacher, compared to the accented instructor. Additional studies have demonstrated this *voice effect*, in that instructor voices with a foreign accent (e.g., Mayer et al., 2003) or that are computer generated (Chiou et al., 2020; Mayer et al., 2003) influence students' subjective impressions of their learning and the speaker, without affecting their actual learning.

Similarly, studies on instructor "fluency" show that an instructor's delivery style can have strong effects on students' subjective impressions of learning, but not on their actual learning. Carpenter et al. (2013) had students watch one of two versions of a video lecture. In the fluent version, the instructor delivered the lecture with apparent ease, standing upright, maintaining eye contact with the camera, and speaking clearly and confidently. In the disfluent version, the instructor delivered the same lecture but in a way that appeared more difficult, hunching over a podium, staring at her notes, and speaking with awkward pauses.[1] After watching the lecture, students rated their learning, evaluated the instructor, and completed a test. Although the instructor's delivery style did not impact students' actual learning, students who watched the fluent lecture believed they had learned more and rated the instructor as more effective compared to students who watched the disfluent lecture. These effects have been replicated with longer lectures, different topics, different instructors, and with long versus short retention intervals before the test (Carpenter et al., 2016; Carpenter, Northern, et al., 2020; Toftness et al., 2018; for an exception, see Wilford et al., 2020). As well, correlational research has demonstrated similar effects in authentic in-person classes (Serra & Magreehan, 2016; Serra & McNeely, 2020).

Thus, instructor fluency can mislead students' impressions of their learning and the effectiveness of their instructors. Importantly, however, the research to date has been conducted in supervised learning environments such as laboratories and classrooms. These effects have not been explored in online learning environments, and there are reasons to expect that the findings may differ (cf. Serra & McNeely, 2020). In particular, the potential for distractions is much greater in an unsupervised online setting. When students watch a lecture in a class or laboratory, they are typically in a quiet space with minimal distractions. By contrast, when students watch online lectures, they can do so from anywhere (e.g., a busy coffee shop, their bed, their car), which creates several potential sources for distraction. In classroom contexts, students readily disengage from class activities if given the opportunity, spending around 40%–60% of the class period off-task when their computer is available (e.g., Ravizza et al., 2017). Such distractions can negatively impact learning (e.g., Flanigan & Titsworth, 2020; Sana et al., 2013; Waite et al., 2018). Given the tendency for disfluent instructors to reduce students' interest and motivation to learn the lecture material (Carpenter, Witherby, et al., 2020; Toftness et al., 2018), it is possible that disfluent lectures lead to greater disengagement, and if so, produce inferior learning relative to fluent lectures. Thus, in an online environment where the potential for disengagement is uncontrolled, disfluent lectures may negatively affect learning.

In addition to the instructor, online lectures can contain other sources of disfluency. As noted by Serra and McNeely (2020), *technology fluency* (i.e., the ease with which technology is experienced) may vary in online learning environments. Specifically, technical issues with a computer, access to the internet, and access to the lecture via course management software can create a sense of disfluency, such as audio and visual difficulties. Critically, it is unclear whether students use technology fluency as a cue when they evaluate their learning and their instructors, and whether it impacts their actual learning.

Given the rapid conversion to online courses amid the coronavirus disease (COVID-19) pandemic, it is especially important to investigate how these sources of fluency impact students' subjective and objective online learning experiences. Many instructors with little to no experience in online teaching created entire online courses quickly, and the limits in preparation time and experience undoubtedly created disfluencies in lecture delivery and presentation. Exploring the effects of fluency on students' online learning, as well as on the perceived quality of instructors, is therefore timely and important. Accordingly, we investigated how instructor fluency (Experiments 1 and 2) and technology fluency (Experiment 2)

[1] We use the term "fluency" to refer to the lecture delivery style of the instructor. In these studies, lecture delivery style included multiple aspects of behavior (including voice intonation, body language, and pace of speaking) and thus it cannot be determined exactly which of these aspects influenced students' judgments. In this way, lecture fluency is more complex than simple perceptual manipulations, such as the size and clarity of font (e.g., Alter et al., 2007; Rhodes & Castel, 2008), but is more authentic to the ways that instructor delivery styles might vary in real educational contexts.

impact students' learning, perceptions of their learning, and perceptions of their instructor in an online setting.

Experiment 1

Students watched a fluent or disfluent online lecture. We manipulated lecture fluency using a narrated video-recorded lecture that included PowerPoint slides and the voice of a female instructor. In the fluent version, the instructor spoke with ease in a confident and clear manner. In the disfluent version, the same instructor spoke the same content but with apparent difficulty (i.e., awkward pauses, use of the word "um," and occasionally stumbling over words). As with many online lectures, the instructor did not visually appear in the videos, but narrated the content with her voice. Afterward, students predicted how well they would score on an upcoming test over the lecture, evaluated the instructor, and completed the test.

Consistent with prior research in laboratory settings, we expected students to evaluate the disfluent instructor as less effective than the fluent instructor (e.g., Carpenter et al., 2013, 2016; Carpenter, Witherby, et al., 2020). Although instructor fluency typically does not affect test scores in the lab (Carpenter et al., 2013, 2016; Carpenter, Witherby, et al., 2020), we hypothesized that the outcome may be different for online lectures. An unsupervised online environment, combined with the tendency of disfluent instructors to decrease interest and motivation (e.g., Carpenter, Witherby, et al., 2020; Toftness et al., 2018), may lead students to disengage from a disfluent lecture, and ultimately learn less, compared to a fluent lecture.

