# The Influence of Social Attention in Eye Movement Modelling Examples

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Abstract

In *Eye Movement Modeling Examples (EMME)* are a model's eye movements displayed on a video. This can create joint attention and guide learners' attention to the right information at the right time. However, it is not yet clear if the effectiveness of EMME is driven by just visual guidance or that the displayed eye movements have a social value. Research suggests that visual cues can affect performance when people believe it indicates another person (Gobel, Tufft, & Richardson, 2018). This study aimed to investigate the role of social attention in EMME for learning procedural problem-solving skills. In this experiment, 52 secondary education students were randomly assigned to one of the three conditions an EMME with a social cue, EMME without a social cue, or a regular VME. Students had to study modelling examples and solve several geometry problems. Results showed no significant differences in performance between the conditions. Suggesting that social attention might not play a role in EMME and that EMME might not even be effective for learning procedural problem-solving tasks.

*Keywords:* Eye Movements Modelling Examples, social attention, learning, procedural problem-solving skills

The Influence of Social Attention in Eye Movement Modelling Examples

Nowadays, using videos for learning is gaining popularity (Van Gog Verveer, & Verveer, 2014). Think about installing a new application on your laptop. Within just a couple of minutes, you can find several videos online where a, so-called, expert shows you how to install the application. Learning from *Video Modelling Examples* (VME) can be seen as a form of example-based learning, which has proven to be especially effective for novice learners (Van Gog et al., 2014; Van Gog & Rummel, 2010). Hence, when novice learners study VME they often experience difficulties selecting relevant information. For novice learners, there is a risk of not attending the right information at the right time and this could cause them missing relevant information (Jarodzka, Van Gog, Dorr, Scheiter, & Gerjets, 2013). VME often provide learners with transient information, it appears only at a specific moment in time. Searching and interpreting this visual information can be challenging (Jarodzka et al., 2013; Jarodzka, Holmqvist, & Gruber, 2017). Therefore, it is suggested that it would be beneficial to guide learners' attention using visual cues (Jarodzka et al., 2013).

*Eye Movement Modelling Examples* (EMME*)* are a way to guide learners' attention. In EMME the model's eye movements are recorded and displayed on the video by for example a coloured dot while performing and often, also, verbally explaining a task. It is suggested that following a model's eye movements would synchronize learners' attention with the model building *joint attention*. Joint attention is an occurrence where someone's attention is automatically directed to where someone else is attending to (Frischen, Bayliss, & Tipper, 2007; Jarodzka, et al., 2013). This could make it easier for learners to understand and to learn the provided visual information (Jarodzka, et al., 2013). A couple of studies have proven the effectiveness of EMME for learning (Jarodzka, Balslev, Holmqvist, Nyström, Scheiter, Gerjets,

& Eika, 2012; Jarodzka et al, 2013; Van Marlen, Van Wermeskerken, Jarodzka, & Van Gog, 2018). However, it is not yet clear if EMME are effective because they just guide visual attention or that the displayed eye movements have a social value.

**Learning from Eye Movement Modelling Examples**

Studying a model performing a task is a successful method for learning and has proven to be more effective than learning by trial-and-error (Kirschner, Sweller, & Clark, 2006). However, not all cognitive processes are observable when studying perceptual tasks and learners could, therefore, experience difficulties selecting and interpreting relevant visual information (Jarodzka, et al., 2013). Then a verbal explanation about the model's thoughts would be helpful. Still, perceptual tasks could be difficult to imitate even when a model gives a verbal explanation (Jarodzka et al., 2017). Kok, Jarodzka, de Bruin, BinAmir, Robben, and Van Merriënboer (2015) argue that these verbal explanations could contain incorrect or incomplete information about viewing behaviour. With the use of EMME, covert processes can be visualized and learners' attention can be guided to the right information at the right time (Jarodzka, et al., 2013; Jarodzka et al., 2017).

