Computers in Human Behavior 65 (2016) 448–459

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Full length article

Showing a model's eye movements in examples does not improve learning of problem-solving tasks

Tim van Marlen [a, b, *], Margot van Wermeskerken [a, b], Halszka Jarodzka [c, d], Tamara van Gog [a, b]

[a] Institute of Psychology, Erasmus University Rotterdam, The Netherlands
[b] Department of Education, Utrecht University, The Netherlands
[c] Welten Institute, Open University of the Netherlands, The Netherlands
[d] Humanities Laboratory, Lund University, Sweden

ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form
8 June 2016
Accepted 27 August 2016

Keywords:
Example-based learning
Eye tracking
Attention cueing
Multimedia learning

ABSTRACT

Eye movement modeling examples (EMME) are demonstrations of a computer-based task by a human model (e.g., a teacher), with the model's eye movements superimposed on the task to guide learners' attention. EMME have been shown to enhance learning of perceptual classification tasks; however, it is an open question whether EMME would also improve learning of procedural problem-solving tasks. We investigated this question in two experiments. In Experiment 1 (72 university students, $M_{age} = 19.94$), the effectiveness of EMME for learning simple geometry problems was addressed, in which the eye movements cued the underlying principle for calculating an angle. The only significant difference between the EMME and a no eye movement control condition was that participants in the EMME condition required less time for solving the transfer test problems. In Experiment 2 (68 university students, $M_{age} = 21.12$), we investigated the effectiveness of EMME for more complex geometry problems. Again, we found no significant effects on performance except for time spent on transfer test problems, although it was now in the opposite direction: participants who had studied EMME took longer to solve those items. These findings suggest that EMME may not be more effective than regular video examples for teaching procedural problem-solving skills.

1. Introduction

Worked examples or modeling examples, in which it is demonstrated how to perform a task, are an effective way to promote learning, especially when learners have no or limited prior knowledge (for reviews, see Renkl, 2014; Van Gog & Rummel, 2010). Indeed, *video* modeling examples have never been more prominent than they are today, thanks to technological advancements, such as digital cameras to record them, online learning environments to store and deliver them, and the availability of digital devices with internet connections (e.g., smartboards, laptops, and tablet PC's) in classrooms and at home to replay them. Video modeling examples come in many forms; for instance, showing the model (partly) who is manipulating objects as part of the demonstration of the task (Braaksma, Rijlaarsdam, & van den Bergh, 2002; Groenendijk, Janssen, Rijlaarsdam, & Van den Bergh, 2013; Hoogerheide, Loyens, & Van Gog, 2014; Van Gog, Verveer, & Verveer, 2014); showing the model in a lecture-style situation next to a screen on which a slideshow is projected that shows the steps needed to complete the task (Ouwehand, van Gog, & Paas, 2015) or on which the model is writing out those steps (Fiorella & Mayer, 2015; Exp. 1); showing only the slides or the model's writing in the form of a computer screen-recording with a voice-over explanation (Fiorella & Mayer, 2015; Exp. 3; see also www.khanacademy.org); or showing a screen-recording of the model working on a computer-based task, with or without a voice-over explaining the procedure (McLaren, Van Gog, Ganoe, Karabinos, & Yaron, 2016; Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009).

It has been suggested that the effectiveness of the latter type of screen recording examples, in which the model is demonstrating a computer-based task, may be enhanced by showing the model's eye movements overlaid on the screen recording (Van Gog et al., 2009). In such *Eye Movement Modeling Examples* (Jarodzka et al., 2012; Jarodzka, Van Gog, Dorr, Scheiter, & Gerjets, 2013; Mason,

* Corresponding author. Department of Education, Utrecht University, P.O. Box 80140, 3508 TC Utrecht, The Netherlands.
E-mail address: t.v.a.vanmarlen@uu.nl (T. van Marlen).

http://dx.doi.org/10.1016/j.chb.2016.08.041
0747-5632/

Pluchino, & Tornatora, 2015a; Van Gog et al., 2009; see for a review Van Gog & Jarodzka, 2013) the model's eye movements are visualized by, for instance, a colored dot. It is expected that by showing the model's eye movements, learners' visual attention is synchronized with that of the model; in other words, that learners are attending to the relevant information at the right time.

That such guidance might be necessary, is suggested by research showing that novices attend to task irrelevant information (i.e., information that is high in visual contrast and therefore more salient), whereas experts attend to task relevant information faster and more often and are able to ignore irrelevant information (Charness, Reingold, Pomplun, & Stampe, 2001; Haider & Frensch, 1999; Jarodzka, Scheiter, Gerjets, & Van Gog, 2010; Van Gog, Paas, & Van Merriënboer, 2005; Wolff, Jarodzka, Van den Bogert, & Boshuizen, 2016). Hence, when novice learners are observing an expert's demonstration of the task, it is likely that their attention is not directed at the information the expert is attending to or referring to at the same time. Especially in cases in which the visual or verbal information in the video modeling example is transient, this might result in the learner missing out on the relevant information, which might hamper learning (see Ayres & Paas, 2007, for a discussion of transience and need for attention guidance in animations). By displaying the models' eye movements in the example, however, the learner not only sees *what* the model is doing on the computer, but also *where* the model is looking, which is hypothesized to guide learners' attention and to improve their learning outcomes by helping them to optimally process the video example (e.g., Jarodzka et al., 2012, 2013; Van Gog et al., 2009).