Method

Design and Participants

A between-participant design was used to explore the effects of a fluent versus disfluent instructor. Given the lack of prior research on instructor fluency with online lectures, we based our sample size on a previous laboratory-based study that used a similar design (Carpenter et al., 2016, Experiment 3), which included 106 participants (i.e., roughly 53 per group). We oversampled somewhat to account for participant attrition in online studies. Thus, 128 students were recruited. For both experiments, students were recruited from the Psychology Department research pool at Iowa State University and participated in exchange for partial course credit. Both experiments were approved by the Iowa State University Institutional Review Board.

Among the 128 students who completed Experiment 1, data from 16 students were removed from all analyses. Data were removed from students because they reported cheating on the test ($n = 8$), their time on task was over three *SD* above the mean ($n = 3$), they had completed the experiment previously ($n = 2$), they reported having high prior knowledge of the content ($n = 2$), they did not have their volume on during the lecture ($n = 2$), and they did not attempt to answer any questions on the test ($n = 1$).[2] Thus, the final sample included 112 students. Students were randomly assigned to the fluent lecture group ($n = 52$) or the disfluent lecture group ($n = 60$). On average, students were 19 years old (fluent group, $M = 19.42$, $SD = 1.30$, four students did not provide their age; disfluent group, $M = 19.05$, $SD = 1.49$, two students did not provide their age) and were predominantly female (fluent group, 27 female, 20 male, 4 other or prefer not to respond; disfluent group, 42 female, 16 male, 2 other or prefer not to respond).

Materials and Procedure

Students signed up for the online experiment through the Psychology Department research pool and completed the study on their personal computer at a time and location of their choosing. Before beginning the experiment, students were told that they would watch a roughly 20 min lecture covering a scientific topic and that they would complete a test following the lecture. Students were also told that they should not take notes during the video and that they should turn their computer volume up so that they could hear the instructor.

Students were randomly assigned to watch one of two versions of a lecture about signal detection theory: the fluent version or the disfluent version. Both versions of the lecture were taken from Carpenter et al. (2016). The lecture covered basic topics from signal detection theory. For instance, it explained situations in which signal detection theory might be used (e.g., by radar operators or radiologists), the outcomes of a signal detection scenario (e.g., hit, false alarm), and the measures that can be produced from these outcomes (e.g., discriminability, receiver operating characteristic curves). Both lectures were 22 min long and contained identical visual information. The lectures were presented using a series of PowerPoint slides with visual aids (e.g., see Figure 1, top panel). The instructor was not visible in either lecture. The fluency manipulation consisted of modifying the instructor's cadence when voicing over the lecture slides. Specifically, the auditory content was scripted to be identical for both the fluent and disfluent versions. What differed was the way the instructor spoke when delivering the content. In the fluent condition, the instructor spoke in a confident and fluid tone. In the disfluent condition, the instructor sounded less confident, delivering the lecture with awkward pauses, frequent use of the word "um," and occasionally having difficulty pronouncing some words. The videos are available upon request by contacting the authors.

Immediately after watching the video, students made a judgment of learning (JOL). We included the JOL to evaluate how students thought they would perform on the upcoming test. This measure was also included in past research on instructor fluency, and as such, allows us to connect the present research to the broader literature. Specifically, students were told:

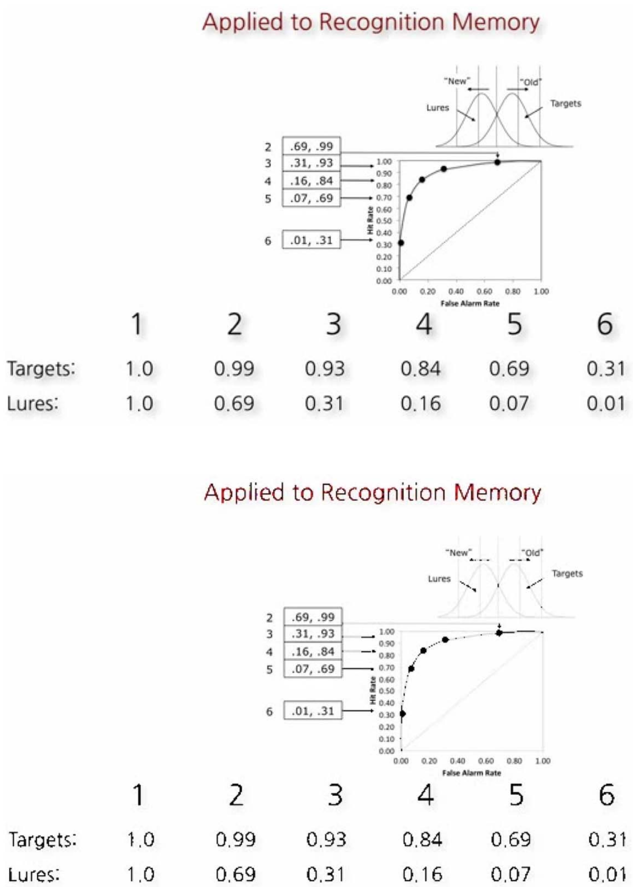
> In about 1 minute from now, we will give you a multiple-choice test on the information from the video. How well do you think you will score on a scale from 0% to 100%?

