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What is my teacher talking about? Effects of displaying the teacher's gaze and mouse cursor cues in video lectures on students' learning

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ABSTRACT

Eye movement modelling examples (EMME) are instructional videos that display a teacher's eye movements as "gaze cursor" (e.g. a moving dot) superimposed on the learning task. This study investigated if previous findings on the beneficial effects of EMME would extend to online lecture videos and compared the effects of displaying the teacher's gaze cursor with displaying the more traditional mouse cursor as a tool to guide learners' attention. Novices ($N = 124$) studied a pre-recorded video lecture on how to model business processes in a 2 (mouse cursor absent/present) × 2 (gaze cursor absent/present) between-subjects design. Unexpectedly, we did not find significant effects of the presence of gaze or mouse cursors on mental effort and learning. However, participants who watched videos with the gaze cursor found it easier to follow the teacher. Overall, participants responded positively to the gaze cursor, especially when the mouse cursor was not displayed in the video.

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Instructional design; eye movement modelling examples; video learning

Introduction

Over the last decade, video education has become more prominent and popular than ever and most recently, the majority of educational institutions worldwide were even forced to teach their courses and lectures remotely due to the global COVID-19 pandemic (Ali, 2020). Hence, teachers often found themselves uploading video recordings of their offline learning materials (e.g. presentations of regular lecture slides). This study investigated the possible benefits of displaying a teacher's gaze in such lecture videos with the help of eye-tracking technology to guide learners' attention, as compared to or in addition to the use of the mouse cursor as a tool for attention guidance.

Lecture videos typically present visual information, for instance from a slideshow or animation, together with the teacher's verbal explanations. To successfully learn from such multimedia materials, learners first need to select the relevant information from different sensory channels at the right time, then mentally organise this information, and finally integrate the different pieces of information with each other and with their prior knowledge to construct a rich mental model (cogntitive theory of multimedia learning, Mayer, 2014a). However, because video content is transient, this first step of selecting the relevant information can already be challenging for learners, because not all information is available at each moment in time (Ayres & Paas, 2007). This can hamper learning, as information that was not attended in time, is no longer available for processing.

A way to foster information selection during multimedia learning is by adding cues for attention guidance to the learning materials (e.g. Richter et al., 2016; Van Gog, 2014). For instance, lecture videos can show the location of the teacher's computer

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mouse (via the "mouse cursor", which is often displayed as an arrow) as a visual cue on the screen to direct the learner's attention to task-relevant elements. However, this requires a deliberate decision by the teacher about what they want to bring to students' attention. In other words, to use the mouse cursor as a pointing device in videos efficiently, teachers need to understand when their students are no longer "with them" and need further attention guidance. However, research shows that domain experts often find it difficult to estimate novices' prior knowledge and understanding (Hinds, 1999; Hinds et al., 2001).

A novel, promising alternative would be to use eye-tracking technology to add visual cues for attention guidance to instructional videos (for information on eye tracking, see Holmqvist et al., 2011). Eye-tracking technology can not only capture where a person looks over time, but also visualise this information. For instance, a person's fixations (during which the eyes rest relatively still on one location to take in information) can be displayed as a moving dot or circle superimposed on the video (hereafter referred to as *gaze cursor*). Videos that show a person's (e.g. an expert teacher's) gaze cursor while they demonstrate how to perform a task are commonly referred to as eye movement modelling examples (EMME, Van Gog et al., 2009). In pre-recorded lecture videos, the gaze cursor of an EMME can highlight to learners what information on the lecture slides the teacher is talking about. Research from different domains has often shown that EMME successfully guide students' attention (e.g. Jarodzka et al., 2012; Van Marlen et al., 2018) and can foster learning (e.g. Bednarik et al., 2018; Krebs et al., 2019; Litchfield et al., 2010; Mason et al., 2015a, 2015b, 2017; Winter et al., 2021). Displaying a teacher's gaze cursor has also been found to foster the learners' understanding of lecture videos (e.g. learners needed less frequent and shorter pauses when watching a MOOC video with superimposed eye movements, Sharma et al., 2015). The effects of displaying the gaze cursor in lecture videos on actual learning outcomes are, however, unknown.

Therefore, the aim of the present study was to compare the effects of displaying a teacher's gaze cursor on students' learning from lecture videos compared to the more traditional (and deliberate) mouse cursor as pointing device.

Guiding attention in instructional videos with visual cues to foster learning

Instructional videos that contain multimedia content have great potential to foster learning (for a recent meta-analysis see Noetel et al., 2021). However, selecting the relevant information in time can be particularly challenging when learning from video materials, as videos often contain transient, dynamically changing information (Ayres & Paas, 2007). To overcome this challenge, teachers might try to verbally guide learners' attention to the relevant video elements. However, there may be several reasons why expert verbalisations remain insufficient to guide learners' attention. First, domain experts may experience difficulty verbalising and explaining the processes of their task performance (Ericsson & Simon, 1980). This is presumably because these processes are often fast, automatised and performed without full awareness (e.g. Boshuizen & Schmidt, 2008). A teacher might therefore create a lecture video without mentioning all the relevant steps that they actually perform themselves. Second, experts have been found to experience difficulties assessing novices' level of prior knowledge (Hinds, 1999). Consequently, an expert video teacher may not appropriately adapt their choice of words to a novice audience and might instead use abstract terms and expert jargon that novices have not learned yet in the video (e.g. Hinds et al., 2001). Third, next to ambiguity due to students' unfamiliarity with the terms used by teachers, Van Marlen et al. (2018) mention two other reasons why teachers' verbal referents can remain ambiguous. First, the video may contain competing visual information, for instance when it displays multiple objects that the teacher refers to, and second, a teacher's descriptions may lack specificity, for instance when their verbalisations lack clear location indications (Louwerse & Bangerter, 2010).

In such cases, novice learners might not be able to follow the teacher's verbalisations and direct their attention to the most relevant visual information elements in the video in time. Instead, novices' attention might be attracted by visually salient, but not necessarily relevant, task elements (as argued by De Koning & Jarodzka, 2017; Lowe, 2003). To conclude, following transient multimedia content may be effortful and challenging for novice learners, especially when teachers with high domain expertise present visually complex (lecture) materials.

Adding visual cues can help to overcome these challenges and support multimedia learning (for a meta-analysis see Richter et al., 2016). Visual cues can be defined as non-content information that directs the observer's attention to relevant task elements in a visual display (De Koning & Jarodzka, 2017). In instructional videos, different tools can serve as cues for attention guidance, such as the mouse cursor, spoken words, but also a teacher's gaze cursor. These cues may reduce the mental effort of learners when selecting relevant video information, because they can clarify what the teacher is verbally referring to. Thus, novice learners might need to spend fewer cognitive resources on trying to infer what the teacher in the video is referring to (Mayer, 2014a). At the same time, cues might help to establish the beneficial state of joint attention more easily, in which communication partners (e.g. novice learners and the teacher) attend to the same information simultaneously (Butterworth & Jarrett, 1991; Tomasello & Farrar, 1986). Joint attention has been found to be fundamental to learning from early on (e.g. Meltzoff & Brooks, 2013) and can foster understanding of what another person is saying (e.g. Richardson & Dale, 2005).

