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Instructor presence in instructional video: Effects on visual attention, recall, and perceived learning

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ABSTRACT

In an effort to enhance instruction and reach more students, educators design engaging online learning experiences, often in the form of online videos. While many instructional videos feature a picture-inpicture view of instructor, it is not clear how instructor presence influences learners' visual attention and what it contributes to learning and affect. Given this knowledge gap, this study explored the impact of instructor presence on learning, visual attention, and perceived learning in mathematics instructional videos of varying content difficulty. Thirty-six participants each viewed two 10-min-long mathematics videos (easy and difficult topics), with instructor either present or absent. Findings suggest that instructor attracted considerable visual attention, particularly when learners viewed the video on an easy topic. Although no significant difference in learning transfer was found for either topic, participants' recall of information from the video was better for easy topic when instructor was present. Finally, instructor presence positively influenced participants' perceived learning and satisfaction for both topics and led to a lower level of self-reported mental effort for difficult topic.

1. Introduction

With the continued expansion of online learning in K-12 and higher education (Picciano, Seaman, Shea, & Swan, 2012), the ability to support all learners in online learning environments is unprecedentedly important. It has been reported that over 5.8 million students have taken at least one online course in higher education (Allen, Seaman, Poulin, & Straut, 2016, pp. 1–4). However, lack of adequate teacher presence is a common problem in online learning environments (Garrison, 2007). Strategies employed to mitigate this issue include instructor introductions to learning modules, synchronous meetings, virtual office hours, consistent presence in course discussions and prompt instructor feedback. Striving to enhance student engagement and perception of instructor presence in online learning, educators are placing much emphasis on designing and developing online videos that present learning content and frequently integrate the instructor as a picture-in-picture effect within the frame. Some instructional

videos, however, particularly those in the pencast format (Sowa & Thorsen, 2015), do not include an embedded video of the instructor, relying on step-by-step hand writing and voice-over narration by the instructor. A good example of an instructional pencast is the highly popular Khan Academy™ video series, which started out as an online resource offering instructional videos in mathematics and has now expanded to include statistics, chemistry, physics and other academic subjects. One prominent feature of Khan Academy™ is that unlike many other instructional videos, particularly those in the lecture format, it is designed without explicit instructor presence.

Many instructional videos integrate a video of the instructor (e.g., Cousera™, edX™) and this design decision comes at a substantial production cost. Theoretical propositions and empirical evidence for the support of incorporating instructor video in instructional materials are limited and mixed. For instance, the image principle of the Cognitive Theory of Multimedia Learning suggests that people do not learn more deeply when the speaker's image is provided in the instructional presentation (e.g., Mayer & DaPra, 2012; Mayer, Dow, & Mayer, 2003). It should be noted, however, that the image principle was tested using low-embodied or high-embodied animated pedagogical agents, rather than actual instructor videos, so little is currently known about the effects of course instructor presence in instructional videos. What is

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apparent is that students report enhanced engagement when instructional videos include a talking head of the instructor compared to those videos that do not (Guo, Kim, & Rubin, 2014; Kizilcec, Papadopoulos, & Sritanyaratana, 2014).

The current study examined how college students learned with the instructional videos produced by Algebra Nation™, an online community for learning mathematics used by hundreds of thousands of students. The main frame of each video is devoted to a Khan Academy™ style pencast, whereas the bottom right-hand corner always shows a shoulder-up view of the instructor (chosen by the student from a list of about four available instructors of different races and gender). The instructor's shoulder-up video shows the body language and facial expressions of the instructor explaining the content, while the rest of the frame presents a synchronized view of the instructor's hands spelling out and diagramming the problems, concepts, and procedures. The research approach used in this study is novel because in addition to data on learning outcomes (retention and transfer of knowledge), it generated data on the process of learning (visual attention distribution using eye tracking), as well as students' perceptions of their learning with videos on easy and difficult mathematics topics that integrated instructor video and those that did not.

2. Conceptual framework

2.1. Learning and engagement

An important theoretical perspective informing research on the effects of instructor presence in instructional videos is Cognitive Theory of Multimedia Learning (CTML, Mayer, 2014). According to CTML, human memory can be divided into sensory, working and long-term systems. Sensory memory selects and stores relevant visual and verbal information that is received via vision and hearing. Working memory is a central processing unit to process incoming information and integrate it with prior knowledge that has been stored in the long-term memory. Long-term memory stores schemas, or mental structures to organize knowledge. Baddeley's working memory model suggests that working memory has limited capacity (Baddeley & Hitch, 1974) allowing only about four items to be processed at a time (Cowan, 2001). Working memory is also assumed to have sub-units to process different types of information: visuospatial sketchpad for processing visual input, and phonological loop - auditory information. In the context of learning with an instructional video, the narration provided by the instructor would be considered as auditory information to be processed by the phonological loop and information displayed on the screen would constitute visual information processed using the visuospatial sketchpad.

Instructor video embedded in the main instructional video frame is a set of visual stimuli that provide primarily nonverbal communication cues. It is acknowledged that nonverbal communication plays an important role in interpersonal interaction (Argyle, 1988) and facilitates face-to-face mathematics learning (e.g., Alibali & Nathan, 2012). The utility of nonverbal communication also extends to online learning. In the context of instructional video, the image/video of instructor may result in deeper cognitive processing of learning content due to the activation of social interaction schema (Clark & Mayer, 2016). The instructor provides means of nonverbal communication such as mutual gaze, gesturing, and facial expressions. These nonverbal cues could support the cognitive processing of verbal information that is narrated by the instructor, thus improving comprehension. As these nonverbal cues constitute visual information, processed primarily by the visuospatial sketchpad, they should not interfere with the processing of auditory information (e.g., narration), which is handled by the phonological loop. In fact, instructor narration and visual presence in the form of instructor video possibly complement each other as they are processed by different channels (e.g., auditory and visual) and could potentially support information processing in two separate channels resulting in enhanced comprehension of the material. Furthermore, social agency theory suggests that social cues in multimedia presentations lead learners to feel as if they are interacting with another person (Cui, Lockee, & Meng, 2013). From this perspective, social cues in the video replicate the social aspects of human interaction, and this may induce beneficial socio-emotional responses in the learner.