Students made their judgment by typing any whole number between 0 and 100. After making their judgment, students clicked a button to continue and were asked about the factors they may have considered when making their JOL. To do so, students were asked to rate on a scale from 1 (*strongly disagree*) to 6 (*strongly agree*) the extent to which they based their JOL on the following factors: the instructor, the material, their own ability to learn information, and something else that was unrelated to the video (e.g., how tired or distracted they felt). Exploring the bases for participants' JOLs is particularly important in an online learning environment given the

[2] The number of students removed for each reason adds up to more than 16 because some students were removed for more than one reason (e.g., one student reported cheating and not having their volume turned on).

Figure 1

Screenshots of the Good Visual Quality (Top) and Poor Visual Quality (Bottom) Manipulation in Experiment 2



Note. For a full-size version, see the online Supplemental document, along with the osf page containing all material at https://osf.io/85ctg/. See the online article for the color version of this figure.

unsupervised context and the open question regarding the degree to which instructor fluency influences online learning. Moreover, it provides information about which factors students think will have the largest impact on their test performance. Each factor was presented individually, and the presentation order was randomized anew for each student. After making their fourth and final rating, students were asked if there was anything else that they based their JOL on and were provided with a text box to type their response (if applicable). The JOL and all follow-up questions about the JOL were self-paced.

Next, students completed a series of evaluation questions. These questions were designed to evaluate students' perceptions of various components of the learning experience (e.g., the teacher, the course, themselves) and were similar to those that students receive at the end of the semester in their actual courses (see Table 1). Students evaluated the instructor's organization, preparedness, knowledge, and overall effectiveness. Students also made self-evaluations including how much they felt they learned from the lecture, their interest in the lecture, and their motivation to learn the information. Finally, students evaluated several other aspects of the instructor and the course including how likely they would be to recommend the instructor and the course to other students, their interest in future learning about the topic, the extent to which the lecture applied to their life, how likely they would be to watch online lectures if they were taking this course, how likely they would be to participate in class discussion, the extent to which they related to the instructor, and the frequency with which they would study if they were taking this course. Students made each evaluation using a Likert-style scale from 1 (*not at all*) to 5 (*very*). We chose this scale to closely mirror how students make end-of-the-semester evaluations in their real courses. The evaluation questions were presented in a fixed order and participants were given unlimited time to make each evaluation.

After making their evaluations, students completed a 20-item multiple-choice test covering the content from the lecture (taken from Carpenter et al., 2016). The questions asked students about factual content that came directly from the lecture (e.g., *When something is not in the environment, but the individual incorrectly says that it is present, that is a:*). Each question included four competitive alternatives (e.g., *hit*, *miss*, *false alarm*, *correct rejection*) as well as a fifth option for students to indicate that they did not know the answer. Each question was presented individually, and presentation order was fixed such that questions were presented in the same order as the content was presented in the lecture. The test was self-paced and students did not receive feedback.

Finally, students were asked whether they had any prior knowledge of signal detection theory, answered demographic questions (age, gender, and year of education), and were asked whether they cheated on the test by taking notes during the lecture or by looking up the answers online.[3] To answer the prior knowledge question, students were given four options, and asked to select which best represented their level of prior knowledge before completing the experiment: (a) *I did not have any detailed prior knowledge of this information*, (b) *I have heard of it before, but I did not know the details until today*, (c) *I may have learned this information before, but I did not remember the details*, and (d) *I learned this information before, and I remembered the details before completing the experiment*.

Results and Discussion

Outcomes regarding test performance are presented first. Next, we report outcomes regarding students' JOLs followed by their evaluations of the instructor, the course, and themselves.

Test Performance

Average test performance is presented in Table 2. Students who watched the fluent lecture performed numerically, but not significantly, better on the test relative to students who watched the disfluent lecture, $t(110) = 1.45$, $p = .15$, $d = .27$.

Judgments of Learning

Although students who watched the fluent lecture provided numerically higher JOLs relative to students who watched the

[3] Students were informed that their response to this question was for data quality purposes only and that their response would not be tied directly to their name or affect their participation credit.