Comparing the gaze and mouse cursor as cues for attention guidance

Previous studies found that the gaze cursor can be an effective tool to guide novices' attention, establish joint attention, and ultimately foster learning (e.g. Jarodzka et al., 2013). However, a simple alternative to the gaze cursor that is already often used in (lecture) videos is the mouse cursor. A previous study by Gallagher-Mitchell et al. (2018) found that viewing both another person's gaze or mouse cursor during a simple number line estimation task increased observers' later estimation performance. In our study, we aim to extend this research by using more complex lecture videos as learning materials that also contain a teacher's verbal explanations. As argued earlier, both the gaze and mouse cursor could serve as valuable visual cues to guide attention, ease information selection and integration with the verbal explanation, and thereby, ultimately, enhance learning from lecture videos. An open question is how the gaze and mouse cursor compare in this context.

On the one hand, a person's mouse cursor movements and their eye movements correlate substantially (Guo & Agichtein, 2010; Huang et al., 2011; Huang et al., 2012). Therefore, visualisations of gaze and mouse cursor positions likely contain overlapping information. On the other hand, the gaze and mouse cursor may differ in important aspects that could affect learning. We present these aspects in the following section and discuss the possible advantages and disadvantages of using these tools for attention guidance in didactic lecture videos.

Human eyes continuously move to take in information about their surroundings. The location of a person's eyes typically reflects the object of their attention and, consequently, often reveals ongoing cognitive processes at each moment in time (Just & Carpenter, 1980). Following such eye movements is a natural, intuitive way to disambiguate spoken communication and guide attention (Hanna & Brennan, 2007). The gaze cursor can provide learners with highly fine-grained information about the teacher's attentional focus, thereby also revealing implicit, unverbalised attentional and cognitive processes (Ericsson, 2006; Ericsson & Simon, 1980). Finally, a possible benefit of displaying a teacher's gaze in instructional videos is that it could serve as a powerful social cue that could increase the perceived social presence of the teacher and support learning (cf., Beege et al., 2020; Wang et al., 2019). Social cues such as human gestures, voice or gaze can activate a social response and lead to deeper processing, motivation, and learning of educational content (e.g. Beege et al., 2020; Mayer, 2014b; Mayer et al., 2003).

Despite the possible benefits of displaying a teacher's gaze cursor in instructional videos, learners may have difficulties making sense of the gaze display. This is because the human gaze is usually rapidly and continuously moving and its visualisation may therefore contain "noisy" information that is difficult to follow. The main advantage that the mouse pointer offers a gaze cursor might be that it can easily rest at one location until the teacher intentionally decides to change its position in the video (Gallagher-Mitchell et al., 2018). Then, the teacher can move it more consciously and voluntarily than their eye movements (Stein & Brennan, 2004). Consequently, the mouse cursor likely only points at the most relevant information that the teacher wants to highlight and contains less noise than the gaze cursor. One drawback, however, could be that directing the mouse cursor, as opposed to displaying a gaze cursor, typically requires attention resources from the teacher. In some cases, the teacher may simply forget to actively point to the relevant task elements while lecturing, which should make the mouse cursor display less informative for learners. In other cases, expert teachers may lack the insight into the knowledge state of novices, which could make it difficult for teachers to decide when novice learners need additional attention guidance with the mouse cursor.

While both the gaze and mouse cursor could serve as visual cues in lecture videos, we argued that they might have different advantages and disadvantages for video learning. To our knowledge, no study has as yet directly compared the gaze and mouse cursor as tools for attention guidance in authentic lecture videos that also include a teacher's verbalisations. Instead, previous studies have compared the mouse and gaze cursor in videos that display another person's problem-solving behaviour without didactic verbalisations (Gallagher-Mitchell et al., 2018). Other studies investigated the effects of sharing the gaze or mouse cursor information to improve remote teamwork and collaboration. Velichkovsky (1995) presented a first attempt to mediate cooperation (i.e. a puzzle task) with displays of a partner's gaze or mouse cursor. Both methods improved participants' performance compared to the condition with purely verbal communication. Similarly, Müller et al. (2013) found that displaying both the gaze and mouse cursor improved performance over verbal explanations during a cooperative puzzle task. However, the mouse cursor facilitated communication more than the gaze cursor (cf. Akkil & Isokoski, 2018; Müller et al., 2013). Finally, Gupta et al. (2016) showed comparable benefits of both tools for improving remote collaboration tasks (e.g. quality of communication and collaboration). Visualising the gaze cursor additionally improved task enjoyment, but using a combination of both tools was rated as the best in most of the aspects of user experience during collaboration. These empirical findings show that displays of the gaze cursor, mouse cursor, or both, can improve performance and communication in collaborative tasks.

In the context of EMME research, it is still an open question whether showing the gaze cursor provides an actual advantage for learning over the mouse cursor in authentic lecture videos (Emhardt, Kok, et al., 2020; Stein & Brennan, 2004; Špakov et al., 2016). An open question is also if and how displaying the combination of both tools in one video affects learning. On the one hand, displaying the gaze and mouse cursor simultaneously should provide rich information to learners. On the other hand, it might require a substantial amount of effort for learners to select the relevant information out of all highlighted information. When the positions of the gaze cursor and the mouse cursor differ in location, learners might have to split their attention, which could additionally hamper learning (Ayres & Sweller, 2014; cf. Redundancy principle, Kalyuga & Sweller, 2014). Since these are, however, only theoretical considerations, it is important to test these assumptions in practice and disentangle the effects of different cueing tools (as well as their combinations) on observers' mental effort and learning.

Overview of the present study

This study aimed to compare if and how displaying a superimposed gaze vs. mouse cursor in a lecture video would affect learners' mental effort during video study and their learning outcomes. Participants studied a pre-recorded introductory lecture video that contained a lecture slide show with the teacher's voiceover explaining how to model (business) processes with Business Process Model And Notation (BPMN, https://www.omg.org/spec/BPMN/2.0/; Freund & Rücker, 2019). BPMN is a standardised way to model such processes as graph-based diagrams. Previous research has shown that highlighting components of business process models with visual cues can support model understanding (Petrusel et al., 2016). Furthermore, a recent EMME study found the first promising effects of displaying a domain expert's gaze cursor on fostering novices' comprehension of process models that were created with BPMN (Winter et al., 2021). The video in the control condition of our study showed the introductory lecture on BPMN with the expert teacher's didactic explanations as voice-over. In the experimental conditions, the video *additionally* displayed the teacher's mouse cursor, gaze cursor or both tools together as superimposed tools for attention guidance. The teacher himself was not visible in any of the videos and the videos were identical except for the superimposed visualisation of the gaze and/or mouse cursor.

Based on theoretical considerations of the cueing principle and multimedia learning that were presented earlier (De Koning et al., 2009; Mayer, 2014a; Van Gog, 2014), we formulated the following three hypotheses (H1–H3): We expected that displaying a visual cue (i.e. mouse cursor or gaze cursor) would decrease participants' mental effort while studying the video (H1), increase participants' recall test performance (H2), and increase participants' transfer test performance (H3). We did not make any predictions about whether the gaze or mouse cursor would be more beneficial for learning, as we argue that both tools have potential advantages and disadvantages for learning (see section "Comparing the gaze and mouse cursor as cues for attention guidance"). In addition, we explored possible interaction effects of displaying a combination of the gaze and mouse cursor on obervers' perceived mental effort and learning outcomes. On the one hand, videos that show the mouse and gaze cursor together provide the most information for learners, which could ease understanding and support learning. On the other hand, it is also conceivable that the two cursors are redundant when highlighting the same information (Kalyuga & Sweller, 2014) or induce split-attention when highlighting different information, which could increase learners' mental effort during video study and hamper learning (Ayres & Sweller, 2014).