So far, research suggests that EMME are most effective for learning perceptual classification tasks (Jarodzka et al., 2012; Jarodzka et al., 2013) and text-picture integration tasks (Mason, Pluchino, & Tornatora, 2015; 2016; Salmerón & Llorens, 2019; Scheiter, Schubert, & Schüler, 2018). Jarodzka et al. (2013) studied how to teach perceptual tasks to novices with the use of EMME. In this experiment, an expert didactically explained the locomotion of a fish, meaning that the expert explained what the relevant aspects of the locomotion patterns were. Participants in the experiment were either shown an EMME or a VME without visual cues. This study found that EMME improved visual search and interpretation. Which is in line with findings of another study by Jarodzka et al. (2012), where participants had to learn to classify epileptic seizure symptoms by infants. They were either instructed with an EMME or with a VME without visual cues. The results of this study showed that learners' attention was guided with EMME and that instruction with EMME resulted in higher learning outcomes. Studies on learning text-picture integrating strategies using EMME have, also, shown to be effective (Mason et al., 2015; 2016; Salmerón & Llorens, 2019; Scheiter et al., 2018). Mason et al. (2015) found that learners who were instructed with an EMME, where a model didactically performed integrative reading strategies, showed better integrative processing and had higher learning outcomes. In a study by Scheiter et al. (2018) similar results were found. Learners had to study mitosis in a multimedia environment and they either received an EMME with a demonstration on how to process the materials or they did not receive a demonstration. Learners who received an EMME showed more intensive processing and made more transition between text and pictures (Scheiter et al., 2018).

In contrast, studies focusing on learning procedural problem-solving tasks with the use of EMME have found mixed results. In a study by Van Gog, Jarodzka, Scheiter, Gerjets, and Paas (2009) university students had to learn how to solve a puzzle and results showed that instruction with EMME could hamper learning. Van Gog et al. (2009) argued that the displayed eye movements could have been redundant due to the clear verbal explanation. Another study by Van Marlen, Van Wermeskerken, Jarodzka, and Van Gog (2016) did not found an effect of EMME for learning. They investigated whether EMME could enhance learning procedural problem-solving tasks. Participants were instructed with EMME or VME on how to solve geometry problems. Results of this study indicated that participants who were instructed with an EMME did not show higher learning outcomes and they needed more time to solve geometry problems.

Nonetheless, in a later study by Van Marlen et al. (2018), on the use of EMME for learning procedural problems-solving tasks, a positive effect was found. This study aimed to investigate the role of verbal ambiguity and prior knowledge in EMME. Participants were instructed on how to solve geometry problems at which verbal ambiguity was manipulated. Although no effect was found on verbal ambiguity, participants in the EMME condition outperformed participants in the VME condition. Also, participants in the EMME conditions perceived the quality of the given instruction as higher (Van Marlen et al., 2018). The main difference with the previous study of Van Marlen et al. (2016) was that the participants in this study were secondary education students without knowledge about the subject. Indicating that prior knowledge plays a role in the effectiveness of EMME. The study of Van Marlen et al. (2018) was the first study to show that EMME could be effective for learning procedural problem-solving tasks.

So far, mixed results have been found on the effectiveness of EMME for learning. EMME aim to build joint attention between the learner and the model (Jarodzka et al., 2013). The mixed results might indicate that joint attention is not properly created. The context in which the visual cue is presented to a learner could play a role. Research by Gobel, Tufft, and Richardson (2018), suggests that visual cues can affect performance when people believe it indicates another person's eye movements. The extent to which a learner believes that they are watching along with someone could drive the effectiveness of EMME.

**Social Attention**

People tend to look at where other people are looking at. Someone else's gaze can provide a lot of information (Friesen, & Kingstone, 1998). For example, someone else's gaze can give an indication of the location of food or someone's emotion (Friesen, & Kingstone, 1998). This so-called *social attention* is important for learning. Six months old infants learn to interpret and understand behaviour by following someone else's gaze (Tomasello, Carpenter, Call, Behne, & Moll, 2005; Gobel, Kim, & Richardson, 2015). So, social attention can help us interpret and understand information. Different research has been done on gaze-cueing, investigating how the attention of others can direct our attention (Frischen et al., 2007; Friesen & Kingstone, 1998). Often, in these experiments, participants are shown a central picture of a face cueing in a certain direction and the participants are asked to respond as quickly as possible to appearing targets, either congruent or incongruent with the direction of the cue. Results have shown that targets appearing congruent with the cue are responded to more quickly (Frischen et al., 2007; Friesen & Kingstone, 1998). This might indicate that gaze cues can induce a reflexive attention shift towards the cued direction. The brain may be specialized to shift attention in response to the gaze direction (Friesen & Kingstone, 1998).