Table 1
Evaluation Questions and Scales Used in Experiments 1 and 2

Question
1. How organized was the instructor in the video? (1 *not at all organized*; 5 *very organized*)
2. How prepared was the instructor in the video? (1 *not at all prepared*; 5 *very prepared*)
3. How knowledgeable was the instructor in the video? (1 *not at all knowledgeable*; 5 *very knowledgeable*)
4. Please rate the overall effectiveness of the instructor in the video. (1 *not at all effective*; 5 *very effective*)
5. How well do you feel that you have learned the information that was presented in the video? (1 *not at all*; 5 *very well*)
6. Please rate your overall level of interest in the information that was presented in the video. (1 *not at all interested*; 5 *very interested*)
7. Please rate your overall level of motivation to learn the information that was presented in the video. (1 *not at all motivated*; 5 *very motivated*)
8. How likely would you be to recommend this instructor to other students? (1 *I would not at all recommend*; 5 *I would highly recommend*)
9. How likely would you be to recommend this course to other students? (1 *I would not at all recommend*; 5 *I would highly recommend*)
10. Please rate how interested you are in learning more about this topic. (1 *not at all interested*; 5 *very interested*)
11. While watching the video, to what extent did you think about how the information applied to your own life? (1 *I did not think about it at all*; 5 *I thought about it often*)
12. If you were taking an online course with this instructor, please rate the likelihood that you would watch the lectures. (1 *I would not watch them regularly*; 5 *I would regularly watch them*)
13. If you were taking an online course with this instructor, how likely would you be to participate in class discussions? (1 *I would not*; 5 *I would regularly*)
14. To what extent did you feel that you related well to this instructor? (1 *I did not relate at all*; 5 *I very much related*)
15. How regularly would you study if you were taking this course? (1 *I would not study at all*; 5 *I would study on a regular basis*)

Note. Questions were taken from Carpenter, Northern, et al. (2020). Two questions (12 and 13) were modified to specifically ask about online courses. Questions are listed in the order that they were presented to participants.

disfluent lecture, this difference was not significant, $t(110) = 1.31$, $p = .19$, $d = .25$ (see Table 2). This nonsignificant effect is likely attributable to the fact that few students used the instructor as a basis for their JOL. Collapsing across groups, only 25% ($n = 28$) of students used the instructor as a strong basis for their JOL (i.e., provided a rating of 5 or 6 to the instructor question). By contrast, most students reported basing their JOL on the material in the lecture (48.2%, $n = 54$), on their own ability to learn the material (41.1%, $n = 46$), or on something unrelated to the lecture such as how tired or distracted they felt (44.6%, $n = 50$).

Student Evaluations

Students made ratings for 15 evaluation items that were designed to mimic the end-of-the-semester evaluation questions that students complete for their actual courses. Six of the questions evaluated the instructor and nine evaluated the course and how the lecture influenced students' ratings of themselves (e.g., their interest or motivation). Given that lecture fluency can have independent effects on these different aspects of the students' learning experience, we analyzed responses to each item using separate independent samples *t* tests.

Table 2 presents descriptive and inferential statistics for student evaluations. On all instructor evaluation items, students in the fluent condition rated the instructor higher than did students in the disfluent condition. All comparisons reached conventional levels of significance, with medium to large effect sizes. After applying a Bonferonni correction to account for the number of comparisons (15 evaluation items), the only instructor evaluation item that did not reach the conservative significance threshold ($p = .003$) was the degree to which students felt they related to the instructor $t(110) = 2.60$, $p = .01$, $d = .48$.

Regarding the evaluations of the course and self-evaluations, students in the fluent condition gave numerically higher ratings than did students in the disfluent condition. Even so, the only item to reach conventional levels of significance was the degree to which students felt they learned the material, $t(110) = 2.84$, $p = .005$, $d = .52$. None of the comparisons reached the conservative significance threshold after applying the Bonferonni correction.

To sum, these outcomes are consistent with laboratory-based studies showing that instructor fluency inflates students' evaluations of teaching effectiveness and perceptions of their own learning but does not significantly affect test scores (Carpenter et al., 2013, 2016; Toftness et al., 2018). Compared to a classroom or laboratory, an online learning environment allows less control over students' attention and more opportunities to disengage from a lecture. Though we hypothesized that students who watched the disfluent lecture might perform worse on the test compared to students who watched the fluent lecture (perhaps because they would be more likely to disengage), the results of Experiment 1 did not support this prediction.

It has not been systematically explored whether other types of fluency associated with online lectures affect students' learning and evaluations of their instructors. Due to issues with internet connectivity or computer graphics, a common factor that may vary with online lectures is the quality of the visual content. Even though the instructor has no control over such things, does the disfluency introduced by poor visual quality affect students' perceptions of the instructor and their own learning? We explored these questions in Experiment 2.

Experiment 2

In Experiment 2 we aimed to replicate the basic design of Experiment 1, and to explore whether technology fluency, manipulated through the visual quality of the lecture, would impact these outcomes. Students in the good visual quality groups watched either the fluent or disfluent lecture from Experiment 1. Students in the poor visual quality groups watched either the fluent or disfluent lecture, but with a visual filter applied to reduce the clarity of the text and images on the slides, similar to the way that bandwidth limitations might affect visual resolution.

We expected instructor fluency to increase students' evaluations of the instructor and perceptions of their learning. Though our predictions for the effects of visual quality were less certain, we anticipated that degraded visual quality might negatively affect students' impressions of their learning based on research with visual clarity of written material. Specifically, students judge their learning to be lower when text information is made less clear by using a font style that is smaller or harder to read (e.g., Diemand-Yauman et al., 2011; Rhodes & Castel, 2008), blurring the text (Yue et al., 2013), or reducing the legibility of handwritten text (Geller et al., 2018).