In the context of H2 and H3, we also explore whether there would be differences in participants' invested mental effort while solving the items of the recall and transfer test. Reporting both participants' performance and their invested mental effort during task performance can reveal valuable additional information about the quality of learning outcomes with the different video formats (Van Gog & Paas, 2008). It is, for instance, possible that there are no significant performance differences across conditions, but students in one condition attained that level of performance with less mental effort investment on the post-test. In this case, the video format of that condition is more desirable to implement in practice, because it seems to facilitate task performance.

To gain a more complete understanding of participants' learning experiences with the different video formats, we also explored participants' ease of following the teacher's video explanations and their opinions on seeing the gaze cursor.

Methods

Participants and design

Participants were recruited through the online platform Prolific (www.prolific.co). Only students with a high fluency in English and a previous study completion rate of more than 97% received a link via Prolific to participate in this study. We excluded six of the initial 131 participants, because they did not seem to pay enough attention when participating in the study (i.e. they answered two attention check items incorrectly). The final sample consisted of 124 participants ($M_{age} = 22.26$ years, $SD_{age} = 3.68$; 48 females, 76 male, 10 with basic experience in working with process models). Power calculation with G*Power (version 3.1.9.6; Faul et al., 2007) revealed that with this remaining sample size, we would be able to detect medium effect sizes of $\eta^2 = .06$ with a power of .79. Comparable effect sizes were observed in the study of Gallagher-Mitchell et al. (2018) that compared the effects of displaying the gaze and mouse cursor in silent EMME videos on observers' task performance.

Participants were randomly assigned to one of four study conditions of the 2 (mouse cursor absent vs. present) × 2 (gaze cursor absent vs. present) between-subjects design. Thus, participants studied the lecture video with only a gaze cursor ($n = 31$), only a mouse cursor ($n = 31$), both the gaze and the mouse cursor ($n = 31$), or without any cursors ($n = 31$). Participants received a payment of 6.40 British Pounds as compensation.

Materials

Video materials and creation

A male professor of business economics from a German university of applied sciences recorded the instructional videos in English. We captured the teacher's screen, eye movements, mouse cursor, and verbal explanations while he introduced the basic components of BPMN. The lecture content was based on authentic lecture materials of an introductory lecture on BPMN and was presented on eight main PowerPoint slides. One of these slides presented animated content (a moving dot). In the video, the teacher controlled the pace at which the slides were presented according to his verbal explanations. The slides in the video contained highly visual content (i.e. BPMN models consisting only of pictorial BPMN symbols), increased in model complexity as slides progressed, and contained few textual elements and explanations. Since the learners were BPMN novices, they had little to no prior knowledge about the meaning or names of these symbols. Therefore, we assumed that learners could only follow the video and learn the correct names and purpose of all elements only if they knew which of the competing BPMN symbols the teacher was referring to while watching the video. The gaze and mouse cursor would be expected to help disambiguate the teacher's references by pointing at the referred model elements (Van Marlen et al., 2018). Appendix A contains all lecture slides that were presented in the video for more information about the design of the slides. We recorded the teacher's verbal explanations with the microphone embedded in an external Logitech Webcam PRO 9000 and captured his mouse cursor movements while presenting the lecture content with a custom Matlab (Mathworks, 2015, version 2015b) script using PsychToolbox (Brainard, 1997; Pelli, 1997). At the same time, the teacher's eye movements were recorded binocularly at 250 Hz with an SMI RED250 infrared eye tracker (SensoMotoric Instruments GmbH, Teltow, Germany) without a forehead rest. The dynamic gaze cursor visualisations were generated with SMI BeGaze (Version 3.7; SensoMotoric Instruments). Visualisations of the recorded mouse cursor movements were superimposed onto the pre-recorded videos using a custom Matlab script. All fixations of more than 100 ms were visualised as single yellow, translucent, moving dot with a constant size of 27 px in diameter moving on the original material. No other methods were used to alter the gaze display (e.g. no slowing down of the gaze display or adding of connection lines between consecutive fixations). Figure 1 shows an example screenshot of the video recording in the condition with gaze cursor and mouse cursor.

The teacher (one of the co-authors of this study) was informed that his screen actions (i.e. presentation slides and mouse cursor location) and eye movements were recorded and would later be shown to novice learners in some, yet not all, of our study conditions. We also asked the instructor to behave in a didactic manner while presenting these slides to a novice audience by keeping the following quality criteria in mind (based on Emhardt, Kok, et al., 2020; Jarodzka et al., 2012, 2013; Jucks et al., 2007):

1. It is important that the audience knows what all terms mean.
2. All terms are explained in comprehensible terms.
3. All terms are explained in enough detail.
4. All information that the audience needs is included in the video.
5. All information mentioned in the video is important for the audience.

After the video recording, the experimenter and the teacher discussed the quality of the didactic

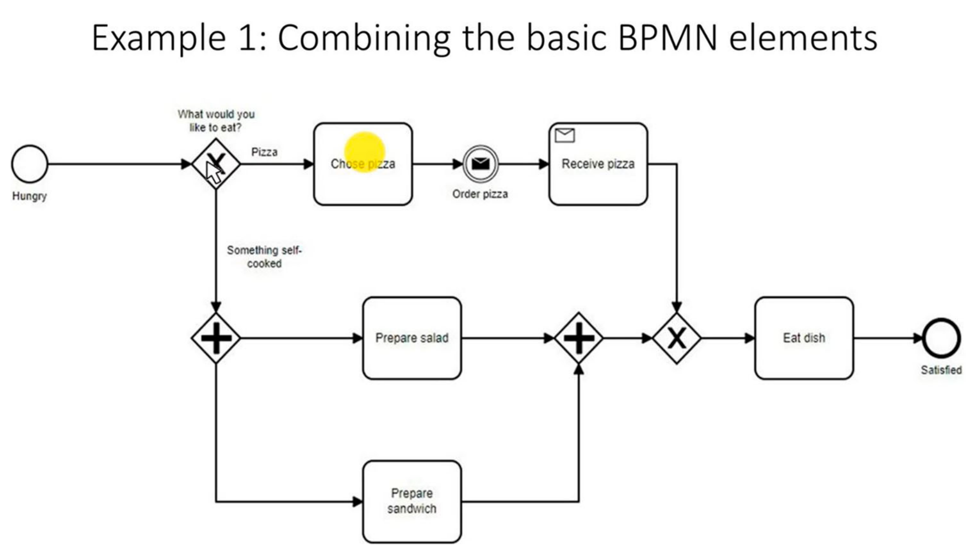

Figure 1. Screenshot of the video in the condition with both a superimposed mouse cursor (computer mouse visualization as arrow) and gaze cursor (eye movement visualization as a yellow, translucent dot). The videos in the other three conditions were identical except for the presence or absence of these gaze and mouse cursor.

video based on these quality criteria. If a video did not meet all criteria, it was re-recorded. The selected video for the main study had a duration of 18.24 min. The video, which included both the gaze and the mouse cursor display, can be found at https://www.youtube.com/watch?v=iqU_BxtKP80. This recording provides detailed information about how the teacher used both tools. For example, it shows how the position of the gaze pointer occasionally overlapped with the mouse cursor but moved faster and more frequently to different video elements.