However, it is unclear if the effect of social cues is due to social components. On the one hand, it is suggested that a social cue steers the attention of someone just as another normal cue would do. Simply orienting attention to a certain direction which does not require a mental representation of who the other person is and what he is doing (Gobel et al., 2018). On the other hand, social cues synchronize learners' attention with the attention of the model, creating joint attention. This causes someone to adjusts cognitive representations and locus with the model. (Gobel et al., 2018).

Several studies found that social cues have a stronger effect on attention than non-social cues (Hegel, Krach, Kircher, Wrede, & Sagerer, 2008; Tufft et al., 2015: Gobel et al., 2018). The study of Tufft et al. (2015) even showed that the effect of social cues could depend on just beliefs about the social context of a cue. Also, Gobel et al. (2018) showed that just beliefs about social cues could influence performance. In their study, participants were interacting with an unseen partner, while detecting a target at the same or a different location as an appearing cue. The participants were manipulated to believe that the cue was connected to their partners' gaze or that it was randomly generated by a computer. Participants who were manipulated to believe that the cue was related to their partner performed better. It seems that social cues and especially beliefs about social cues can impact performance.

**The Present Study**

This study aimed to investigate the influence of social attention in EMME. The following research question will be addressed: *To what extent do Eye Movement Modelling Examples with a social cue versus Eye Movements Modelling without a social cue impact student performance?* In this study, EMME were used to explain how to solve geometry problems. The verbal introduction of the EMME were manipulated. Participants either knew that the displayed eye movements were connected to the instructor or no additional information about the cue was provided. The verbal explanation on how to solve geometry problems and visual guidance were kept the same. To our knowledge, the impact of social attention in EMME has never been investigated before and the answer on this research question would reveal mechanisms that drive the effectiveness of EMME for learning. The literature suggests that beliefs about the social context of a cue can impact performance (Gobel et al., 2018). Therefore, it was expected that (H1) learners in the EMME condition with a social cue would perform better on (H1a) solving isomorphic problems and (H1b) transfer problems. Also, Van Marlen et al. (2018) found that participants perceived the quality of instruction higher in the EMME conditions. Therefore, it was expected that (H2) participants in the EMME conditions would perceive the quality of instruction as higher. As an exploratory attempt mental effort was included in this study given that Van Gog et al. (2009) found that attentional guidance might increase perceived mental effort while learning and solving test problems. It seemed interesting to examine if the same results could be obtained in this study. Meaning that perceived mental effort would be higher in the EMME condition when (H3a) learning and (H3b) solving geometry problems.

# Method

## Participants and Design

Participants were 58 secondary education students who had completed the online experiment. One participant did not give consent and was therefore deleted from the sample. Four participants were deleted from the sample because they had spent more than 130 minutes on participating in the experiment. Which indicated that these participants could have been distracted during the experiment or did not make the experiment in one go. Another participant was excluded from the sample because of being an outlier on several measures. Resulting in a final sample of 52 secondary education students ($M_{age}$ = 12.56, $SD_{age}$ = .61, 22 male, 30 female). Participants were randomly assigned to one of the three conditions: (1) the EMME condition with a social cue ($n$= 15), (2) the EMME condition without a social cue ($n$= 23), (3) or the VME condition ($n$= 14).

## Materials

This study was conducted using the survey software Qualtrics (www.qualtrics.com). Materials for this experiment, such as geometry examples and geometry problems, have been used before in a study by Van Marlen et al. (2018).

**Prior knowledge test.** A prior knowledge test was used to check whether there were differences in prior knowledge between the three conditions. The prior knowledge test consisted of five geometry questions. Three multiple choice questions tested general geometry knowledge and two open questions asked participants to determine the degree from an angle (e.g., Angle A is equal to …..).