Table 2
Mean Test Performance, Judgments of Learning, and Student Evaluations in Experiment 1

Measure	Fluent lecture	Disfluent lecture	Inferential statistics	
			t value	*d* value
Test performance	60.58 (22.87)	54.42 (22.04)	1.45	0.27
Judgments of learning	53.33 (21.95)	47.88 (21.97)	1.31	0.25
Instructor evaluations				
Organized	4.08 (.84)	3.67 (1.17)	3.63*	0.65
Prepared	4.50 (.64)	3.55 (1.16)	5.26*	0.90
Knowledgeable	4.63 (.56)	4.17 (.81)	3.51*	0.63
Effectiveness	3.42 (.96)	2.78 (1.12)	3.22*	0.59
Relate to instructor	2.44 (1.04)	1.97 (.90)	2.60	0.48
Recommend instructor	3.44 (.94)	2.47 (1.10)	5.02*	0.86
Course and self-evaluations				
Apply to life	2.29 (1.09)	2.27 (1.21)	0.10	0.02
Watch lectures	3.37 (1.34)	3.05 (1.52)	1.15	0.22
Participate	3.13 (1.17)	2.78 (1.08)	1.65	0.31
Study	3.73 (1.03)	3.70 (1.17)	0.15	0.03
Learn more	2.25 (.97)	2.03 (1.13)	1.08	0.20
Recommend course	2.75 (.97)	2.43 (1.03)	1.67	0.31
Motivation	2.29 (.94)	2.27 (1.12)	0.11	0.02
Interest	2.27 (1.09)	1.92 (1.12)	1.67	0.32
Learned	2.67 (.88)	2.20 (.88)	2.84	0.52

Note. Values reflect the mean for each measure. Standard deviations of the mean are in parentheses. Test performance and judgments of learning are on a scale from 0 to 100. Student evaluation items are on a scale of 1 to 5.
* $p < .002$.

Experimental manipulations that make learning feel difficult can have beneficial effects on actual learning (i.e., desirable difficulties, Bjork, 1994). For instance, Diemand-Yauman et al. (2011) found that students learned information better when it was presented in a font that was difficult to read compared to a font that was easy to read (cf. French et al., 2013; Geller et al., 2018; Weltman & Eakin, 2014). Experiment 2 explored the potential effects of visual degradation on lecture-based learning, which have yet to be investigated.

Method

Design and Participants

A 2 (Lecture fluency: fluent, disfluent) × 2 (Visual quality: good, poor) between-participant design was used. Based on the same rationale from Experiment 1, our target sample size was 240 students (i.e., 60 per group). Accordingly, 243 students were recruited and participated in exchange for partial course credit.

Among the 243 students who completed the study, data from 29 students were removed from all analyses. Data were removed because students reported cheating on the test ($n = 17$), their time on task was over 3 *SD* above the mean ($n = 11$), and because they reported having high prior knowledge of the content ($n = 2$).[4] Thus, the final sample consisted of 214 students who were randomly assigned to group: fluent lecture—good quality, $n = 54$, fluent lecture—poor quality, $n = 50$, disfluent lecture—good quality, $n = 58$, disfluent lecture—poor quality, $n = 52$.

As in Experiment 1, the students were roughly 19 years old (fluent lecture—good quality, $M = 19.12$, $SD = 1.38$, two students did not provide their age; fluent lecture—poor quality, $M = 19.23$, $SD = 1.22$, three students did not provide their age; disfluent lecture—good quality, $M = 19.11$, $SD = 1.25$, two students did not provide their age; disfluent lecture—poor quality, $M = 19.14$, $SD = 1.21$, two students did not provide their age). As well, students were predominantly female (fluent lecture—good quality, 27 female, 25 male, 2 other or prefer not to respond; fluent lecture—poor quality, 24 female, 22 male, 4 other or prefer not to respond; disfluent lecture—good quality, 34 female, 19 male, 5 other or prefer not to respond; disfluent lecture—poor quality, 35 female, 15 male, 2 other or prefer not to respond).

Materials and Procedure

The fluent and disfluent lectures from Experiment 1 were used for the good visual quality groups. Two additional versions of the lecture were created to be used for the poor visual quality groups. To do so, we used a video editor to reduce the visual transparency of the slides. The legibility of the poor visual quality lecture was reduced such that it was noticeably less clear, but still readable, so that it would not affect students' ability to perceive the content (see Figure 1 for an example screenshot). Thus, the resulting good and poor quality versions of the lecture provided the same content, with the only difference being how clearly that content was presented. We manipulated only the visual quality of the lectures and left the audio quality unchanged. Students were randomly assigned to watch one of the four versions of the lecture (i.e., fluent lecture—good quality, fluent lecture—poor quality, disfluent lecture—good quality, or disfluent lecture—poor quality).

The remainder of the procedure was identical to Experiment 1 with two small exceptions. First, in addition to rating the extent to which they based their JOL on the instructor, material, themselves, or something else, students rated the extent to which they based their JOL on the visual quality and the audio quality of the lecture.

[4] The total sums to 30 because data from one student were removed due to cheating and having high prior knowledge.

Ratings were made on the same 1 (*strongly disagree*) to 6 (*strongly agree*) scale that was used for rating the other factors. The presentation order for all six factors was randomized anew for each participant. Second, we added a manipulation check to the end of the experiment. Specifically, after rating their prior knowledge, students rated the visual quality of the lecture on a scale from 0% (*terrible*) to 100% (*perfect*). Next, students rated the audio quality of the lecture using the same scale. These ratings were self-paced.