Several studies have examined the influence of instructor presence on learning and perceptions; however, overall, the results appear to be tentative and inconclusive. Evidence of positive effect was provided by Chen and Wu (2015), who used an experimental design and compared the influence of three types of videos on learning: voice over (i.e., instructor's image in the upper left corner of the screen), lecture capture (i.e., a video recording of the lecture) and picture-in-picture. Participants each watched three learning units on document writing presented in each experimental format. Results indicated that performance on recall and transfer of learning with picture-in-picture and lecture capture types was superior to that related to the voice-over type. The three types of video did not cause significantly different levels of positive or negative emotions among participants. On the contrary, Homer, Plass, and Blake (2008) conducted an experiment in which undergraduate students viewed one of two versions of a computer-based multimedia presentation on child development: one included a lecturer with synchronized slides, and the other consisted of slides with audio narration. They compared learning in the two conditions using measures of recall and transfer of knowledge, as well as a social presence questionnaire. No significant difference was found in learning or social presence by including a lecturer in slides with audio narration. Kizilcec et al. (2014) investigated how adding the instructor to instructional video influences undergraduate and graduate students' perceptions and learning on a topic in organizational sociology. Although learners strongly preferred video instruction with instructor presence and perceived it as more educational, they did not perform significantly better on short-term or mid-term recall tests compared to the control condition without instructor presence.

Besides using experimental designs, scholars have also mined Massive Open Online Course (MOOC) server logs and examined the influence of instructor presence in Coursera™ (Bhat, Chinprutthiwong, & Perry, 2015) and edX™ (Guo et al., 2014) MOOC platforms. In a large-scale study of MOOC videos based on 6.9 million video watching sessions across four courses on the edX™ MOOC platform, Guo et al. (2014) examined two proxies for engagement: engagement time (i.e., video watching session length) and problem attempt at follow-up problems. They found students were engaged more with videos that intersperse an instructor's talking head, compared to videos with PowerPoint™ slides alone. Interestingly, the study also suggested that some learners were concerned about the "jarring" effect of having to switch repeatedly between talking head and on-screen text. In a similar study, Bhat et al. (2015) used clickstream data from one Coursera™ course to analyze the engagement (i.e., video watching time, discussion forum visits following a lecture view), motivation (i.e., certificate-earner proportion, fraction of lectures and quizzes that the learner viewed and submitted) and navigational patterns of learners upon being presented with lecture videos incorporating an instructor video in two formats: (a) where the instructor is positioned right next to the slide and seamlessly interacts with the content, and (b) where the instructor appears in a fixed window at the lower left corner of the screen, alongside the content window.

The results showed that learners prefer to watch videos in the mode where the instructor seamlessly interacts with the course content. It was suggested that the video that integrates the instructor interacting with course content offers access to the instructor's eye-gaze and gestures in proximity to the lecture content that results in a better learning experience for the learners via the availability of more realistic social cues (Bhat et al., 2015).

Existing evidence as to the effect of instructor presence on learning and engagement in instructional videos is limited and somewhat conflicting. Besides, much of the previous work has focused on videos in MOOC environments, such as Coursera™ and EdX™ and each of these complex environments comes with its own set of affordances and constraints. Despite the widespread use of instructional videos in K-16 settings, there is a pronounced lack of studies within the context of online mathematics instruction, particularly videos designed in the popular pencast format.

2.2. Cognitive load and split attention

Cognitive load theory (Kalyuga, Chandler, & Sweller, 2011; Paas, Renkl, & Sweller, 2003; Sweller, Merrienboer, & Paas, 1998) explains and predicts how working memory processes information and interacts with long-term memory. Cognitive load is defined as the amount of information being stored and manipulated in working memory (Sweller et al., 1998). When the information learners need to process exceeds the limited working memory capacity, learning is hindered due to excessive demands on cognitive processing. Cognitive load theory distinguishes among three types of load: intrinsic load, extraneous load, and germane load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). The extraneous cognitive load is mainly associated with a poor presentation of information and design of learning materials. Intrinsic cognitive load is determined by the complexity of the material (i.e., element interactivity) and is moderated by the prior knowledge learners possess. Different topics (e.g., solving a calculus problem vs. adding two single digits) differ in their levels of element interactivity and thus impose different levels of intrinsic cognitive load. Germane load occurs when assimilation or accommodation of presented information is encouraged during learning challenging learners but not overwhelming them. Thus, intrinsic and extraneous types of load tend to hinder learning, whereas germane load facilitates learning (Plass, Moreno, & Brünken, 2010). Ideally, multimedia materials should be designed to decrease extraneous cognitive load and allow more cognitive resources for germane processing of content imposing either high or low levels of intrinsic load.

In the context of learning with online videos that integrate instructor presence, it is important to recognize that the instructor's face may attract a significant amount of attention (see Yee, Bailenson, & Rickertsen, 2007 for a review of research on the important effects of faces in human-computer interfaces). It has been noticed humans' preferential orientation to faces developed in newborns (Johnson, Dziurawiec, Ellis, & Morton, 1991). Consequently, it is reasonable to expect that instructor presence in instructional video may result in a profound impact on learners' distribution of visual attention.

Given that the instructor's face in an instructional video likely attracts a considerable amount of visual attention, the instructional video frame provides other important instructional components that require significant visual processing - such as text, diagrams, pencasts and so on - and so, instructor presence may distract learners' attention away from important instructional information, thus hindering learning. Based on Baddeley's working memory model, both the content information on the screen and video of the instructor need to be processed by the visuospatial sketchpad structure of working memory, which has severe limitations in terms of both capacity and duration (Paivio, 1991). Thus, the video of the instructor would draw on additional cognitive resources and possibly overload the visual channel.

