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Learning to see: Guiding students' attention via a Model's eye movements fosters learning

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ABSTRACT

This study investigated how to teach perceptual tasks, that is, classifying fish locomotion, through eye movement modeling examples (EMME). EMME consisted of a replay of eye movements of a didactically behaving domain expert (model), which had been recorded while he executed the task, superimposed onto the video stimulus. Seventy-five students were randomly assigned to one of three conditions: In two experimental conditions (EMME) the model's eye movements were superimposed onto the video either as a dot or as a spotlight, whereas the control group studied only the videos without the model's eye movements. In all conditions, students listened to the expert's verbal explanations. Results showed that both types of EMME guided students' attention during example study. Subsequent to learning, students performed a classification task for novel test stimuli without any support. EMME improved visual search and enhanced interpretation of relevant information for those novel stimuli compared to the control group; these effects were further moderated by the specific display. Thus, EMME during training can foster learning and improve performance on novel perceptual stimuli.

1. Introduction

In many domains such as medicine, navigation and control of transport, or biology, people examine complex, dynamic, and information-dense visual material such as CT scans, cockpit displays, or film recordings of animals. Tasks within these domains rely heavily on visually searching and interpreting perceptual information; hence, we refer to them as *perceptual tasks* (cf. Chi, 2006). An important question for educators in these domains is how to effectively teach accomplishment of perceptual tasks. A promising avenue is suggested by studies that show that guiding people's attention via the eye movements of a successful model enhances their performance on the perceptual task for which guidance was provided (Grant & Spivey, 2003; Litchfield, Ball, Donovan, Manning, & Crawford, 2010). However, it is crucial to take this research one step further and investigate whether such attention guidance cannot just enhance performance on the task at hand, but can also foster *learning*, that is, enhance performance on future, novel tasks when attention guidance is no longer present. The present study addresses this question against the backdrop of instructional design theories that analyze learning from a cognitive information processing perspective.

1.1. Learning as cognitive processing of perceptual input

Instructional design theories, such as Mayer's (2005) cognitive theory of multimedia learning (CTML) and Sweller's cognitive load theory (CLT; Sweller, Van Merriënboer, & Paas, 1998) describe how the human mind handles information from a perceptual input (e.g., visual or auditory information) at different stages of processing in order to construct a long-lasting mental representation of this input in long-term memory, that is, in order to learn. Both theories rely on models with a long-standing tradition in cognitive psychology for describing human information processing, such as the multi-store model of memory by Atkinson and Shiffrin (1968) or the working memory (WM) model by Baddeley (e.g., Baddeley, 1992; for a more recent version cf. Baddeley, 2012). According to the CTML and CLT, attention and working memory are fundamental during learning, because all information needs to be attended and processed in working memory before it can be integrated with prior knowledge and stored in long-term memory. Because

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attentional as well as working memory resources are limited with regard to the amount of information that can be processed in parallel (Fougnies & Marois, 2006; Miller, 1956; Peterson & Peterson, 1959), according to CTML and CLT instruction needs to be designed in a way that makes optimal use of these limited processing resources. Accordingly, various instructional design principles have been postulated that prescribe how instructional materials should be designed so that learners can select relevant information from the perceptual input, organize it in working memory and integrate it with prior knowledge. Only if such an active processing of the instructional materials can be achieved, (deeper) learning will occur. We will refer to two of these principles, namely, (1) the worked examples principle, that advocates the use of examples for novices' skill acquisition (e.g., Atkinson, Renkl, Derry, & Wortham, 2000; Van Gog & Rummel, 2010) and (2) the cueing or signaling principle, that is, the use of cueing techniques to highlight relevant information (e.g., De Koning, Tabbers, Rikers, & Paas, 2009), in a later stage of this paper.

The assumptions made by the CTML and CLT are assumed to hold true for any kind of task. In the following, we will address the specifics of learning to accomplish perceptual tasks, which are at the focus of the present paper, by first describing the processes necessary for task accomplishment and the way they develop with experience and then highlighting the characteristics of highly perceptual tasks that make them particularly difficult to accomplish.