Prior knowledge, recall and transfer test

The materials for the prior knowledge test and the recall and transfer post-tests were created in collaboration with a domain expert who also presented the lecture video. The prior knowledge test and the recall test consisted of the same list of 11 names of common BPMN elements that had to be matched to their symbols. Participants received one point for each correct match and could thus score a maximum of 11 points. The recall test aimed to evaluate the direct learning gain in comparison to the prior knowledge test by assessing whether learners were able to recall the names of the BPMN symbols after watching the video. We assumed that learners would perform better in the conditions with the gaze and mouse cursor because they served as pointing devices to the referred objects in the video and could therefore disambiguate the verbal utterances of the teacher. Appendix B contains all items of the prior knowledge and recall test. The transfer test consisted of questions on nine processes models that were not introduced in the video before. The transfer test assessed whether participants had acquired a deeper and correct understanding of the individual BPMN elements, beyond naming the individual symbols. For instance, learners had to answer multiple-choice questions about what function a particular BPMN element has in the model or where the element should be inserted. In total, participants had to write down all possible process traces for three of these models, find and correct errors in two process models, and answer multiple-choice questions on three models. Additionally, participants had to insert the right BPMN symbols in one model themselves. In total, participants could receive a maximum of 18 points on the transfer test. Appendix C contains all items of the transfer test.

Subjective ratings

Participants were asked to rate how much mental effort they invested in studying the lecture video and solving the post-test items, on a nine-point subjective rating scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort; Paas, 1992). After studying the video, participants were asked to indicate how often it was clear to them what the teacher was referring to in the video on a scale from 1 (never clear) to 9 (always clear). In all conditions with a gaze cursor display, participants were furthermore asked about their opinion on the EMME format (i.e. "What is your opinion on seeing the teacher's eye movements in the learning video? Please explain your answer briefly").

Attention check items

We included two items to test whether participants paid attention to the content of this study. Among the question about participants' demographic and personal background, we placed the first attention check item:

When asked for your favorite school subject you must enter the word "attention" in the text box below to show us that you are paying attention to our instructions. Based on the text you read above, what word have you been asked to enter as favorite school subject?

The second attention check item was asked after participants had studied the instructional video. This item was formulated as follows: "What voice did you hear in the video that you watched in this study? Select 'I did not hear a voice' as answer to this question so that we know you are still paying attention". Participants could subsequently select one of the following multiple-choice options: "male", "female", "I don't know", or "I did not hear a voice". The format of the two attention check items was approved by prolific.co as being fair, meaning that data from participants ($N = 6$) who answered both items incorrectly was immediately discarded. Like this, data from new participants could directly be collected to compensate the dropout.

Procedure

When signing up for the study via Prolific (www.prolific.co), participants received a Limesurvey link (www.limesurvey.org, version 3.17.0) to the online study. After giving informed consent, participants answered demographic questions on their age, sex, native language, and highest level of education. In addition, they indicated their years of experience with process models in general and BPMN in particular. Then, participants were asked to perform the prior knowledge test by naming 11 common BPMN symbols. Subsequently, participants watched the lecture video on how to model the process using the BPMN notation according to their assigned condition (i.e. video with or without the mouse cursor and with or without the gaze cursor). After studying the video, participants rated how much mental effort they invested in studying the video and how often it was clear to them to what the teacher was referring to in the video. In the conditions in which the gaze cursor was present, participants additionally gave their opinion on seeing the teacher's eye movements in the video. In the post-test phase, participants first solved the recall test and indicated how much mental effort they invested in completing this task. Finally, they performed the transfer post-test, rating how much mental effort they invested in solving each item on this test. On average, the experiment took about 45 min to complete.

Data analysis

The raw data was prepared and visualised with R (R Core Team, 2020, version 4.0.3). The subsequent analyses were performed with JASP (JASP Team, 2020, version 0.14.1) with a significance level of α = .05. The main analysis consisted of 2 (mouse cursor: absent vs. present) x 2 (gaze cursor: absent vs. present) ANCOVAs on the outcome variables, which take participants' scores in the prior knowledge test as a continuous covariate into account. We used QQ plots (theoretical quantiles vs. standardised residuals) to confirm that the model residuals were approximately normally distributed for all models. Furthermore, we performed Levene's tests to check for equality of variances. Only for the mental effort ratings of the recall test did the Levene's test indicate unequal variances; $F(3, 120) = 3.27$, $p = .024$. However, we consider this deviation acceptable, because ANCOVAs are relatively robust to violations of the assumption of equality of variances, especially when group sizes are equal (e.g. Blanca et al., 2018). Eta-squared specified the effect sizes of the main analysis with $\eta^2 = .01$, $\eta^2 = .06$, $\eta^2 = .14$ indicating small, medium, and large effects respectively (Cohen, 1988).

In addition, we coded participants' responses to the open-ended question regarding their opinion on seeing the teacher's eye movements in the conditions with gaze cursor to perform a small-scale, exploratory qualitative analysis. All but one participant in the conditions with gaze cursor responded to this question and were therefore included in the analysis ($N = 61$). First, an overall valence score (i.e. positive, negative, or neutral) was assigned to participants' responses. A participant's response was coded as −1 when it contained only negative evaluations about the video format; as 0 when it contained either a neutral response or both positive and negative evaluations; and as 1 when it contained only positive evaluations about the video format. Furthermore, the qualitative data was analysed on a more fine-grained level to identify themes in their responses using an exploratory, open-coding approach (Holton, 2007; Ryan & Bernard, 2000). First, participants' responses were split into meaningful units and labelled based on their content (Khandkar, 2009). Four responses that did not directly answer the question on the video format (e.g. "I think that BPMN is a great notation") were excluded from this analysis. Then, the units were sorted into meaningful categories. In the results section, we report an analysis of whether the valence scores of participants' opinion on seeing the gaze cursor display differed as a function of whether they additionally saw the mouse cursor or not (independent samples Mann–Whitney U test with a Rank–Biserial Correlation as a measure of effect size). In addition, we report the content of all categories and how many responses each category contained. The anonymised dataset that was used for the main analysis is available on the Data Archiving and Networked Services (Open Universiteit Nederland, 2021).

Results

Table 1 displays the means and standard deviations of all variables that were analysed in the following results section.

An ANOVA indicated that prior knowledge test scores did not differ across conditions, $F(3,120) = 0.07$, $p = .976$, $\eta^2 = 0.002$. In addition, an exploratory measure of direct learning gain was calculated by subtracting participants' prior knowledge test scores from their recall test scores. This learning gain did not differ between conditions, $F(3,120) =$

Table 1. Means and standard deviations (SD) of participants' scores in the prior knowledge, recall, and transfer tests, and of participants' learning gain, mental effort ratings, perceived ease of following the teacher, and the valence of their response to the gaze cursor display.

