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Eye-movement modeling of integrative reading of an illustrated text: Effects on processing and learning

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ABSTRACT

Integrative processing of verbal and graphical information is crucial when students read an illustrated text to learn from it. This study examines the potential of a novel approach to support the processing of text and graphics. We used eye movement modeling example (EMME) in the school context to model students' integrative processes of verbal and pictorial information by replaying a model's gazes while reading an illustrated text on a topic different from that of the learning episode. Forty-two 7th graders were randomly assigned to an experimental (EMME) or a control condition (No-EMME) and were asked to read an illustrated science text about the food chain. Online measures of text processing and offline measures of reading outcomes were used. Eye-movement indices indicated that students in the EMME condition showed more integrative processing than students in the No-EMME condition. They also performed better than the latter in the verbal and graphical recall, and in the transfer task. Finally, the relationship between the duration of reprocessing the graphical segments while rereading the correspondent verbal segments and transfer performance was stronger in the EMME condition, after controlling for the individual differences of prior knowledge, reading comprehension, and achievement in science. Overall, the findings suggest the potential of eye-tracking methodology as an instruction tool.

1. Introduction

Students mainly rely on reading to learn new knowledge in the school context. Regardless of the presentation format of their information sources, either paper or digital, they should be able to understand written texts. It is therefore not surprising that a fruitful line of research in educational psychology is that of learning from text in content areas (Alexander, 2012; Sinatra & Broughton, 2011) and several studies have investigated the effects of text type (e.g., refutation text) on conceptual understanding and change (Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014; Diakidoy, Kendeou, & Ioannides, 2003; Diakidoy, Mouskounti, & Ioannides, 2011; Kendeou, Muis, & Fulton, 2011; Mason, Gava, & Boldrin, 2008).

In learning from texts students also encounter different types of visualization as textbooks are accompanied by illustrations. It has been documented that images enhance learning (Butcher, 2006; Carney & Levin, 2002; Mayer, 1989), although not always (Mayer & Gallini, 1990). The superiority of an illustrated text over a non-illustrated text depends on a successful integration of verbal and graphical information (Mayer, 2009, 2014; Schnotz, 2002, 2014). Nevertheless, research has also indicated that students may pay little attention to illustrations (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010a; Hannus & Hyönä, 1999) and are often under the illusion that they comprehend them (Schroeder et al., 2011).

To help students integrate words and pictorial elements when reading it is therefore very important to enhance not only text comprehension but also learning from illustrated text, given that the association between reading performance and academic performance has been documented, especially in the domain of science (Cromley, 2009; Cromley, Snyder-Hogan, & Luciw-Dubas, 2010b). Previous research has focused on the characteristics of learning materials that can better support the integration of text and pictures, in particular the corresponding parts of the two types of external representation, for example using labels and highlights as visual cues (Bartholomé & Bromme, 2009; Florax & Ploetzner, 2010; Mason, Pluchino, & Tornatora, 2013). However, cueing by making relevant information more salient is not necessarily successful, as indicated in studies on learning from static (Bartholomé & Bromme, 2009) and animated visualizations (Lowe & Boucheix, 2011).

An alternative way to sustain readers' integration of verbal and graphical information is based on the opportunity of modeling the readers' processing behavior, that is, to show a novice student the behavior of an expert who reads an illustrated text. A very recent approach in research on learning and instruction supports students' orientation of attention in video-based modeling examples by means of eye tracking (Jarodzka, van Gog, Dorr, Scheiter, & Gerjets,

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2013). Eye tracking captures a person's eye position, which is linked to attention and information processing (Just & Carpenter, 1980; Rayner, 1998, 2009). Eye-tracking methodology has recently received increased attention in educational research about multimedia learning (van Gog & Scheiter, 2010) to examine the processing of text and static graphics (Eitel, Scheitel, Schüler, Nyström, & Holmqvist, 2013) – especially the time course of this processing (Mason, Pluchino, Tornatora, & Ariasi, 2013) – complex graphics (Canham & Hegarty, 2010), animations (Boucheix & Lowe, 2010), and dynamic stimuli (Jarodzka, Scheiter, Gerjets, & van Gog, 2010). Modern technology related to eye movement recordings not only provides unique information regarding perceptual and cognitive processes underlying learning performance, but it also makes gaze replays available in the form of videos. In standard eye tracking software, fixations on specific information are represented as solid dots: The larger a dot, the longer the fixation time on it. Videos of gaze replays can be used to model a learner's behavior. In this regard, Eye Movement Modeling Examples (EMME) is a recent instructional strategy based on eye position recordings of a skillful expert, which are replayed to less skillful students with the aim of helping them acquire the desired skills (van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009).