Instructor face and visual information in the rest of the video frame can be understood as two complex sets of visual stimuli that compete for the cognitive resources of the visuospatial sketchpad, potentially resulting in split attention (Antonenko & Niederhauser, 2010; Kalyuga et al., 2011). From the cognitive load perspective, the instructor video may be construed as extraneous information that results in increased extraneous cognitive load (Paas, Renkl, et al., 2003; Paas, Tuovinen, et al., 2003). The additional extraneous processing could hinder the cognitive processing of the important content information presented in the rest of the frame and ultimately impede learning. Empirically, Kizilcec et al. (2014) observed that learners spent more time looking at the instructor than the rest of the screen with important instructional content. It is reasonable to hypothesize that as learners attend to the instructor in the video more, they would devote less visual attention to the rest of the frame, resulting in inhibited learning. Limited empirical evidence suggests such a tradeoff between the costs and benefits of instructor presence in video and the findings are not consistent. Using the cognitive load self-report scale (Paas, 1992), Homer et al. (2008) found that participants experienced a significantly higher cognitive load in the format with slides with instructor's image, compared to the audio narration condition. Conversely, Chen and Wu (2015) revealed that participants perceived a significantly lower cognitive load in the picture-in-picture type of video compared to the voice-over type.

2.3. Understanding attentional dynamics using eye tracking

Compared to traditional product measures that assess learning outcomes, typically retention and transfer of learning, eye tracking can be used to provide insights into the underlying attentional dynamics during the learning process. The eye-mind hypothesis (Just & Carpenter, 1980) suggests that eye movement recordings can provide a trace of where the person's attention is directed to and where the person is engaged in cognitive processing. Empirical methods like eye tracking can be used to understand the dynamics of visual attention distribution during multimedia learning (e.g., Mayer, 2010). Empirically, eye tracking method has been used to study multimedia learning in recent years. These studies helped determine that (a) a strong link exists between eye fixations and learning outcomes (Boucheix & Lowe, 2010); (b) visual cues guide learners' visual attention (Boucheix & Lowe, 2010; de Koning, Tabbers, Rikers, & Paas, 2010); (c) prior knowledge guides visual attention (Canham & Hegarty, 2010; Jarodzka, Scheiter, Gerjets, & Gog, 2010); and (d) learners who view animation and on-screen text must split their attention between graphics and printed words (Schmidt-Weigand, Kohnert, & Glowalla, 2010). Compared to traditional outcome measures, eye tracking is a process measure that could shed light on the mechanism of split attention that occurs when attention is switched between the instructor and the rest of content in the video frame (Johnson, Ozogul, Moreno, & Reisslein, 2013; Schmidt-Weigand et al., 2010).

So far, few empirical studies have used eye tracking to study the role of human instructor in instructional videos to explore visual attention distribution. Two studies concluded that including the instructor profoundly changed learners' watching behavior. Kizilcec et al. (2014) determined that participants spent about 41% of the time looking at the instructor and switched between the instructor and the slide content every 3.7 s. Similarly, Louwerse, Graesser, McNamara, and Lu (2008) found that even when pedagogical agent only made up around one-fourth of the display, participants contributed 56% of visual attention to the agent.

Assuming that the learner has to divide attention between the instructor and the learning content in an instructional video with instructor presence, learners should be able to process information more efficiently when they are presented with an easy topic (lower intrinsic load) compared to a difficult topic (higher intrinsic load, Paas, Renkl, et al., 2003; Paas, Tuovinen, et al., 2003). It is reasonable to hypothesize that the distribution of visual attention and learning performance should vary based on the complexity of the video. This assumption has yet to be tested empirically.

This study is important because despite decades of research on multimedia learning and learning with video specifically, we still know very little about the efficacy of instructor presence in instructional videos, specifically in the content area of mathematics. On one hand, the presence of instructor could elicit beneficial socio-emotional responses and support learners' understanding by providing nonverbal modalities of interaction (Clark & Mayer, 2016). On the other hand, the presence of a real instructor on the screen provides a group of complex visual stimuli that might unnecessarily distract learners and add to learners' extraneous cognitive load, especially when the content itself has already imposed a relatively high intrinsic cognitive load. It is possible that the potential benefits from eliciting socio-emotional responses by adding instructor in the video may be offset by the extraneous visual and cognitive processing associated with attending to the instructor video, as it demonstrates little pedagogically pertinent content. Therefore, more empirical research guided by relevant theoretical frameworks is needed to explore the issue of instructor presence in video.

3. Method

Given the theoretical perspectives and empirical evidence discussed above, the current study was designed to explore the following research questions:

Question 1. To what extent does instructor presence in instructional video influence learning for easy and difficult mathematics topics?

Question 2. How does instructor presence in instructional video influence visual attention distribution for easy and difficult mathematics topics?

Question 3. To what extent does instructor presence in instructional video influence perceived learning, mental effort, satisfaction for easy and difficult mathematics topics?

3.1. Participants

Thirty-six undergraduate students (age 18–21, 21 female) were recruited for the study. Participants represented various majors including education, biology, accounting, architecture, and others. All participants had normal or corrected to normal vision. No participant was color-blind or had any neurological disorders.

Demographics statistics are provided in Table 1.

4. Materials

The instructional videos represented two typical areas of college mathematics (Geometry and Algebra), reflecting different levels of difficulty. After expert review by three Mathematics Education experts, Similar Triangles represented an easy mathematics topic and Trigonometric Function - a difficult mathematics topic. The two videos with instructor presence were designed by Algebra Nation™. The two videos without instructor presence were made by Khan Academy™. Algebra Nation™ videos on Trigonometric Function and Similar Triangles featured a picture-in-picture instructor video overlaid on the screen in the lower right-hand corner, whereas Khan Academy™ videos did not. All videos were assessed and optimized regarding length, rate of narration and pencasting, and amount and nature of concepts covered. Each video lasted approximately 10 min. Each participant was randomly assigned to one of two conditions (i.e., Similar Triangles with instructor present and Trigonometric Function with instructor absent or vice versa) and viewed the two videos in random order.