1.1. Attention guidance based on eye movement displays

Several different approaches have been taken to designing attention guidance based on the differences in attention allocation between experts and novices or successful and unsuccessful problem solvers. First, the observation that successful problem solvers allocate their visual attention to other information than unsuccessful problem solvers, has been used to design visual cues to guide visual attention to the information successful problem solvers attended to (Grant & Spivey, 2003; Groen & Noyes, 2010). And indeed, such cues resulted in higher solution rates on an insight problem-solving task (i.e., Duncker's radiation problem; Grant & Spivey, 2003; Thomas & Lleras, 2007).

Second, the eye movements themselves can be displayed to function as a visual cue. Also using Duncker's radiation problem, Litchfield and Ball (2011) investigated whether dynamically displaying a solution-related sequence of eye movements for 30 s would increase performance. In Duncker's radiation problem a schematic drawing of a tumor is presented surrounded by healthy tissue and skin. The goal is to destroy the tumor without damaging healthy surrounding tissue by means of converging low intensity lasers from multiple sides. Litchfield and Ball (2011) showed that a didactic (very deliberate, 'clean') or a natural (more chaotic) sequence of eye movements related to the solution (i.e., crossing the skin area from different angles), led to enhanced solution rates compared to eye movements focused on other areas of the task. Similar results of displaying another person's eye movements to guide attention and improve performance were obtained in studies with visual search tasks, in which people had to search for faults in software code (Stein & Brennan, 2004), faults on printed circuit boards (Nalanagula, Greenstein, & Gramopadhye, 2006), or lung-nodules on X-ray scans (Litchfield, Ball, Donovan, Manning, & Crawford, 2010). These studies show that attention guidance by displaying eye movements improved *performance*. However, they did not consider potential effects on *learning* (i.e., later performance in the absence of such guidance), which is the objective of displaying eye movements in modeling examples.

1.2. Learning from eye movement modeling examples

Research on *eye movement modeling examples* has found mixed support for the usefulness of displaying eye movements to guide attention and enhance learning. It seems that this kind of guidance is effective for learning tasks relying on visual inspection in order to classify or diagnose motion patterns from dynamic and visually rich stimuli. For instance, in the study by Jarodzka et al. (2013), participants had to learn how to classify fish locomotion patterns and were shown either only the video of the fish with the expert model's explanation, or they additionally saw the expert's eye movements. Consequently, when the expert verbally explained which fins the fish used for locomotion, the learners knew which fins he was referring to because they saw what he was looking at. The expert model's eye movements (i.e., fixations) were either visualized as a solid dot or as a 'spotlight' by means of blurring the video except for the part where the expert was fixating. After the video modeling examples participants were shown novel videos, without the expert's eye movements and verbal explanations, displaying fish locomotion patterns that they had to classify. Participants who had seen the model's eye movements showed marginally better performance on this classification task, with the dot condition outperforming the spotlight condition. In a similar vein, Jarodzka et al. (2012) showed that attention guidance by means of displaying the expert's eye movements in modeling examples, yielded superior learning outcomes. Participants had to learn to interpret symptoms of epileptic seizures in infants, either being shown only the video of the infant along with the expert model's verbal explanation, or they additionally saw the expert's eye movements being displayed either as a circle or as a spotlight. The spotlight condition outperformed the condition that did not receive attention guidance.

Eye movement modeling examples were also shown to be effective in learning a text-picture processing strategy (Mason et al., 2015a). Children who were presented with an example that showed a model's eye movements, with the model deliberately making transitions between corresponding elements of the text and picture in order to emphasize integration, showed more text picture integration (i.e., number of transitions between text and picture) on a novel text and recalled more information units and performed better at the transfer test about that novel text than children in the control condition who did not receive such an example. Recently, these results were replicated and extended by showing that children with lower reading comprehension skills benefitted more from eye movement modeling examples regarding factual knowledge and the transfer of knowledge, compared to children with high reading comprehension skills (Mason, Pluchino, & Tornatora, 2015b). Thus, EMME are not only effective for learning a domain-specific task, but also for learning general processing strategies.

In contrast, when it comes to learning procedural problem-solving tasks, guiding the learners' attention by displaying the model's eye movements did not yield beneficial effects on learning, and even had a negative effect on learning when the modeling example also contained a verbal explanation (Van Gog et al., 2009). In this study, participants were shown an example of how to solve an animated puzzle problem (i.e., frog leap) with or without a verbal explanation and with or without the model's eye movements being displayed. All examples showed a screen recording of the solution steps, which were executed by the model clicking on a frog to move it forward. The verbal information (when present) explained the different choice options at each step, and indicated which options were incorrect and why. The displayed eye movements also showed the model considering the various choice