	Gaze absent		Gaze present	
	Mouse absent ($N=31$)	Mouse present ($N=31$)	Mouse absent ($N=31$)	Mouse present ($N=31$)
Score prior knowledge test from 0 to 11 points	1.45 (2.29)	1.29 (2.37)	1.29 (2.24)	1.19 (2.06)
Score recall test from 0 to 11 points	8.10 (1.96)	7.94 (2.85)	8.32 (2.47)	8.10 (2.53)
Score transfer test from 0 to 18 points	8.58 (3.38)	8.05 (3.85)	7.89 (4.10)	8.55 (4.14)
Score direct learning gains from 0 to 11 points	6.65 (2.50)	6.65 (3.19)	7.03 (3.08)	6.90 (3.25)
Mental effort while watching the video on a Likert scale from 1 to 9	6.68 (1.68)	6.68 (1.68)	6.87 (1.50)	6.97 (1.60)
Mental effort during the recall test on a Likert scale from 1 to 9	7.42 (1.71)	7.00 (2.07)	7.36 (1.45)	7.42 (0.96)
Average mental effort during the transfer test on a Likert scale from 1 to 9	6.63 (1.42)	6.59 (1.73)	7.13 (1.44)	6.95 (1.12)
Perceived ease of following the teacher on a Likert scale from 1 to 9	6.74 (2.14)	7.29 (1.66)	7.84 (1.29)	7.74 (1.34)
Valence of the response to seeing the gaze cursor from −1 (negative) to 1 (positive)	–	–	0.57 (0.72)	0.10 (0.94)

0.13, $p = .944$, $\eta^2 = 0.003$ (detailed values per condition can be found in Table 1).

Mental effort while studying the video

Our first hypothesis stated that displaying the mouse cursor or gaze cursor would decrease participants' mental effort while watching the video (i.e. we expected the main effects of mouse and gaze cursor). In addition, we were interested in exploring whether displaying both types of cursor simultaneously in the video would affect mental effort investment (which would be evidenced by an interaction effect). However, there was no main effect of displaying the mouse cursor, $F(1) = 0.02$, $p = .888$, $\eta^2 = .0002$, or the gaze cursor, $F(1) = 0.65$, $p = .422$, $\eta^2 = .005$, nor was there an interaction effect, $F(1) = 0.03$, $p = .863$, $\eta^2 = .0002$ on the amount of mental effort participants reported to have invested in studying the lecture video. The left graph of Figure 2 visualises these results.

Recall test performance and invested mental effort

Our second hypothesis stated that displaying the mouse cursor or displaying the gaze cursor would increase participants' recall test performance (i.e. we expected the main effects of mouse and gaze cursor). In addition, we aimed to explore whether displaying both types of cursor simultaneously would affect participants' recall performance (which would be evidenced by an interaction effect). However, there was no main effect of displaying the mouse cursor, $F(1) = 0.15$, $p = .703$, $\eta^2 = .001$, or the gaze cursor; $F(1) = 0.25$, $p = .618$, $\eta^2 = .002$, nor was there an interaction effect, $F(1) = 0.01$, $p = .930$, $\eta^2 = .00006$, on participants' recall test performance. The middle graph of Figure 2 visualises these results.

Regarding the explorative analysis of partipants' mental effort investment during the recall test, there were no significant main effects of displaying the mouse cursor, $F(1) = 0.44$, $p = .509$, $\eta^2 = .004$, or gaze cursor, $F(1) = 0.34$, $p = .564$, $\eta^2 = .003$, nor a significant interaction effect, $F(1) = 0.74$, $p = .393$, $\eta^2 = .006$.

Transfer test performance and invested mental effort

Our third hypothesis stated that displaying the mouse cursor or displaying the gaze cursor would increase participants' transfer test performance (i.e. we expected main effects of mouse and gaze cursor). In addition, we explored whether displaying both types of cursor simultaneously would affect participants' transfer test performance (which would be evidenced by an interaction effect). However, we found no main effect of displaying the mouse cursor, $F(1) = 0.008$, $p = .930$, $\eta^2 = .00006$, or the gaze cursor; $F(1) = 0.02$, $p = .887$, $\eta^2 = .0002$, nor did we find an interaction effect, $F(1) = 0.73$, $p = .395$, $\eta^2 = .006$ on participants' transfer test performance. The right graph of Figure 2 visualises these results.

Regarding the explorative analysis of participants' mental effort investment during the transfer test, there were no significant main effects of displaying the mouse cursor, $F(1) = 0.23$, $p = .632$, $\eta^2 = .002$, or gaze cursor, $F(1) = 2.64$, $p = .107$, $\eta^2 = .021$, nor a significant interaction effect, $F(1) = 0.06$, $p = .801$, $\eta^2 = .0005$.

Opinions on ease of following the teacher and on the display of the gaze cursor

We explored whether the display of gaze and mouse cursors affected how easy partipants felt it

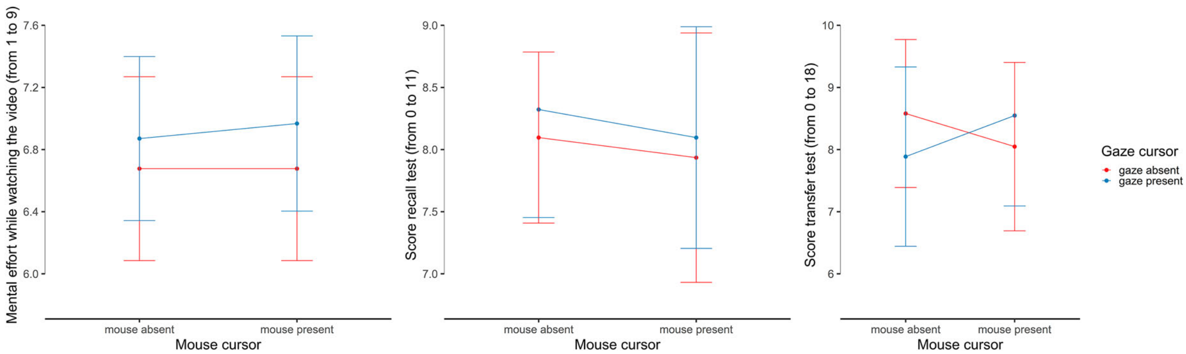

Figure 2. Figures of the main results regarding H1 (left), H2 (middle), and H3 (right). The graphs show the effects of displaying the gaze cursor and mouse cursor (main and interaction effects) on participants' mental effort while watching the video (left), recall test performance (center), and transfer test performance (right). The error bars represent the 95% confidence intervals.

was to follow the teacher in the video (i.e. how clear it was to them what the teacher was talking about). There was no significant main effect of displaying the mouse cursor, $F(1) = 0.62$, $p = .432$, $\eta^2 = .005$. However, there was a significant main effect of displaying the gaze cursor $F(1) = 0.99$, $p = .009$, $\eta^2 = .054$. There was no significant interaction effect, $F(1) = 1.20$, $p = .275$, $\eta^2 = .009$. The main effect of displaying the gaze cursor signified that participants who studied videos with gaze cursor found it easier to follow the teacher than participants who studied videos without gaze cursor. The left graph of Figure 3 visualises this result.