4.1. Apparatus

Videos with and without instructor presence were displayed on an external 20-inch flat panel monitor viewed at a 55-cm distance, with a resolution of 1600 by 900 pixels and a refresh rate of 60 Hz. Eye-tracking data was collected via Eyelink 1000 Plus system (SR Research, Ontario, Canada) using a desktop-mount (Fig. 1). Participants used a chinrest (SR-HDR) with a forehead bar to minimize head movement. Eyelink's Screen Recorder software was used to simultaneously capture locus of participants' gaze while recording screen capture videos, at a sampling rate of 1000 Hz.

4.2. Measures

4.2.1. Prior knowledge

Participants answered 8 multiple-choice questions establishing their knowledge of Similar Triangles and Trigonometric Function. No feedback was provided to participants to avoid influence on the post-test. The prior knowledge test was reviewed and optimized by three Mathematics Education experts.

4.2.2. Visual attention

Visual attention distribution is typically inferred using gaze fixations, which occur when the eye settles on something for around 300 ms. Eye tracking has been proved as a useful tool to study visual attention distribution (van Gog & Scheiter, 2010) and it is very suited to study differences in attentional processes evoked by different types of multimedia (Holsanova, Holmberg, & Holmqvist, 2009. Thus, in order to examine the influence of

Table 1
Participant demographics.

Variables	Statistics
Gender	21 F, 15 M
Age	M = 19.56 (SD = 0.84)
Ethnicity	29 White/Caucasian, 6 Hispanic/Latino, 1 Asian-Pacific Islander
Undergraduate classification	5 Freshman, 19 Sophomore, 10 Junior, 2 Senior
Wear glasses	12 Yes, 24 No
English as first language	32 Yes, 4 No
Resources used in addition to textbooks when learning outside the classroom	Websites, Wikipedia, YouTube, Google, Smokin Notes, Wolfram Alpha, Newspapers, Journals, Quizlet, Khan Academy, Study Edge

Fig. 1. Experimental setup.

instructor presence on visual attention in instructional video, this study defined the portion of the frame showing the instructor as the interest area (IA). Attentional dynamics were inferred by examining participants' fixation count, fixation count percentage, dwell time, dwell time percentage, and number of transitions between the instructor video (IA) and other visual content on the screen (i.e., the pencast). As visual attention is split between instructor video and the rest of the screen when the instructor is present, the number of transitions between fixating on the instructor and the content was calculated to examine the magnitude of split attention caused by instructor presence in the video.

Research topics of social presence in computer-mediated instruction generally examined the influence of online social presence on students' perceived learning (Richardson & Swan, 2003) and satisfaction (Gunawardena & Zittle, 1997; Richardson & Swan, 2003). As instructor in instructional video was hypothesized to provide socio-emotional cues, we decided to examine the influence of instructor presence on participants' perceived learning and satisfaction in this study.

4.2.3. Perceived learning

Immediately after viewing the two videos on Similar Triangles and Trigonometric Function, participants indicated how much they had learned from each video on a scale from 1 to 9 where 1 stands for "did not learn anything" and 9 means "learned a great deal".

4.2.4. Satisfaction

After reporting perceived learning, participants were asked to rate their satisfaction regarding learning with each video using a 9-point Likert scale that ranged from extremely dissatisfied (1) to extremely satisfied (9).

4.2.5. Mental effort

Participants reported on the perceived amount of mental effort for each video using 1-item measure on a 9-point Likert scale (Paas, 1992). The scale ranged from very, very low mental effort (1) to very, very high mental effort (9). This scale has been validated in many prior studies as a subjective measure of cognitive load (e.g., Antonenko & Niederhauser, 2010; Antonenko, Paas, Grabner, & van Gog, 2010; Paas, Renkl, et al., 2003; Paas, Tuovinen, et al., 2003; Plass, Heidig, Hayward, Homer, & Um, 2014) and the reliability of the scale was estimated at 0.90 using Cronbach's coefficient alpha (Paas & van Merriënboer, 1994).

4.2.6. Perceptions of instructor presence

After rating perceived learning, satisfaction, and mental effort for each video, participants answered one open-ended question regarding their perceptions of instructor presence in one of the two videos they had been assigned to: Please explain what you think about seeing the instructor in the video, compared to not seeing the instructor. Then, participants were asked to provide feedback on their perceptions of instructor presence by selecting all adjectives that helped characterize their experience (e.g., 'helpful', 'useful', 'engaging' 'distracting', 'annoying', 'other').

4.2.7. Learning

Recall and transfer are two typical measures that have been used to measure learning in relevant studies on instructor presence in video-based instruction (e.g., Chen & Wu, 2015; Homer et al., 2008; Kizilcec et al., 2014). After the participants shared their perceptions

of instructor presence, learning performance was measured using recall and then transfer assessments. Four recall questions for each video assessed participants' comprehension of key concepts covered in the two videos (e.g., 'How could you use the unit circle in Trigonometric Function?'). Four transfer questions for each video focused on participants' ability to apply what they had learned from the videos in a new context (e.g., 'The following two triangles are similar, what is the length of side AB?'). The questions were reviewed and optimized by three Mathematics Education experts. Test scores were calculated by assigning one point for a fully correct response, 0.5 points for a partially correct response (only in recall questions), and zero points for incorrect responses.

4.3. Procedure

After signing the informed consent form, participants completed a brief demographics survey and a test of their prior knowledge of Similar Triangles and Trigonometric Function. At the beginning of the experiment, the gaze of each participant was calibrated and validated with a 13-point calibration algorithm. Participants watched the videos without pauses and did not take notes while watching the videos. Immediately after watching the two videos, participants reported perceived learning, satisfaction, and mental effort for Trigonometric Function and Similar Triangles respectively, and their perceptions of instructor presence. After that, participants responded to the recall questions and transfer questions focusing on the easy and difficult topics. No time limit was imposed on participants for completing the assessments.