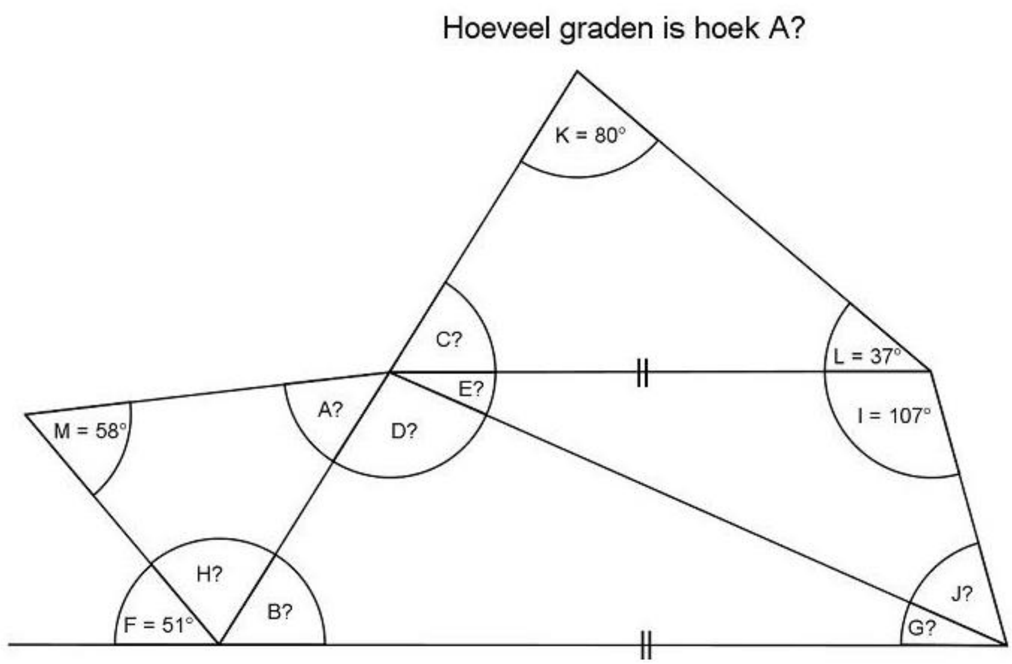


*Figure 1.* Example of an isomorphic problem used in this experiment. The problem statement for this exercise is (translated from Dutch) ‘’How many degrees is angle A?’’.

**Geometry problems.** The geometry problems were created with the program *Geogebra* (www.geogebra.com). Two geometry problems were created for the modelling examples. Another two geometry problems were created for the isomorphic problems. The modelling examples and the isomorphic problems had the same layout but the values in the figure were changed. Four geometry problems with different layouts and values were created for the transfer problems. These transfer problems challenged participants to use the learned skills and apply these skills in a new situation. Each geometry problem had a problem statement above the figure, stating which angle had to be solved. Some angles in the figure had values and angles with unknown values were marked with a question mark (see Figure 1). To provide an answer to the problem statement, four angles had to be solved.

**Quality of instruction.** To measure the perceived quality of instruction, participants were asked to rate the quality of each modelling example on a 5-point Likert scale ranging from 1 (very poor) to 5 (excellent).

**Paas scale.** The scale developed by Paas (1992) was used to examine the perceived amount of mental effort put into watching the modelling examples and solving the geometry problems. Participants were asked to rate mental effort on a 9-point scale from 1 (very, very, very low effort) to 9 (very, very, very high effort).

**Modelling examples.** For creating the EMME, SMI Experiment Center 3.4.165 was used to record eye-movements and the SMI BeGaze 3.4.52 was used to make the EMME. In the EMME conditions, the models eye movements were visualized as a blue circle with a diameter of 30 pixels. Each condition contained two modelling examples. The duration of these two modelling examples were 131 seconds and 140 seconds.

In the modelling examples, a woman gave a verbal explanation on how to solve geometry problems. In the introduction of the EMME with a social cue the model mentioned that the blue circle in the video represents a person's eye movements, ‘There is a blue circle in this video in addition to the verbal explanation and this blue circle shows you where another person is looking at when solving the geometry problem. This will help you solve the upcoming geometric problems’. In the EMME without a social cue, this explanation was changed into, 'There is a blue circle in this video in addition to the verbal explanation. This will help you solve the upcoming geometric problems’. Except for the verbal introduction, all modelling examples had the same verbal explanation on how to solve the geometry problem. All modelling examples started with stating the problem statement. Then the model visually located the angle from the problem statement and explained what is needed to calculate this angle. Then the model explained which angle needs to be calculated first and then explained each following step until calculating the problem statement.