Participants in the gaze cursor conditions were additionally asked to report their opinion on seeing the teacher's gaze cursor while watching the video. The valence of their responses was, overall, positive, with an average score of $M = 0.33$ ($SD = 0.87$). An independent samples Mann–Whitney U test showed that participants' evaluation of the video format was significantly more positive when the video did not additionally include a mouse cursor than when it did include it (i.e. gaze cursor only > gaze and mouse cursor), $W = 587.50$, $p = .045$, Rank–Biserial Correlation = 0.263. The right graph of Figure 3 visualises this result.

Table 2 shows the results of the qualitative analysis of participants' responses to the videos with gaze cursor on a more fine-grained level. It describes the content of all identified categories and how many response units (units) fell into each of these categories. As for the disadvantages of the gaze cursor, participants most frequently stated that the gaze cursor was distracting (8 units), difficult to follow (7 units), and perceived as less effective than the mouse cursor (6 units). Other disadvantages related to the perception that the locations of the gaze cursor were not helpful (3) and that the gaze cursor reduced participants' independence (1 unit). Two participants stated that they disliked the gaze cursor without further specification.

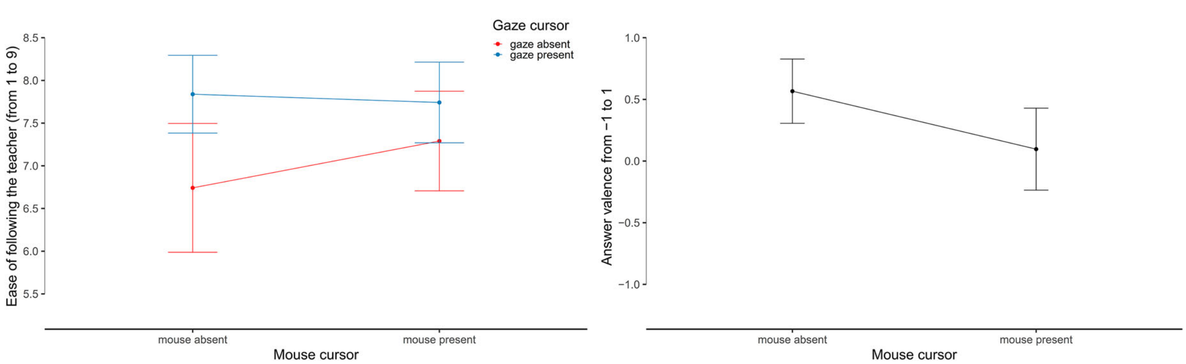

Figure 3. Effect of displaying the gaze cursor and mouse cursor on participants' perceived ease to follow the teacher in the video (left) and the average valence of participants' responses to the gaze cursor display in the two mouse-cursor conditions (right). The error bars represent the 95% confidence intervals.

Table 2. Categories of participants' responses to the question on their opinion about seeing the gaze cursor in the video (81 answer units from $N = 61$ participants).

Category	Category description	Valence	Count of units
Distracting	Participants perceived the gaze cursor as annoying, distracting, or confusing	Negative	8
Difficult to follow	Participants indicated that it was difficult to follow the gaze cursor, for instance, due to many fast movements	Negative	7
Less effective than mouse cursor	Participants indicated that they preferred the mouse cursor over the gaze cursor	Negative	6
Fixated location not helpful	Participants stated that seeing the fixated location was not helpful, for instance, because the teacher was not only looking at what he was referring to	Negative	3
General negative evaluation	Participants stated that they disliked the format without providing specific reasons	Negative	2
Reduces independence	One participant stated that they preferred to look things up more independently	Negative	1
As effective as mouse cursor	Participants compared the effectiveness of the gaze cursor with that of the mouse cursor	Neutral	2
Understanding the teacher	Participants stated that seeing the gaze cursor made the teacher's processes and explanations more understandable	Positive	21
General positive evaluation	Participants stated that they liked the format without providing specific reasons	Positive	13
Attention guidance helpful	Participants felt that the gaze cursor guided their attention to the relevant elements	Positive	11
Increased attention	Participants stated that they paid more attention to the video and were more concentrated due to the gaze cursor	Positive	2
Positive feeling when watching the gaze cursor	One participant indicated that the gaze cursor was "comfortable and pleasant to watch"	Positive	1

The categories have either a positive or a negative valence. The values in the last column indicate how often participants' answers units fell into each category.

The advantages of the gaze cursor were seen mainly in a better understanding of the teacher (21 units) and that it guided learners' attention to the relevant video elements (11 units). Further advantages mentioned, were that participants felt more concentrated due to the presence of the gaze cursor (2 units) and that they experienced a positive feeling when watching the gaze cursor (1 unit). Thirteen participants stated that they liked the format without providing specific reasons. Finally, two participants stated that they felt the gaze cursor was equally effective as the mouse cursor.

Discussion

This study compared the effects of displaying the gaze cursor and mouse cursor as visual cues for attention guidance in lecture videos. Participants watched a lecture video on how to model business processes using the BPMN notation (Freund & Rücker, 2019) that contained no attention guidance or displayed the teacher's gaze cursor, mouse cursor, or both types of cursor. We expected that attention guidance, by means of either type of cursor, would reduce the amount of mental effort learners would have to invest in studying the video and foster learning outcomes (cf. Literature on the cueing effect in multimedia learning, e.g. De Koning et al., 2009; Van Gog, 2014). In addition, we explored whether displaying a combination of the gaze and mouse cursor would have additive effects (as signified by an interaction effect), whether the presence of gaze and mouse cursors in the lecture video affected participants' mental effort during post-test performance, and whether it affected how easy they felt it was to follow the teacher.

Unexpectedly, we did not find any significant main or interaction effects of displaying the gaze and mouse cursor on participants' mental effort ratings or their post-test (recall and transfer test) performance. Thus, we did not find evidence in favour of our hypothesis in this experiment. However, the self-report data revealed that participants who studied videos that showed the gaze cursor, found it easier to follow the teacher than participants who studied videos without a gaze cursor. Moreover, participants who studied videos with the gaze cursor were, overall, positive about this video format, but their responses were more positive when the videos did not additionally display the mouse cursor. This is possibly because videos that show a mouse cursor already provide sufficient attention guidance, which could cause participants to perceive the additional gaze cursor as less beneficial.

A substantial amount of prior research on EMME has found beneficial effects of displaying the teachers' gaze cursor to students. In these studies, the gaze cursor fostered attention guidance (e.g. Jarodzka et al., 2012; Van Marlen et al., 2018) and learning with video modelling examples (i.e. "how-to" videos) (e.g. Bednarik et al., 2018; Krebs et al., 2019; Litchfield et al., 2010; Mason et al., 2015a, 2015b, 2017). The beneficial effects of EMME were more recently also observed for the comprehension of process models using the BPMN notation (Winter et al., 2021). A relevant question is why displaying the gaze (and/or mouse) cursor did not affect learning from video lectures in the present study. In the next section, we discuss specific aspects of the present study that might have influenced our results.