Results and Discussion

As in Experiment 1, we first report analyses of test performance, JOLs, and student evaluations. Next, as a manipulation check, we report outcomes regarding students' ratings of the visual and audio quality of the lecture.

Test Performance

Test performance was unaffected by lecture fluency and visual quality (see Table 3). A 2 (Lecture fluency) × 2 (Visual quality) analysis of variance (ANOVA) revealed nonsignificant effects of both factors, $Fs < 1.03$, $ps > .31$. The interaction was also not significant, $F < 1$.

Judgments of Learning

As evident in Table 3, JOLs were not influenced by lecture fluency or visual quality. A 2 (Lecture fluency) × 2 (Visual quality) between-participant ANOVA revealed nonsignificant effects for both factors, $Fs < 1$. The interaction was also not significant, $F(1, 210) = 1.10$, $p = .30$. As in Experiment 1, these outcomes were likely driven by the fact that few students used these factors as a basis for their JOLs. Specifically, only 31.8% ($n = 68$) of students reported using the instructor as a basis for their JOL, and only 17.8% ($n = 38$) of students reported using the visual quality of the lecture as a basis for their JOL. By contrast, most students reported basing their JOL on the material (57.5%, $n = 123$), their own ability (44.4%, $n = 95$), or something else unrelated to the lecture (36.9%, $n = 79$). Few students reported using the audio quality as a basis for their JOL (16.4%, $n = 35$).

Student Evaluations

Students' responses to each evaluation item were analyzed using separate 2 (Lecture fluency) × 2 (Visual quality) between-participant ANOVAs. Consistent with Experiment 1, students' ratings of the instructor were higher in the fluent relative to the disfluent groups (see Table 3). Specifically, students in the fluent groups rated the instructor as more organized ($M = 4.04$, $SD = .92$), $F(1, 210) = 37.68$, $p < .001$, $\eta_p^2 = .15$, prepared ($M = 4.46$, $SD = .79$), $F(1, 210) = 62.76$, $p < .001$, $\eta_p^2 = .23$, knowledgeable ($M = 4.55$, $SD = .68$), $F(1, 210) = 23.48$, $p < .001$, $\eta_p^2 = .10$, and effective ($M = 3.52$, $SD = 1.00$), $F(1, 210) = 21.86$, $p < .001$, $\eta_p^2 = .09$, relative to students in the disfluent groups (organized, $M = 3.22$, $SD = 1.01$; prepared, $M = 3.35$, $SD = 1.20$; knowledgeable, $M = 4.04$, $SD = .83$; effective, $M = 2.84$, $SD = 1.10$). In addition, students reported being more likely to recommend the instructor if they watched the fluent lecture ($M = 3.11$, $SD = 1.08$) compared to the disfluent lecture ($M = 2.31$, $SD = 1.08$), $F(1, 210) = 28.81$, $p < .001$, $\eta_p^2 = .12$. These effects were significant according to conventional threshold as well as the more conservative threshold resulting from the Bonferonni correction ($p = .003$). Although students in the fluent groups ($M = 2.34$, $SD = .94$) reported that they

Table 3
Mean Test Performance, Judgments of Learning, Ratings of Visual and Audio Quality, and Student Evaluations in Experiment 2

Measure	Fluent lecture		Disfluent lecture		Inferential statistics	
	Good visual quality	Poor visual quality	Good visual quality	Poor visual quality	*t* value	*d* value
Test performance	56.39 (22.87)	55.10 (23.66)	57.33 (22.44)	52.21 (23.52)	0.27	0.04
Judgments of learning	52.43 (20.69)	56.28 (21.24)	53.53 (21.05)	51.35 (21.30)	0.62	0.08
Visual quality	81.39 (19.39)	69.02 (22.96)	73.95 (25.00)	67.83 (20.86)	1.42	0.19
Audio quality	84.61 (19.92)	79.50 (20.48)	70.19 (28.00)	71.58 (24.73)	3.50*	0.47
Instructor evaluations						
Organized	4.09 (.98)	3.98 (.87)	3.19 (.95)	3.25 (1.08)	6.20*	0.78
Prepared	4.52 (.79)	4.40 (.78)	3.26 (1.18)	3.44 (1.23)	8.00*	0.96
Knowledgeable	4.57 (.63)	4.52 (.74)	4.00 (.92)	4.08 (.74)	4.90*	0.64
Effectiveness	3.57 (1.00)	3.46 (1.01)	2.74 (1.04)	2.94 (1.16)	4.74*	0.62
Relate to instructor	2.24 (.93)	2.44 (.95)	1.91 (.94)	2.08 (.84)	2.76	0.37
Recommend Instructor	3.11 (1.11)	3.10 (1.05)	2.33 (1.13)	2.29 (1.04)	5.39*	0.69
Course and self-evaluations						
Apply to life	2.09 (1.00)	2.46 (1.13)	2.05 (.94)	2.37 (1.27)	0.46	0.06
Watch lectures	3.30 (1.35)	3.20 (1.28)	2.53 (1.27)	2.65 (1.20)	3.78*	0.50
Participate	3.02 (1.17)	2.94 (.91)	2.71 (1.08)	2.79 (1.07)	1.62	0.22
Study	3.37 (.83)	3.36 (1.01)	3.53 (1.13)	3.42 (1.02)	0.85	0.12
Learn more	1.94 (.86)	2.10 (.86)	1.81 (.87)	2.10 (.93)	0.61	0.08
Recommend course	2.72 (.96)	2.84 (1.00)	2.17 (1.03)	2.56 (.96)	3.12*	0.42
Motivation	2.30 (.84)	2.40 (.93)	2.05 (.91)	2.15 (1.06)	1.94	0.26
Interest	2.02 (.92)	2.18 (.87)	1.88 (.90)	2.06 (.98)	1.06	0.14
Learned	2.67 (1.01)	2.86 (.95)	2.24 (.94)	2.50 (.92)	3.02*	0.41