1.1.1. Active processing in perceptual tasks

In the case of visuo-perceptual tasks, information is selected by means of *visual* attention (i.e., the conscious devotion of attention to visual information required to absorb it and transfer it to working memory). Visual attention is closely linked to where a person is looking (Deubel & Schneider, 1996; Just & Carpenter, 1980), which in turn can be captured by means of eye tracking (Holmqvist et al., 2011). Eye tracking research has shown that experience with a perceptual task influences visual attention, for instance in static material – -such as artwork – or dynamic material – such as biological motion or traffic (Huestegge, Skottke, Anders, Müsseler, & Debus, 2010; Jarodzka, Scheiter, Gerjets, & Van Gog, 2010; Vogt & Magnussen, 2007). In particular, less experienced individuals often attend to salient information (i.e., bottom-up or stimulus-driven attention allocation) that may not necessarily be relevant for task performance (Jarodzka et al., 2010; Lowe, 1999). Individuals with higher expertise, on the other hand, know which information is important for task performance (i.e., top-down or observer-driven attention allocation), which enables them to efficiently attend to it. It has been repeatedly shown that individuals with higher expertise focus faster and/or proportionally longer on relevant information than individuals with lower expertise, while ignoring potentially salient, but irrelevant information (e.g., Haider & Frensch, 1999; Huestegge et al., 2010; Jarodzka et al., 2010; Van Gog, Paas, & Van Merriënboer, 2005). Hence, individuals with little or no experience in a perceptual task may have difficulties to *select* task-relevant information by adequately controlling their visual attention. This may not be overly problematic with static stimuli, where it will only take more time to identify the relevant information; however, it might pose more severe problems with dynamic stimuli, which often require that information is attended to at a certain time, since, otherwise, this information will be missed. Consequently, novices need support in selecting information from a complex perceptual input.

Attending to relevant information is necessary, but not sufficient for successfully performing or learning to perform a perceptual task, however. This information also needs to be organized and interpreted, which requires it to be *integrated* with other information from the environment and with prior knowledge. Research has shown that even when less experienced individuals attend to thematically relevant information, they do not necessarily know how to interpret it. For instance, Cook, Wiebe, and Carter (2011) showed that when learning from complex visualizations of DNA strings, students of diverse expertise levels all attended to the thematically relevant features. However, less experienced students were not able to interpret the ongoing processes. Therefore, when teaching perceptual tasks, it is important to keep in mind that less experienced individuals will not only have difficulties with *selecting*, but also with *interpreting* information.

1.1.2. Specific challenges in active processing of realistic and dynamic stimuli

As mentioned above, visually searching for the right information and correctly interpreting that information is challenging, the more so when materials are *realistic* and *dynamic*.

Realistic materials, such as photographs and videos, reproduce the real world and keep many features of real objects intact, such as color, shape, etc. (cf. Rieber, 1994). Such materials typically contain much more information than is relevant to the task at hand. Hence, relevant information has to be searched for among many irrelevant elements, which, however, may be salient and could therefore easily distract visual attention away from the thematically relevant information (Dwyer, 1969). Visual saliency has a large influence on visual attention, in the sense that visually salient areas are looked at faster and longer and are also better remembered; this latter effect, however, can be overridden by the thematic relevance of specific areas – given the observer knows what is thematically relevant (Kaakinen, Hyönä, & Viljanen, 2011). This however, is not the case for novices in a domain; hence, we must assume that they will be mainly driven by visual saliency. Often the relation between thematic relevance and visual salience is not straightforward, and as a consequence the most attention attracting elements may be entirely irrelevant to the task, whereas the crucial element may not be very visually salient at all (Schnotz & Lowe, 2008). Research has shown that students have more difficulties to learn from realistic than from schematic material (e.g., Scheiter, Gerjets, Huk, Imhof, & Kammerer, 2009). Hence, for realistic material the *visual search* for relevant information is particularly challenging. In an educational context this means that when studying realistic material it may be beneficial to support the learner's visual search of the relevant information.

Dynamic material represents changes over time. The challenging aspect is that information is transient, that is, it appears only in specific moments in time (Hegarty, 1992). Thus, this information not only has to be attended to at the right moment in time (i.e., selected), but it also has to be kept active in working memory, while new information enters the perceptual system, which imposes high working memory load (e.g., Ayres & Paas, 2007; Spanjers, Van Gog, & Van Merriënboer, 2010). Moreover, several important elements may be present at the same time, which makes it difficult to attend to all of them (Lowe, 2003). That is, the attention of the observer would need to be divided among multiple elements, thereby causing split attention, which has been shown to hamper information processing (cf. split-attention effect: Chandler & Sweller, 1991). Hence, it is not only challenging to select dynamic information but also to keep it active in working memory so that it can be *interpreted*. For educational purposes this means that when studying dynamic material it may be beneficial to support the learner's visual search *and* interpretation of the relevant information.

In the following section, we will introduce an instructional format for perceptual tasks that fulfills the aforementioned premises and that relies heavily on the use of examples.