Possible reasons why cues for attention guidance did not affect mental effort or learning outcomes

The unexpected finding that displaying the teacher's gaze and mouse cursor did not affect participants' mental effort ratings and learning outcomes could be due to several factors that possibly limit the generalisation of our results. One explanation for this finding could stem from the video format in this study. Previous studies on the effects of displaying the teacher's gaze cursor during task performance in video modelling examples (EMME) did not focus on the teacher's presentation of didactically prepared lecture slides. Instead, they typically showed a teacher engaged in a task, with the aim of demonstrating to learners how to perform this task (e.g. Bednarik et al., 2018; Jarodzka et al., 2012, 2013; Mason et al., 2015a, 2015b, 2017; Van Marlen et al., 2016, 2018; Winter et al., 2021). Similarly, the study of Gallagher-Mitchell et al. (2018) found comparable beneficial effects of both displaying another person's gaze cursor and displaying the mouse cursor during task performance on learners' later performance. Finally, a recent study found that visualising the teacher's gaze during the interpretation of process models with BPMN fostered novices' model comprehension (Winter et al., 2021).

At first glance, these findings seem to contradict our results that displaying the gaze (and/or the mouse) cursor in a lecture video on how to model processes using the BPMN notation does not foster novices' learning. One possible explanation for our results might be that the gaze cursor serves a different purpose in videos that show another person's task performance (video modelling examples) and videos with a lecture format (lecture videos). In videos of both formats, the gaze cursor can be considered a visual cue to guide the learners' attention and hence establish joint attention and foster information selection (e.g. De Koning et al., 2009; Van Gog, 2014). However, the gaze cursor in video modelling examples can, in addition to guiding attention, serve another purpose: Due to the link between a task performer's cognitive processes and visual attention allocation (Just & Carpenter, 1980) the gaze cursor can help novice learners to gain additional insights into the model's visual and cognitive task performance strategies (e.g. Krebs et al., 2019; Scheiter et al., 2018). Videos that show a teacher's gaze cursor during task performance (e.g. EMME that show a model's problem-solving behaviour) can thus reveal perceptual processing strategies that are not necessarily verbalised, and that learners could later adopt in their own performance. In our lecture videos, that was not the case, as the gaze cursor did not show naturally occurring task behaviour, but accompanied a didactic explanation.

Indeed, the learners in our study reported that they felt the eye gaze cursor helped them follow the teacher, even though it did not actually improve their learning outcomes. To support this claim, it would be interesting to record participants' eye movements while they watched the lecture video in future research. Due to the COVID-19 pandemic, collecting such gaze measures was not possible in our study, but doing so in future research could provide an indication of whether participants actually followed the teacher's explanations in the conditions with gaze cursor more closely. In addition, gaze data (e.g. pupil diameter, amount of saccades, blinks, fixation durations) could provide a more objective, continuous measure of cognitive load than mere self-reports (e.g. Krejtz et al., 2018; Perkhofer et al., 2019; Zagermann et al., 2018). In conclusion, the gaze cursor may serve different purposes depending on the video format (here lecture videos and video modelling examples), which could explain the seemingly contradictory results between our study and previous EMME studies.

Another possible reason why we did not find the expected positive effects of displaying the gaze and mouse pointer could be that the perceptual demands of the task explained in the video were lower than we had originally expected. We assumed that the novice learners would experience difficulties in selecting the correct BPMN symbols due to a high visual complexity. This complexity was due to a large number of competing BPMN symbols on each slide. Nevertheless, it is possible that the materials were visually not complex enough and that the teacher's verbal explanations were sufficient to guide the learners to the correct elements. In fact, the teacher in the video was highly experienced in giving BPMN lectures. The content of the video was based on these lectures and the slides built on each other by gradually introducing more and more BPMN elements. This didactically strong material design might have made it possible for learners to follow the video in all conditions, also in those without a gaze and mouse cursor display. Future research should establish if gaze and mouse cursor guidance do affect learning when tasks are more visually complex and verbal explanations are more ambiguous.

Taking these considerations into account, we can assume that the design of instructional videos can affect the effectiveness a gaze or mouse cursor display in general. These tools could, for instance, be more helpful for learning with videos on visually complex content. In previous studies, the gaze cursor effectively fostered task performance of complex visual tasks such as the interpretation of fish locomotion patterns (Jarodzka et al., 2013), medical diagnostics (Litchfield et al., 2010), or complex BPMN models (Winter et al., 2021). Furthermore, displaying the gaze and mouse cursor may be more beneficial when the videos do not contain additional verbal explanations (Van Gog et al., 2009). It is likely that the added value of the gaze and mouse cursor to guide attention is higher in lecture videos with less didactic guidance though verbal explanations of an experienced teacher. In order to investigate this issue, future studies could perform an analysis of how the task demands (e.g. based on expert opinions and gaze patterns) affect the effectiveness of different tools for attention guidance.

Finally, another possible reason why we did not find beneficial effects of displaying the teacher's gaze and mouse cursor could be due to specific participant characteristics. Our study was conducted via an online platform with a heterogeneous, international participant population. We specifically asked participants to only participate if they had no experience with BPMN. However, it is possible that they had experience with other, similar process flow visualisations. Since participants had a variety of backgrounds, it is likely that some participants were not complete novices to this topic, which might have made our video less effective overall. In contrast to our study, most previous EMME studies collected data from samples that were more homogeneous. Furthermore, they were conducted in more controlled and supervised settings such as laboratories or classrooms. These settings could also evoke stronger participant commitment and thus lead to stronger effects of the manipulations. While the heterogeneity of our sample can also be regarded as a strength of the present study, it may be responsible for a higher variance in the observed data.

Implications for practitioners and future research

This study represents a first step in gaining insights into the effects of using different tools for attention guidance in instructional videos (i.e. lecture videos). The finding that displaying the gaze and/or the mouse cursor neither harmed nor enhanced participants' learning outcomes implies that educational practitioners who create lecture videos have some freedom to select different tools for attention guidance. One benefit of the gaze cursor was that the learners felt it helped them better follow the teacher's explanations in lecture videos. This is in line with previous eye-tracking studies that confirmed that the gaze cursor guides learners' attention (e.g. Jarodzka et al., 2012; Van Marlen et al., 2018). Qualitative analysis confirmed that participants responded overall positively to the gaze cursor, but even more so when the videos did not display the mouse cursor. Sometimes, using a mouse cursor is not convenient or even possible, for instance when the teacher demonstrates a manual task with the dominant or both hands. Especially in such situations, practitioners could use the gaze cursor as a valuable tool for attention guidance in instructional videos. In this context, it would also be interesting to compare teachers' experiences when creating videos with the gaze or mouse cursor for their own educational practices. As discussed earlier, it is conceivable that, despite initial technical challenges, it may be easier and less effortful for them to create videos with a gaze cursor than with a mouse cursor. For practical applications, an open question also remains whether our results could be transferred to other educational situations, such as live lectures, in which a teacher's eye movements are projected onto the wall of the lecture room (e.g. as suggested by Špakov et al., 2016). This investigation could be a valuable addition to the traditional EMME literature and would increase its applicability to a broader range of situations. The general, underlying assumptions about the benefits of gaze cursors do not change for this particular situation. In a live lecture, the teacher's face with the exact line of sight is only visible to the students sitting closest to the teacher. Aside from looking at the audience, the teachers need to occasionally look at the content of their slides that is typically visible on a small screen in front of them. In this situation, learners can never exactly observe what the teacher is looking at. Unlike a video lecture, learners cannot control the pace of the lecture to follow the content (e.g. by pausing and repeating the video), nor can they zoom in on important elements. Streaming the teacher's eye movements as soon as they gaze at the lecture slides could help learners to better follow and understand the lecture content. Furthermore, it could be convenient for the teachers, as they do not have to turn around to the projection at the wall to point at important slide elements. Finally, learners would also likely receive information about the teacher's attentional focus more frequently than usual. How streaming the gaze cursor would work in practice and how it compares to other pointing devices in a lecture room (e.g. a stick) remains a topic for future research. As discussed in previous sections, the results of the present study also show the need for researchers to evaluate the gaze cursor as a visual cue in different types of instructional videos (e.g. videos that model task performance vs. lecture videos). In this context, future studies should take factors that are known to affect learning with EMME into account, such as the effectiveness of other types of visual cues (e.g. Jarodzka et al., 2012) or learners' prior knowledge (e.g. Richter et al., 2016; Van Marlen et al., 2018). In the present study, cannot draw any conclusions about the effects of prior knowledge in this study, as only students with no or very limited prior knowledge participated ($M_{\text{pretest score}} = 1.31$ of 11 points, $SD_{\text{pretest score}} = 2.22$).