5. Results

5.1. Learning performance

A paired samples t-test revealed no significant differences across the two groups on pre-test scores of prior knowledge. After that, a one-way MANOVA was conducted on the recall and transfer scores for the easy and difficult topics. Table 2 shows the average recall and transfer accuracy (%) between participants who watched the videos with and without instructor presence. For the easy topic, the effect of instructor presence on learning transfer was not significant ($F (1, 34) = 0.092$, $p = 0.764$); however, the effect of instructor presence on recall was significant ($F (1, 34) = 8.588$, $p < 0.05$, $\eta 2 = 0.202$). Specifically, instructor presence accounted for about 20 percent of the variance in the recall scores for the easy topic. For the difficult topic, the effect of instructor presence was insignificant for either recall ($F (1, 34) = 0.481$, $p = 0.493$), or for transfer ($F (1, 34) = 0.652$, $p = 0.425$). Although no significant difference in transfer scores was found for either topic, participants' ability to recall information from the video was significantly better for easy topic when instructor was present.

5.2. Visual attention distribution

Heat maps of where participants tended to fixate when the instructor was present and absent are shown for the easy topic

(Fig. 2) and for the difficult topic (Fig. 3). The figures indicated that the instructor attracted considerable visual attention for both easy and difficult topics.

We also defined instructor as IA and examined participants' fixation counts, fixation count percentage, dwell time, dwell time percentage, and number of transitions between the instructor and the rest of the visual information on the screen. The results are summarized in Table 3. Participants spent 26% of time attending to the instructor in the easy topic video, whereas they spent 22% of the time attending to the instructor in the difficult topic video. Considering the instructor IA only occupied about 7% of the entire screen in either video, this result suggests that participants attended considerably more to the instructor than to the rest of the video content. Participants devoted a larger portion of fixations to the instructor while watching the easy topic video, as evidenced by the ANOVA test on the effect of topic difficulty level on instructor fixations count percentage ($F (1, 34) = 0.042$, $p < 0.05$, $\eta 2 = 0.130$). No significant differences were found for the number of transitions between fixating on the instructor and content between the easy and difficult topic videos.

5.3. Perceived learning, satisfaction, and mental effort

The average ratings on the scales of perceived learning, satisfaction, and mental effort for the easy and difficult topics are provided in Fig. 4. The items were all rated on a 9-point Likert scale. A MANOVA test was conducted to explore the effects of instructor presence for the easy and difficult topics on perceived learning, satisfaction, and mental effort.

For the easy topic video, results indicated a significant difference in perceived learning ($F (1, 34) = 28.640$, $p < 0.05$, $\eta 2 = 0.457$) and satisfaction ($F (1, 34) = 41.624$, $p < 0.05$, $\eta 2 = 0.550$). For the difficult topic video, results revealed a significant difference in perceived learning ($F (1, 34) = 6.050$, $p < 0.05$, $\eta 2 = 0.151$), satisfaction ($F (1, 34) = 11.108$, $p < 0.05$, $\eta 2 = 0.246$), and mental effort ($F (1, 34) = 9.129$, $p < 0.05$, $\eta 2 = 0.212$). Participants tended to have higher perceptions of learning and reported higher level of satisfaction when the instructor was present in both easy and difficult topic videos. Also, self-reported mental effort was considerably lower for the difficult topic video when the instructor was present compared to when the instructor was absent.

The participants also identified all adjectives that describe their feeling towards instructor presence in video. Participants who viewed the difficult topic video with instructor present felt instructor presence was helpful ($n = 14$), useful ($n = 8$), and entertaining ($n = 1$). Participants who viewed the easy topic video with instructor present felt instructor presence was helpful ($n = 15$), useful ($n = 12$), engaging ($n = 2$), annoying ($n = 1$), and distracting ($n = 1$). Moreover, out of 36 responses to the question "Please explain what you think about seeing the instructor in the video, compared to not seeing the instructor", five participants mentioned seeing the instructor in the video imitates a real classroom setting and thus increases the perception of an "in-class" atmosphere. Compared to not seeing the instructor on the screen, they reported feeling as if they were working with someone and

Table 2
Mean accuracy (%) and standard deviation on recall and transfer tests.

Topic		Instructor present	Instructor absent
Easy	Recall	0.94 (0.16) [*]	0.56 (0.29) [*]
	Transfer	0.96 (0.11)	0.94 (0.24)
Difficult	Recall	0.58 (0.26)	0.47 (0.21)
	Transfer	0.81 (0.26)	0.74 (0.22)

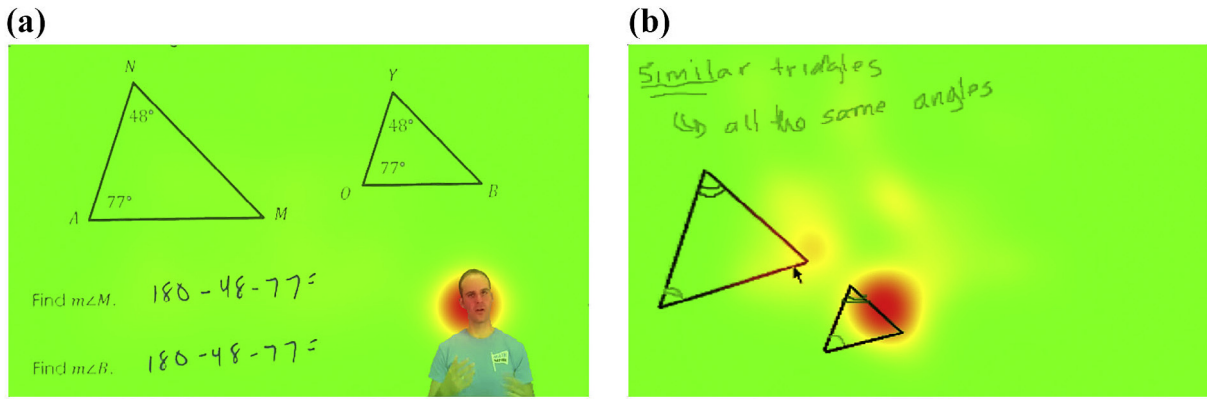[*]Significant difference at $p < 0.05$.