In the present study we used eye-tracking methodology in the real school context to model students' integration of text and graphics when interacting with the learning material. The aim was to extend current research on students' processing and comprehension of illustrated text, taking into account the main issues of two separate lines of research, one on multimedia principle, and the other on eye movement modeling examples. In the next sections, relevant issues of these lines of research are briefly reviewed for the foundation of the current investigation.

1.1. Comprehension of text and picture

The beneficial effects of supplementing texts with pictures have been accounted for by the cognitive theory of multimedia learning (Mayer, 2009, 2014). This theory envisages three processes as important for a successful comprehension of verbal and graphical representations. The first is the selection of relevant words from the text and relevant elements from the picture. The second is the organization of selected information in which the material is further processed to understand and retain the information. Organization takes place separately for textual and pictorial information; therefore a verbal model and a pictorial model are constructed. The third process is the integration of verbal and pictorial models with the help of prior knowledge retrieved from long-term memory.

In his integrated model of text and picture comprehension, Schnotz (2002, 2014; Schnotz & Bannert, 2003) developed Mayer's theory to take into consideration the representational nature of a text and a picture as two different sign systems, distinguishing between the processing of descriptions and depictions. Texts are considered to be descriptive representations with a higher representational power than depictive representations. Paivio's (1986) dual-coding theory is applied to the processing of images and texts. However, in contrast to this traditional theory, the integrated model of text and picture comprehension posits that multiple representations are constructed during text and picture comprehension. During text comprehension, the reader first generates a representation of the text surface structure, then a propositional representation of the semantic content – which is a representation of the ideas conveyed in the text at a conceptual level – and finally a mental model of the subject matter presented in the text. Propositional representations and mental models interact continuously through processes of model construction and model inspection guided by schemata that have selective and organizational functions.

Similarly, in picture comprehension, an individual first generates a visual representation of the graphic visualization via perceptual processing and then a mental model, as well as a propositional representation of the content through semantic processing (Schnotz, 2002, 2014; Schnotz & Bannert, 2003). Structural mapping processes are essential to the formation of a coherent mental model of an illustrated text from the continuous interactions between the propositional representation and the mental model, both in text comprehension and picture comprehension. The mapping process takes place when graphical entities are mapped onto mental entities and spatial relations are mapped onto semantic relations. The resulting mental mappings are integrated conceptually with prior knowledge and enable the use of acquired knowledge in various situations.

To exemplify, if a student reads that "Some migrant birds fly to the south of Europe for wintering" (Schnotz, 2014), she constructs a first representation of the text surface structure, which cannot be considered understanding, but allows repetition of the content read. A propositional representation derived from the surface representation leads to a conceptual organization of the content around the proposition "fly", which is independent of the sentence wording and syntax. Further, the readers construct a mental model of the text content, for example a mental map of Europe with a north–south bird transfer. Similarly, if a student inspects a map of bird migration in Europe, an internal visual image of the map is formed first, then a mental model of bird migration in Europe, complemented by a propositional representation, as an effect of selection and elaboration of information through structure mapping (Schnotz, 2014).

According to both the cognitive theory of multimedia learning and the integrated model of text and picture comprehension, integration processes are essential for learning from illustrated texts, after selecting and organizing relevant information. How can integrative processing of verbal and graphical information be enhanced to facilitate text comprehension and learning from text? To answer this question, research on multimedia learning has examined various characteristics of the learning material. For example, the potential of visual cueing in the form of labeling has been investigated. In a study with university students, labeling included either the presentation of numerical labels to mark each central concept in the text and the corresponding unit in the graphics, or colored highlights of the central areas of the texts and the corresponding areas of the graphics (Bartholomé & Bromme, 2009). Numerical labeling was more effective than highlighting, at least in one of the various knowledge measures at posttest, a classification task, when other prompts were not provided. In a study with lower secondary school students, labeling referred to the presence of only one or two key words placed near each part of a picture (Mason et al., 2013). Results showed that only for the transfer performance, did participants who studied the text illustrated by a labeled picture outperform those who interacted with the same text visualized by an unlabeled picture, or text only. Moreover, the labeled illustration promoted stronger integrative processing of the learning material, as revealed by the eye-fixation index of the time spent refixating text segments while reinspecting the illustration (look-from illustration to text) during the second-pass reading and inspection. It is worth underlining that this study examined the time course of text and picture processing and indicated that their integration occurs during the second-pass reading and is related to deeper learning. The latter outcomes confirmed those of a correlational study with fourth graders, which indicates that the greater integrative processing of an illustrated text was associated with higher learning performance (Mason, Tornatora, & Pluchino, 2013).

Another potentially advantageous characteristic of learning materials that has been examined is spatial contiguity. It entails placing