Note. Values reflect the mean for each measure. Standard deviations of the mean are in parentheses. Test performance, judgments of learning, visual quality, and audio quality are on a scale from 0 to 100. Student evaluation items are on a scale of 1 to 5. The inferential statistics represent the main effect of lecture fluency.
* $p < .003$.

related more to the instructor compared to students in the disfluent groups ($M = 1.99$, $SD = .89$), this difference reached conventional levels of significance but not the more conservative threshold, $F(1, 210) = 7.56$, $p = .007$, $\eta_p^2 = .04$. The main effect of visual quality was not significant for any evaluation item, $F\text{s} < 2.08$, $p\text{s} > .15$, nor was the interaction between lecture fluency and visual quality, $F\text{s} < 1.19$, $p\text{s} > .28$.

Consistent with Experiment 1, lecture fluency had a significant main effect on students' evaluation of how much they felt they had learned, $F(1, 210) = 9.01$, $p = .003$, $\eta_p^2 = .04$. Students who watched the fluent lecture felt like they learned more ($M = 2.76$, $SD = .98$) relative to students who watched the disfluent lecture ($M = 2.36$, $SD = .94$). Lecture fluency also affected students' evaluation of the likelihood that they would watch the online lectures, $F(1, 210) = 13.95$, $p < .001$, $\eta_p^2 = .06$, and the likelihood that they would recommend the course, $F(1, 210) = 9.47$, $p = .002$, $\eta_p^2 = .04$. Students who watched the fluent lecture reported being more likely to watch the online lectures if they were taking the course ($M = 3.25$, $SD = 1.31$) and more likely to recommend the course to others ($M = 2.78$, $SD = .98$) relative to students who watched the disfluent lecture ($M = 2.59$, $SD = 1.24$ and $M = 2.35$, $SD = 1.01$, respectively).

The main effect of lecture fluency on the remaining evaluation questions (i.e., the extent to which the information applied to their life, how likely they would be to participate in class discussions, how frequently they would study for the course, how interested they would be to learn more information about the topic, their level of motivation, and their level of interest in the material) was not significant, $F\text{s} < 3.69$, $p\text{s} > .06$. The main effect of visual quality reached conventional (but not the conservative) level of significance only for one item: a small effect occurred for the extent to which students applied the information to their own life, $F(1, 210) = 5.24$, $p = .02$, $\eta_p^2 = .02$. Students who watched the poor visual quality lectures gave higher ratings ($M = 2.41$, $SD = 1.20$) relative to students who watched the good visual quality lectures ($M = 2.07$, $SD = .97$). The main effect of visual quality did not reach conventional (or conservative) levels of significance for the remaining items, $F\text{s} < 3.46$, $p\text{s} > .06$, nor did it interact with lecture fluency for any evaluation item, $F\text{s} < 1$.

Ratings of Visual and Audio Quality

Consistent with the visual quality manipulation, students in the poor visual quality groups rated the visual quality of the lecture to be worse than did students in the good visual quality groups (see Table 3). This outcome was confirmed with a 2 (Lecture fluency) × 2 (Visual quality) between-participant ANOVA. A significant main effect of visual quality indicated that students' ratings of the visual quality were lower in the poor visual quality group ($M = 68.41$, $SD = 21.81$) relative to the good visual quality group ($M = 77.54$, $SD = 22.68$), $F(1, 210) = 9.25$, $p = .003$, $\eta_p^2 = .04$. The main effect of lecture fluency was not significant, $F(1, 210) = 2.02$, $p = .16$, nor was the interaction between lecture fluency and visual quality, $F(1, 210) = 1.06$, $p = .31$.

Although we did not manipulate audio quality per se, students in the fluent group rated the audio quality higher than did students in the disfluent group (see Table 3). Specifically, a 2 (Lecture fluency) × 2 (Visual quality) between-participant ANOVA revealed that students in the fluent groups provided higher ratings of audio quality ($M = 82.15$, $SD = 20.26$) relative to students in the disfluent groups ($M = 70.85$, $SD = 26.40$), $F(1, 210) = 11.90$, $p = .001$, $\eta_p^2 = .05$. This is likely because students conflated audio quality with the instructor's fluency (i.e., the clear confident tone in the fluent condition and the frequent use of "ums" and unconfident tone in the disfluent group). The main effect of visual quality was not significant, $F < 1$, nor was the interaction between lecture fluency and visual quality, $F(1, 210) = 1.01$, $p = .32$.