Future studies could furthermore investigate how teachers make use of the gaze and mouse cursor when creating instructional videos, and how this affects learning. Previous studies have found that a person's mouse cursor movements and their eye movements correlate substantially (Guo & Agichtein, 2010; Huang et al., 2011; Huang et al., 2012). However, the actual overlap of the two tools might vary greatly between people. Some teachers might only use the mouse infrequently, whereas others might use it to continuously guide the learners' attention. The latter could reduce the benefit of showing an additional gaze cursor display.

In our study, only one teacher's video was used, without comparing this teacher's use of gaze and mouse cursor with a reference group of other teachers. Thus, we do not know whether the mouse cursor was used relatively frequently and whether there was a relatively large overlap with the gaze cursor. We leave the exploration of the effects of different uses of the mouse cursor in combination with the gaze cursor on learning to future research and provided the all videos of our study on https://youtube.com/playlist?list=PLI09U8aTDcv28n4gM2JyXCjPwGY_I_3LI for detailed information.

In addition, future studies could compare other frequently used tools for attention guidance that may affect video learning. For instance, teachers may often not use a simple mouse cursor, but also other highlighting tools, pointing devices, or gesture cues for attention guidance (Ouwehand et al., 2015). In contrast to the gaze and mouse cursor that were constantly visible in the videos of the present study, teachers may use these tools more intermittently (e.g. by turning on and off a highlighted pointing tool). This could affect learning, because these tools might direct the learners' attention more specifically to only the most relevant video elements. Future research could therefore investigate the potential benefits of using intermittently used highlighting tools over using the gaze cursor to foster learning. However, one disadvantage of these tools (in comparison to the gaze cursor) is that such tools would again require a teacher's deliberate decisions on when novices need additional attention guidance in instructional videos. Domain experts in particular might often experience difficulties in estimating novices' level of prior knowledge correctly (Hinds, 1999). Comparing the effects of using different cues to direct attention can ultimately help provide guidelines to educational practitioners on how to create effective instructional videos.

Future studies could furthermore test the generalisability of the results of our study to natural behaviour, by displaying the eye movements and screen activities of a teacher/expert who was entirely unaware that their gaze and mouse cursor location were recorded and would later be displayed in a video. In the present study, the teacher knew that his gaze and mouse cursor would later be shown to novice learners in some of the study conditions, which might have influenced his behaviour. For instance, he might have, consciously or unconsciously, altered his gaze behaviour during the video recording to make it more understandable for the novice audience (e.g. by performing extra-long fixations on relevant elements). Previous research found that experts do alter their gaze and mouse cursor behaviour when creating EMME that aim to teach novices in a didactic manner (Emhardt, Kok, et al., 2020). Similarly, it is likely that the teacher in our video used the mouse pointer as a pointing device for the learners, which he might not have done had he not known that the recording would be shown to the learners. Finally, the knowledge that the gaze and mouse cursor were recorded could have ultimately also affected the teacher's verbal behaviour, for instance by using more deictic references, such as "here", "this", or "there" to refer to the locations that he was looking and pointing at (e.g. Bednarik et al., 2018; D'Angelo & Begel, 2017). While this creates a less authentic scenario and might therefore be less relevant for educational practice (i.e. instructional videos, including EMME, are typically recorded by teachers with their audience in mind), this type of basic research is important to understanding the mechanisms behind EMME.

Finally, the qualitative data of the present study also provides insights that could serve as a basis for future investigations in the context of EMME research and the design of EMME. We found that participants evaluated the EMME format overall positively. This was mainly because seeing the gaze cursor made the teacher's processes and explanations more understandable ($n = 21$) and fostered attention guidance ($n = 11$). While the finding that the comments about the gaze cursor were mostly positive is promising, this result should be regarded with some caution. It is likely that many (if not all) learners in our study were exposed to a gaze cursor in an instructional video for the first time. Thus, it is possible that the positive ratings are partially a result of the gaze cursor's perceived novelty (novelty effect, Clark, 1983). Novelty can, for example, increase the perceived usability of a new tool, regardless of its actual effectiveness (e.g. Jeno et al., 2019; Koch et al., 2018). However, such positive effects might diminish when learners become more accustomed to the technology (e.g. Merchant et al., 2014). Longitudinal studies on the effects of the gaze cursor are lacking to date but would be needed to determine its usefulness as a tool for attention guidance in actual educational practice. Furthermore, participants responses to the EMME format also revealed the gaze cursor was sometimes perceived as distracting ($n = 8$) and difficult to follow ($n = 7$). Smoothening the eye movement visualisations, for instance by only displaying longer fixations may have helped help learners to follow the EMME displays with less effort, as the gaze cursor display contains less (but presumably the most relevant) information. Only a few studies have to date manipulated the characteristics of the gaze cursor displays systematically to explore such effects. These studies found effects of using different gaze display options on learning (e.g. a circle vs. spotlight visualisation Jarodzka et al., 2012) and on the interpretation of different gaze cursor displays (see Van Wermeskerken et al., 2018). Effects of other EMME design choices are conceivable but, to date, mostly unknown. For instance, consecutive fixation visualisations could be connected with trail lines (see e.g. Emhardt, van Wermeskerken, et al., 2020) to highlight the order of fixations and smoothen the gaze displays. This could make it easier for learners to follow the visualisations. Similarly, it is possible that mouse cursor displays could be enhanced, for instance by increasing the cursor's saliency through highlights, a noticeable colour, or an increased size. To conclude, such design choices could improve the effectiveness of the gaze and mouse cursor display, possibly resulting in more beneficial effects on observers' mental effort and learning outcomes. However, to date, no study has performed a systematic comparison of how to best visualise gaze information to optimise attention guidance and learning. Such investigations could ultimately lead to more evidence-based design guidelines on how to create effective EMME.

General conclusion

In conclusion, our study found that displaying the gaze and mouse cursor in lecture videos did not affect mental effort and learning outcomes. However, participants who studied the videos that displayed the gaze cursor did indicate they found it easier to follow the teacher than participants who did not see the gaze cursor. Overall, participants who saw the gaze cursor responded positively to it, especially when the videos contained only the gaze cursor and not an additional mouse cursor. Therefore, displaying a gaze cursor can still be a useful tool to guide learners' attention, especially in situations when the teacher cannot easily use a mouse as pointing device. Future research should further investigate the value of the gaze cursor as a visual cue in different types of instructional videos.

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