**Procedure**

The set-up of this study was changed due to the corona crisis. The original plan was to conduct the experiment at a high school. However, during the corona crisis high schools were closed and, therefore, the experiment was changed into an online experiment.

All participants participated in this experiment from home. The experiment lasted approximately 45 minutes. The participants were asked to make the experiment in a quiet space with minimal distraction. Before the start of the experiment, participants got a general instruction via email about how to participate. After reading the general instruction, participants were asked to go to a website and start the experiment (www.qualtrics.nl). The URL of the website was presented in the email.

When participants entered the website, the program started with asking participants to fill in some demographics and give consent to participate. Then the prior knowledge test started and five questions had to be answered. After the prior knowledge test, the learning phase started. Participants were instructed that they were going to watch a modelling example about solving a geometry problem. Participants had put on their headphones and listen to a verbal introduction about the modelling example. The introduction either contained a social cue or a social cue was absent. After watching the modelling example, participants were asked to rate mental effort and quality of instruction. Then participants had to solve an isomorphic problem. This process was repeated one more time and then participants had to solve another four transfer problems. After finishing each geometry problem in the test phase, participants were asked to rate mental effort. When participants finished the experiment they clicked on the finish button and their performances were automatically saved in Qualtrics.

**Data Analysis**

**Prior knowledge.** Participants could score one point for each correctly answered question on the prior knowledge test. Meaning that a participant could score a maximum of five points in total.

**Performance.** Participants could obtain one point for each correctly answered geometry problem. Participants could score a maximum of two points for the isomorphic problems and a maximum of four points for the transfer problems.

**Quality of instruction.** Participants had to rate the quality of instruction of the two shown modelling examples. An average of both scores was computed.

**Mental effort.** Participants had to rate perceived mental effort twice in the learning phase and an average of these scores was computed. Participants, also, had to rate perceived mental effort after each transfer problem in the test phase and an average of these scores was computed.

**Analysis.** Statistical tests were run using SPSS.24. To check the assumption of normality a histogram, a P-P plot, and a Shapiro- Wilk test were run. Levene's test was run to check the assumption of homoscedasticity. With normality and homoscedasticity assumed the data were analysed with one-way ANOVAS ($\alpha$ = < .05). When the assumption of normality was violated, data were analysed with non-parametric Kruskal-Wallis tests ($\alpha$ = < .05). Tests were run with dependent variables performance on isomorphic problems, performance on transfer problems, quality of instruction, mental effort in the learning phase, and mental effort in the test phase and the independent variable was belief about the social cue.

## Results

Table 1

*Mean and Standard Deviation of the Prior Knowledge Test, Performance on Isomorphic problems, Performance on Transfer problems, Rating Quality of Instruction, Perceived Mental Effort Learning Phase, and Perceive Mental Effort Test Phase*

| | EMME (*N*= 15) | | Non-social (*N*= 23) | | Control (*N*= 14) | |
|---|---|---|---|---|---|---|
| Variable | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Prior knowledge test | 2.67 | 1.11 | 3.17 | 1.53 | 3.71 | 0.94 |
| Performance Isomorphic | 1.27 | 0.70 | 1.22 | 0.34 | 1.43 | 0.76 |
| Performance Transfer | 1.87 | 1.30 | 2.13 | 1.46 | 2.36 | 1.01 |
| Quality of instruction | 4.27 | 0.46 | 4.11 | 0.50 | 4.25 | 0.43 |
| Mental effort learning phase | 2.63 | 1.17 | 2.72 | 1.09 | 3.04 | 1.17 |
| Mental effort test phase | 4.83 | 1.96 | 4.20 | 1.60 | 3.98 | 1.59 |

First, normality of all variables was tested. Only mental effort in the test phase had a normal distribution. Therefore, when normality was violated Kruskal-Wallis tests were used. First, differences in prior knowledge were checked between participants in the three different conditions. On the prior knowledge test, participants could score a maximum of 5 points. The average score on the prior knowledge test could be considered as sufficient to high ($M$ = 3.17, *SD* = 1.31). Results of the Kruskal-Wallis test indicated no significant differences in prior knowledge between the conditions, $H(2) = 4.53$, $p = .104$.