(a)

(b)

Fig. 2. Aggregated heat map of gaze fixation count percentage for the easy topic video when instructor was present (a) and instructor was absent (b).
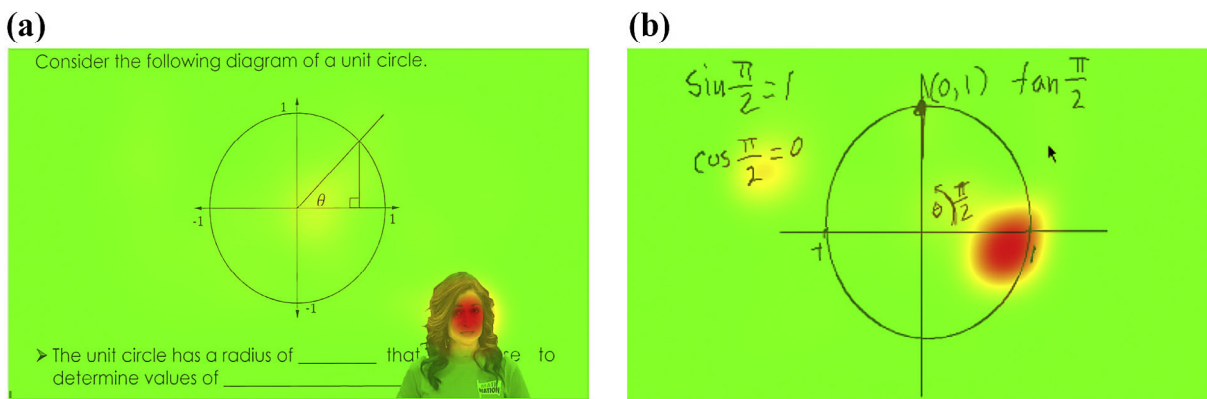
(a)

(b)

Fig. 3. Aggregated heat map of gaze fixation count percentage for the difficult topic video when instructor was present (a) and instructor was absent (b).

Table 3
Mean and standard deviation values for fixation count, fixation count (%), dwell time, dwell time (%), and number of transitions when instructor was present. (Notes: Instructor was defined as IA across participants).

Parameters	Easy topic	Difficult topic
Fixation count (Average number of total fixations on IA)	319.38 (95.03)	267.88 (85.28)
Fixation Count (%) (Average percentage of all fixations on IA)	0.20 (0.05) [*]	0.16 (0.05) [*]
Dwell Time (ms) (Average sum of all fixation durations on IA)	141147.66 (43,256.38)	125,265.25 (46,367.24)
Dwell Time (%) (Average percentage of trial time spent on IA)	0.26 (0.07)	0.22 (0.07)
Number of Transitions (Average number of times IA was entered and left)	104.00 (26.56)	112.81 (38.85)

[*]Significant difference at $p < 0.05$.

would be more focused when watching the video. Based on these results, participants generally had a positive attitude toward the videos with instructor presence, regardless of the topic difficulty.

Using a Pearson product-moment r correlation, we examined the relationship between participants' visual attention distribution during the video viewing session and their recall and transfer of learning as well as perceptions, for both easy and difficult topics. Participants' perceived learning, mental effort and satisfaction were not significantly correlated with their visual attention distribution, for either topic. In other words, participants who reported a higher rating in perceived learning and satisfaction, or experienced less mental effort did not devote more visual attention to the instructor. Finally, we explored potential relationships between learning performance scores and responses to questions on perceived learning,

satisfaction, or mental effort, for easy or difficult topic. No significant correlations were identified.