In summary, as in Experiment 1, lecture fluency did not affect students' test performance. Even so, lecture fluency enhanced students' evaluations of the instructor and perceptions of their own learning. Experiment 2 also offers new data showing that the visual quality of a lecture, although noticed by students, did not impact any outcome. These results are different from those with text-based learning in which manipulations that degrade the visual quality of text can impact students' perceptions of their learning and their actual learning (e.g., Diemand-Yauman et al., 2011; Geller et al., 2018; Yue et al., 2013).

General Discussion

The present research sheds new light on how students' learning and metacognition are affected by different sources of fluency. Lecture fluency and technology fluency did not influence students' learning. By contrast, students' ratings of their own learning and their instructor's effectiveness were inflated by lecture fluency. Technology fluency did not affect students' ratings of their learning or the instructor.

These findings show that fluency-based cues that are internal to the instructor (e.g., lecture delivery style) affect students' evaluations of the instructor and of their own learning, whereas fluency-based cues are external to the instructor (e.g., visual quality) do not. These outcomes are consistent with those of Serra and McNeely (2020) who found that instructor fluency was strongly related to evaluations of the instructor (e.g., effectiveness, $r = .74$), but weakly related to ratings of items external to the instructor (course textbook, $r = .16$).

The present study is the first to show experimental evidence that internal versus external sources of fluency are utilized differently by students. Future research on students' perceptions of instructor effectiveness could directly examine the influence of factors internal to the instructor (e.g., lecture style, personality, gender) versus external to the instructor (e.g., technology, the classroom, classroom equipment). Understanding how students treat these cues could be addressed by manipulating a particular aspect of a lecture (e.g., the volume of an instructor's voice) and exploring its effects on students' evaluations of the instructor according to whether students are led to believe that the manipulation is attributable to the instructor (e.g., the instructor speaks quietly) or to something external to the instructor (e.g., a computer glitch that resulted in lower volume).

These findings have important implications for the effective evaluation of teaching. They suggest that instructors who are concerned about their evaluations should invest efforts into improving the fluency of their lecture delivery. External factors relating to technology are less likely to affect instructor evaluations. Teaching evaluation instruments typically contain items about both the instructor and course. Furthermore, student comments on teaching evaluations reflect various things that instructors sometimes have control over (e.g., preparedness, timeliness of feedback), and sometimes do not have control over (e.g., the time of day a class is scheduled, class length). To the extent that things external to the instructor (or outside their control) unfairly bias students' evaluations of instructors, actions could be taken to mitigate those biases by conducting independent evaluations of factors internal versus external to the instructor. Students' independent evaluations of factors such as campus technology and classroom spaces could even help identify areas where upgrades are needed.

Whereas visual quality of the lectures had no effects in the present study, other research shows that visual quality of written material can affect students' subjective and objective learning (Diemand-Yauman et al., 2011; Geller et al., 2018; Yue et al., 2013). The different effects of visual quality on lecture-based and text-based learning could be driven in part by modality. Whereas in prior work students only had access to visual text-based information, in Experiment 2, students were presented with both visual and auditory information. Even though the visual quality was degraded, having access to clear auditory information may have decreased students' reliance on the visual information when assessing their learning. Indeed, Fiechter et al. (2018) found that, when evaluating potential job candidates, audiovisual quality of the online interview significantly influenced participants' ratings of the candidates. Participants rated the candidates with poor audiovisual quality as less hirable compared to candidates with good audiovisual quality. One potential explanation for the different findings between their study and Experiment 2 could be because Fiechter et al., manipulated both the audio and visual quality, whereas we only manipulated the visual quality.

Although instructor fluency did not directly affect immediate test performance in the present study, it could indirectly benefit learning. That is, the positive experience with a fluent instructor could lead to increased motivation to attend class, ask questions, and engage in other behaviors that benefit learning over time in a real course. Indeed, some preliminary evidence for this might be gleaned from the evaluation items showing that students in Experiment 2 (but not Experiment 1) reported being more likely to watch online lectures from a fluent instructor than from a disfluent instructor. Students who watched the fluent lecture also tended to give numerically (but not significantly) higher ratings to evaluation items addressing the likelihood of studying and participating in class, as well as overall interest and motivation.

Students in both experiments reported that they learned the material better from a fluent instructor compared to a disfluent instructor, but instructor fluency did not significantly affect students' JOLs. This suggests that students' judgments about how well they have learned are not always equivalent to their predictions of exact test scores, and could indicate that students do not regard the two as one and the same. This possibility is in line with research showing that the framing of a question about learning—for example, whether students are asked to estimate how much they will remember versus how much they will forget—can influence students' responses (e.g., Finn, 2008; Tauber & Rhodes, 2012).

One limitation of the present experiments is that students were unsupervised when completing the tasks. Thus, we do not know how closely students paid attention to the lecture or what the environmental conditions were like during task completion. Even so, this study mimics how students would learn in authentic online courses. Given the unsupervised and less structured nature of online courses compared to face-to-face courses, students' metacognitive skills are vitally important to their success and thus represent a worthwhile topic for future research.

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