**Performance.** Hypothesis one suggested that participants in the EMME condition would perform better in solving the isomorphic problems and the transfer problems. The control condition scored a little bit higher on the isomorphic problems ($M = 1.43$, $SD = .756$) than the social EMME condition ($M = 1.27$, $SD = .704$) and non-social EMME condition ($M = 1.22$, $SD = .736$) (see Table 1). A Kruskal-Wallis test was used to test whether there were differences in performance on the isomorphic problems between the social EMME condition, the non-social EMME condition, and the control condition. The condition was used as a between-subject variable and performance on isomorphic problems was used as dependent variables. Results showed no significant difference between the conditions on the performance on the isomorphic problems, $H(2) = 0.92$, $p = .632$.

The same trend in results was found by performance on transfer problems. The control condition performed a little bit better ($M = 2.36$, $SD = 1.01$) than the social EMME condition ($M = 1.87$, $SD = 1.30$) and non-social EMME condition ($M = 2.13$, $SD = 1.55$) (see table 1). To test whether there were differences between the three conditions, a Kruskal-Wallis test was conducted. Again, the condition was used as a between-subject variable and performance on transfer problems was used as dependent variables. Results showed no significant differences between the conditions on the performance in solving transfer problems $H(2) = 0.98$, $p = .613$.

**Quality of instruction.** The second hypothesis suggested that participants would rate the quality of instruction higher in the EMME conditions. The social EMME condition, the non-social EMME condition, and the control condition all rated the quality of instruction as high (see Table 1). The results of the Kruskal-Wallis showed no significant differences between the quality of instruction between the conditions, $H(2) = 1.83$, $p = .401$.

**Mental Effort.** A Kruskal Wallis test was conducted to explore whether the conditions differed on perceived mental effort in the learning phase. The results indicated that there were no differences in mental effort between the three conditions, $H(2) = 1.14$, $p = .565$. A one-way ANOVA was conducted to analyse the differences in perceived mental effort during the test phase. With the assumption of homoscedasticity assumed, results of the one-way ANOVA showed that there were no significant differences on perceived mental effort in the test phase between the conditions, $F(2,49) = 1.014$, $p = .370$.

The assumption of normality was violated on one variable in perceived mental effort in the learning phase. However, an ANOVA is a robust test and if group sizes are approximately equal the *F*-statistics can be robust to violations of normality (Field, 2013). Therefore, a repeated measure ANOVA, with perceived mental effort in the learning phase and test phase as within-subject variables, was conducted to explore if there was a difference between the conditions on perceived mental effort over time. Mauchly's test indicated that the assumption of sphericity was not violated. The results of the repeated measure ANOVA showed that the condition did not affect mental effort over time, $F(2,49) = 2.200$, $p = .122$, $\omega^2 = .082$.

## Discussion

This study aimed to investigate the role of social attention in EMME. Several studies have found mixed results for the effectiveness of EMME for learning procedural problem-solving tasks (Van Gog, 2009; Van Marlen et al, 2016; 2018). This study investigated the effectiveness of EMME for learning procedural problem-solving tasks and added a new perspective by examining the influence of social attention. In this study, three different hypotheses were tested. None of the hypotheses was supported in this study.

First, this study investigated the relationship between social attention in EMME and performance in solving procedural problems. It was expected that participants in the EMME condition would outperform students in other conditions. However, the results indicated that social attention in EMME does not significantly influence performance. These findings contrast with Gobel et al. (2018), who found that social beliefs about a visual cue could affect performance. In the study of Gobel et al. (2018), participants performed a task where they had to respond as quickly as possible to the appearance of a blue square. Participants who were manipulated to believe that, while performing the task, they had direct interaction with an unseen partner performed better. It seems possible that the participants in the study of Gobel et al. (2018) showed pro-social behaviour because of the *watching eyes effect* (Conty, George, & Hietanen, 2016). Conty et al. (2016) argue that direct gaze perception could stimulate pro-social behaviour and therefore could increase performance. However, in the experiment of this study participants did not have direct interaction with the instructor and they had to solve geometry problems by themselves. Therefore, it seems possible that in this task pro-social behaviour was not stimulated and, therefore, did not affect learning performances. Another explanation for these findings might be that participants in the non-social EMME condition perceived the displayed eye movements as a normal visual cue guiding their attention. A study of Doneva, Atkinson, Skarratt, and Cole (2017) argues that spatial orientating between people does not involve higher-order mechanisms that require knowing personal attributes of the other person, it is standard orientating where the cue happens to be a person.