In summary, we found that transfer of learning was not improved or hindered by instructor presence in the video, for either the easy or difficult topic. The ability to recall information from the easy topic video; however, was enhanced when the instructor was present. Instructor presence significantly influenced learners' visual attention distribution for both topics. Participants allocated a larger percentage of fixations to the instructor in the easy topic video, compared to the difficult topic video. Perceived learning and satisfaction increased by including the instructor for both topics and learners experienced a significantly lower level of mental effort when the instructor was present in the difficult topic video.
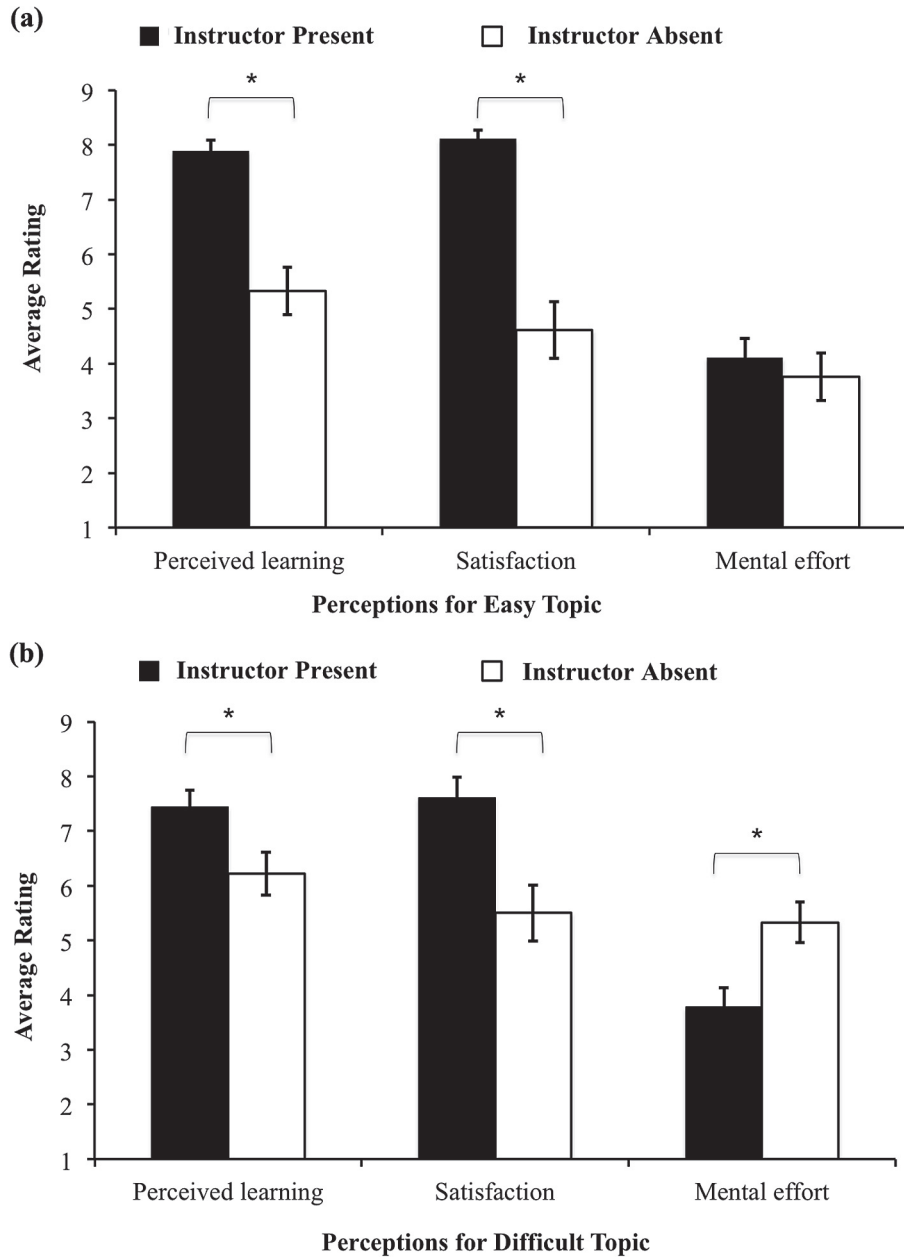
(a)

(b)

Fig. 4. Average rating on scales of perceived learning, satisfaction, and mental effort for easy topic (a) and difficult topic (b) ($^*p < 0.05$).

6. Discussion

This study examined how instructor presence in a mathematics instructional video would influence learning, visual attention distribution, and student perceptions for easy and difficult learning content. The results indicate that learners contributed a considerable amount of visual attention to the instructor, especially when they viewed the video on an easy topic. Instructor presence significantly improved satisfaction and perceived learning for both easy and difficult topics. Moreover, instructor presence resulted in decreased self-reported mental effort in the context of learning from a video on a difficult topic. While recall performance was significantly better on the easy topic when the instructor was present, instructor presence did not influence transfer of learning for either topic in a statistically significant way.

Participants assigned to the instructor presence condition in this

study significantly outperformed their counterparts who watched the video with instructor absent. This finding applied to the two videos on an easy topic. A possible explanation for this result can be provided using cognitive load theory (Sweller et al., 1998). Using this framework, it is reasonable to assume that the intrinsic cognitive load imposed by videos on an easy mathematics topic is relatively low, and learners may have a cache of cognitive resources that are available for attending to the instructor. The instructor in this study used a variety of nonverbal communication means including mutual gaze, facial expressions, and gestures, which attracted a significant amount of participants' visual attention (i.e., 26% of total dwell time). As discussed in the introduction to this study, nonverbal cues are very important in everyday social interactions (Argyle, 1988) and in mathematics learning and instruction specifically (e.g., Alibali & Nathan, 2012). The nonverbal cues provided by the instructor in our study likely served an

important signaling function (Mayer, 2014; van Gog & Tamara, 2014) and direct learners' attention to the most important and relevant aspects of the instructional content, thus resulting in better recall performance.

This finding provides empirical evidence for the assumption that the instructor in the video could help direct and possibly maintain learners' attention and keep them engaged in the cognitive processing of learning materials. However, the positive effect of instructor presence on recall was not replicated in the case of the difficult topic video. It is reasonable to assume that in this situation, learners experienced a higher level of intrinsic load imposed by the learning content, resulting in somewhat decreased levels of visual attention allocated to the instructor (i.e., 22% of total dwell time) compared to dwell time demonstrated when viewing the video on an easy topic. Attention to the instructor could still result in positive effects elicited by nonverbal cues and signaling as described above for the easy learning content, but involuntary attention to the instructor may have also interfered with the processing of cognitively demanding (difficult) learning content. As such, the possible signaling benefits of instructor presence could have been offset in this study by the negative influence of split attention, that is, attention split between the difficult learning content in the main frame of the video and the picture-in-picture presentation of the instructor in the lower right-hand corner of the frame. Split attention is a frequent issue in the design of learning materials (Antonenko & Niederhauser, 2010; Kalyuga et al., 2011; Paas, Renkl, et al., 2003; Paas, Tuovinen, et al., 2003) and it appears that in this study, the negative effects of split attention in the difficult video may have overridden the possible positive effects of nonverbal cuing.

The present study did not identify evidence that instructor presence enhanced recall of information for the difficult topic video. Thus, future studies could consider including the instructor in instructional videos in a more strategic manner; for example, hide the instructor frame when learners' attention must be devoted to the particularly challenging information in the main frame of the video, in order to reduce unnecessary distraction and possible split attention and allow learners to devote more cognitive resources to the processing of complex information. Moreover, the positive effect of instructor presence on learning in this study was limited to recall of information, and it did not carry over to the higher level of cognitive learning (i.e., learning transfer). This observation is consistent with the finding by Homer et al. (2008), who reported no increase in transfer of learning by adding a lecturer to slides with audio narration.