However, participants in the EMME and the non-social EMME conditions did not perform better than the control condition. This result suggests that EMME might not be effective for learning procedural problem-solving skills. Which is in line with the findings of Van Gog et al. (2009) and Van Marlen et al. (2016). Van Gog et al. (2009) argued that the verbal explanation could have been redundant to the task. When learners have to process redundant information this will require cognitive resources. The additional information leads attention away from the primary learning source, which could infer with learning (Bobis, Sweller, & Cooper, 1993). In this study, it was expected that the eye movements would support the participants to better understand how to look at geometric problems. However, it seems possible that the verbal explanation could have provided enough information to guide the learners' attention. Van Marlen et al. (2016) indicated that a model performing a procedural problem-solving task in itself could guide a learners' attention. When a model performs a procedural problem-solving task he has to visually interact with the object. In this case the geometric problem. The model has to make the calculations and type the answer to show the learner how to solve the geometric problem. These overt actions of the model might guide the learners' attention and support learning (Van Marlen, 2016). In contrast to tasks where no overt actions are shown, like perceptual classification tasks (Jarodzka et al., 2012; Jarodzka et al, 2013). There the displayed eye movements show the, otherwise, covert processes which could guide a learners' attention and support learning.

The findings of this study contrast with the findings of Van Marlen et al. (2018). In the study of Van Marlen et al. (2018) an effect of learning with EMME on the performance on procedural problem-solving tasks was found. This study used the same materials and examined the same target audience as the study of Van Marlen et al. (2018). However, due to the changed set-up, these two studies might not be comparable. The corona crisis forced us to change the set-up of this study in an online experiment where participants had to participate from home. Therefore, it was impossible to control the environment of the participants. It seems reasonable to believe that some participants were distracted during the experiment or got help from someone. This could have affected their performance in this experiment. Also, it seems possible that the representativeness of this study is affected by its sample. Students were not actively stimulated to participate, they had to participate on their own and they had to put in their own time. These circumstances required efforts from the participants. It seems possible that highly motivated students participated in the experiment and that less motivated students did not participate.

Another explanation for these opposing findings could be the amount of prior knowledge of the participants. Participants in this study scored sufficient to high on the prior knowledge test. Although they did not have lessons about the F and Z principles in geometry, they might already did have knowledge about basic geometry principles. This could have affected their performance in solving the geometry problems. In the study of Van Marlen et al. (2018) two experiments were conducted. In the first experiment, the prior knowledge of participants was relatively high and Van Marlen et al. (2018) found that learners' attention was guided by EMME. However, this did not affect their learning outcomes. In the second experiment where the prior knowledge of the learners was relatively low, an effect of EMME for learning procedural problem-solving tasks was found. Van Marlen et al. (2018) suggested that learners with more prior knowledge have a higher working memory capacity. Which made that the learners in the conditions without visual guidance were able to adjust to the additional load of searching for the verbal cues. In this study, participants score relatively high on the prior knowledge test. In comparison, to the study of Van Marlen et al. (2018) (2$^{nd}$ experiment), participants in this study scored on average more than one point higher on the same prior knowledge test. Therefore, due to the relatively high amount of prior knowledge, the eye movements probably did not have an additional effect on learning procedural problem-solving tasks.

Second, the effect of EMME on perceived quality of instruction was tested. It was expected that participants in the EMME conditions would perceive the quality of instruction higher than the control condition. Results of this study do not support this hypothesis, no differences on perceived quality of instruction were found. Van Marlen et al. (2018) found that learners in EMME conditions rated the quality of instruction higher than the learners in the control conditions. The perceived quality of instruction was especially higher when the verbal explanation in an EMME was ambiguous (Van Marlen et al., 2018). However, in this study, only an unambiguous verbal explanation was used in the modelling examples. Therefore, the participants might felt that the displayed eye movements in the EMME conditions did not contribute to the clarity of the explanation.

Third, perceived mental effort was tested in the learning phase and in the test phase to explore the differences between the conditions. It was expected that EMME would increase the perceived mental effort. Van Gog et al. (2009) found that participants rated perceived mental effort higher when they had to learn with an EMME. However, results indicate that participants overall did not experience a high amount of mental effort in the learning and test phase. Also, no differences in mental effort in the learning and testing phase were found. An explanation for these findings could be the amount of prior knowledge of the learners. Prior knowledge affects the amount of cognitive load someone has to put into performing a task. According to Amadieu, Van Gog, Paas, Tricot, and Mariné (2009), prior knowledge allows for coping with the cognitive demands imposed by learning. It seems possible that the amount of prior knowledge decreased mental effort they had to put into learning and solving geometry problems.

The findings of this study provide some theoretical and practical implications. This study strengthens the results of Van Gog (2009) and Van Marlen (2016) that EMME might not be effective for learning procedural problem-solving skills. Currently, just one study has proven the effectiveness of EMME for learning procedural problem-solving tasks (Van Marlen, 2018). It seems possible that this type of tasks already provides enough guidance for learners to learn the subject being taught. Also, prior knowledge seems to play a vital role in the effectiveness of EMME for learning procedural problem-solving tasks. Therefore, future research should investigate the role of prior knowledge for learning procedural problem-solving tasks with EMME. This would contribute to a better understanding of when the use of EMME could be effective for teaching procedural problem-solving tasks.

This study also investigated the role of social attention in EMME. This study did not find a relationship between social attention and learning with EMME. Which might indicate that the displayed eye movements are just received as a normal visual cue guiding attention. However, since it is not clear if EMME are effective for learning procedural problem-solving tasks, further research is needed. Future research could investigate the influence of social attention by tasks where the effectiveness of EMME already has been proven, like perceptual classification tasks and text-picture integration tasks. This research could give insight into the role of social attention in EMME.

This study also provides a practical implication for the use of EMME for learning procedural problem-solving tasks. When a teacher wants to teach procedural problem-solving tasks to learners, it is recommended to develop a VME instead of an EMME. So far, it does not seem to matter if a models' eye movements are displayed on the video. Making an EMME is a complicated and effortful process in contrast to making a regular VME. Also, nowadays, eye-trackers are still very expensive for schools to purchase.

When interpreting these findings, it is important to consider the limitations of this study. One limitation of this study is the sample size. This study aimed to recruit 159 participants to attain enough statistical power. However, due to the corona crisis, it was not possible to conduct the experiment at a high school. Therefore, participants were asked via mail to participate in the experiment. When conducting an experiment online it is less likely to achieve response rates as high as an experiment on paper (Nulty, 2008). Our final sample was too small to gain statistical power. This reduces the chance of finding a true effect, but also when a significant was found low power reduces the chance that results represents a true effect (Button, Ioannidis, Mokrysz, Nosek, Flint, Robinson, & Munafò, 2013). Therefore, future research could replicate this study with a larger sample.

Another possible limitation of this study is the manipulation. The manipulation in this study was a spoken sentence before the start of the modelling examples and the social cue was either present or absent. The duration of the manipulation varied between the 7 – 16 seconds. Participants had to process a lot of information during the experiment and it seems possible that this spoken sentence did not stand out between all the other information. Therefore, the manipulation might not have attracted enough attention to influence the participants.

In summary, this study investigated the role of social attention in EMME. The results of this study indicate that social attention might not play a role in EMME. Also, EMME might not even be effective for learning procedural problem-solving tasks. However, the findings of this study need to be interpreted with great caution. Further research is necessary to examine the effectiveness of EMME for learning procedural problem-solving tasks and the role of social attention in EMME. Different kinds of modelling examples are being used in contemporary education to support learning. However, still, a lot is unknown about the working mechanisms of modelling examples. Therefore, more research is needed to reveal the secrets of learning with modelling examples.

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