The empirical work presented in this article is perhaps the first study that has used eye-tracking technology to explore the effect of instructor presence on visual attention distribution in mathematics instructional videos. Eye-tracking measures such as dwell time, fixation counts, and transitions between areas of interest in the visual field allowed us to illustrate the attentional dynamics as the learner switched attention between the content portion of the video and the picture-in-picture video of the instructor. As hypothesized, the difficulty level of content moderated the distribution of visual attention when the instructor was present. In the case of the video on an easy topic, learners likely experienced lower intrinsic load and thus could strategically or inadvertently allocate more visual attention to the instructor. While watching the video on a difficult topic, attentional and cognitive processing of the content is increased and thus, less visual attention can be devoted to the instructor frame in the video as both content and instructor are processed through the visual channel. A similar interpretation was provided by Schmidt-Weigand et al. (2010). Eye tracking data in that study showed that while presented with multimedia instruction, learners who listened to spoken text attended to

visualizations more fully compared to those who read the written text. Written text and visualizations that were both processed through the visual channel likely overwhelmed the visuospatial sketchpad, resulting in decreased visual attention to the visualizations. Similarly, participants in the current study devoted less visual attention to the instructor frame when the processing of intrinsically complex content could have possibly increased the load on the visual channel. In this study, the instructor presence influenced participants' visual attention distribution in important ways, as evidenced by a higher percentage of fixation count on the instructor overall, and increased fixation count percentage in the video on an easy topic.

Unlike many studies that focus on multimedia learning, the current study included measures of participants' perceptions of the efficacy of the educational intervention — that is, instructor presence — in instructional video. Participants' ratings on perceived learning and satisfaction scales demonstrated a strong preference for the videos with instructor presence for both easy and difficult topics. Apparently, videos with instructor presence elicited positive affective responses from the learners, possibly due to the social cues in the instructor videos. The non-verbal social cues provided by the instructor such as gestures, mutual gaze, facial expressions, as well as the instructor's seamless interaction with the content could have contributed to an improved socio-emotional reaction in the learners, which has been a consistent finding in prior studies (Bhat et al., 2015; Cui et al., 2013; Krämer & Bente, 2010).

The results of this study align with the findings from Fredericksen, Pickett, Shea, Pelz, and Swan (2000), who reported that student-instructor interaction is the most significant factor that contributes to a higher level of perceived learning and satisfaction with the course. Similarly, empirical data on the affective effects of animated pedagogical agents in multimedia learning suggests that learners tend to appreciate the "humanness" of agents, especially when the level of embodiment is high (e.g., Baylor & Kim, 2005; Kim & Baylor, 2016). Having said this, seeing the instructor was not unanimously preferred by all learners in our study. Two participants, both experiencing instructor presence in the difficult topic video, expressed negative feelings toward instructor presence. One participant stated "I thought it was really distracting seeing him in the bottom corner. He kept moving around, and my eye was naturally drifting towards him so I couldn't pay attention to the equations." Overall, however, instructor presence in this study was found to have a significantly positive effect on participants' perceived learning and satisfaction, both of which are essential factors that influence learner engagement, interest, and motivation (e.g., Bandura & Cervone, 1986; Kim, Kim, & Wachter, 2013).

Interestingly, participants' perceptions of learning (i.e., "How much do you think you have learned from this video?") were not correlated with their actual learning performance on either the recall test or the transfer test. This result confirms findings from other relevant studies that tried to compare subjective, self-reported learning performance or judgments of learning with the results of objective learning tests. For example, in a study published in the journal *Science*, Karpicke and Blunt (2011) found that students could not accurately predict what learning strategy was the most effective. The strategy they identified in their metacognitive predictions (repeated study) was significantly less effective than retrieval practice, which resulted in the highest learning outcomes on recall and inference tests. Other relevant studies have reported the following problems with self-reports of learning: students typically overestimate how well they understand, fail to recognize their own states of impasse in problem solving, and persist with unproductive strategies (Anderson & Beal, 1995; Gobert, Sao Pedro, Baker, Toto, & Montalvo, 2012; Markman, 1977; Stevens & Thadani,

2007). Thus, an unintended contribution of the present study is empirical evidence that when it comes to introspecting on learning, individuals may not be able to provide reliable data.

7. Limitations

Despite the contributions of the current study, there were certain limitations to the study design that may have influenced the reliability and generalizability of the findings. First, the study was conducted in a highly controlled lab setting with the use of an eye tracker, which could have possibly influenced participants' viewing behavior. Second, the participants were told they would be tested on the materials after watching the videos, and this possibly increased their engagement with the video content. Moreover, the participants in the current study were not allowed to take notes or pause while viewing the instructional videos, which is not representative of authentic video viewing contexts.

8. Conclusion

This study explored the influence of instructor presence on learning, visual attention distribution, and perceived learning, mental effort, and satisfaction, when viewing mathematics instructional videos at easy and difficult levels of content complexity. Findings suggest that while the picture-in-picture video of the instructor attracted significant levels of visual attention across the entire viewing session (particularly when learners viewed an easy topic video), instructor presence did not result in increased transfer for both easy and difficult learning content and increased recall for difficult content. Although positive or negative effects on learning transfer were not observed, the ability to recall information from the easy topic video was significantly better when the instructor was present. Moreover, instructor presence produced a significant positive effect on participants' perceived learning, satisfaction, and mental effort, which are essential factors that contribute to learner motivation and engagement in the autonomous and self-regulated online learning environment.

Future research could test the efficacy of instructor presence in other learning contexts and with different populations of learners. It would also be useful to examine the effect of adaptive instructor presence, specifically when the instructor frame is presented not all of the time but only during the times when the instructor provided nonverbal cues and signaling can enhance the processing of learning content. As millions of learners representing a variety of attentional and cognitive differences use instructional videos today, it is also imperative to understand how learners with individual differences respond to instructor presence in online videos and learn with such videos and how the design of videos can be improved to accommodate the needs of a wider range of learners.

Conflict of interest

The authors declare that they have no conflict of interest.

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