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Does self-generating a graphic organizer while reading improve students' learning?

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ABSTRACT

To understand a document, learners must select the relevant information, organize this information into a coherent representation, and integrate it with their prior knowledge. One way of facilitating these cognitive processes is to display a graphic organizer alongside the document, showing the main items of information contained in the text and the links between them. To ensure students' active engagement in these processes, they can also be asked to self-generate an organizer (generative processing). However, this kind of task can be too demanding and overload their cognitive capacity (extraneous processing). We therefore compared the learning of students who were instructed to study an illustrated text either on its own or accompanied by a readymade graphic organizer (displayed statically or step-by-step). In another group, students had to self-generate the organizer while reading. As predicted, providing a graphic organizer improved students' recall compared with that of the control group. Contrary to the generative hypothesis and consistent with the cognitive load hypothesis, the self-generated organizer group 1) performed more poorly on the recall test than the readymade organizer groups, and 2) achieved lower transfer scores.

1. Introduction

Computer-based learning environments are extensively used by learners to study multimedia documents such as illustrated explanatory texts. However, learners may need guidance to actively process this kind of document. We investigated the benefits and drawbacks for learning of either adding a visual aid (i.e., a graphic organizer) to a document or asking students to self-generate one while studying.

1.1. *Cognitive theory of multimedia learning: a theoretical framework*

One of the most influential models of the learning processes elicited by pedagogical documents is Mayer's cognitive theory of multimedia learning (CTML; Mayer, 2001, 2005, 2014). The CTML model is based on three assumptions: 1) learners use two separate channels to process information (an auditory/verbal channel and a visual/pictorial channel); 2) learners have limited cognitive capacity to process this information; and 3) learners actively engage in three generative cognitive processes to construct a coherent mental model of the information they have been given (Mayer, 2014). These three processes are: selecting the relevant information; organizing this information into a coherent cognitive structure; and integrating it with existing prior knowledge to form a coherent

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mental representation (Mayer, 1989, 2009, 2014; Wittrock, 1989). Learners need to actively engage in these selecting-organizing-integrating (SOI) processes in order to make sense of the material (i.e., model of generative learning; Mayer, 1996; Fiorella & Mayer, 2016). It is therefore critical to foster these cognitive processes with learning strategies that support the construction of a coherent mental model. Because learners possess limited capacity, the learning material has to be constructed in such a way as to avoid cognitive overload (for a complementary cognitive load theory, see also Paas & Sweller, 2014; Sweller, 1994; Sweller, van Merriënboer, & Paas, 1998). Mayer (2014; see also Mayer & Moreno, 2003) identified three kinds of cognitive demands: 1) *essential processing* stemming from the complexity of the document (selection and organization of the relevant information); 2) *generative processing* arising from the motivation to learn, referring to learners' efforts to make sense of the learning material; and 3) *extraneous processing* elicited by poor instructional design (e.g., irrelevant words or pictures) that may prevent learners from learning effectively.

One learning strategy that can be used to foster generative learning is *mapping* with graphic organizers. Semantic visual displays can promote cognitive processes in several ways (McCrudden & Rapp, 2015). Adding a graphic organizer to a pedagogical document facilitates not only the selection process, insofar as only key items of information are featured, but also the organization process, as the structure of the text and the hierarchical links between the concepts are made explicit. The effects on students' learning performances of adding a graphic organizer to a pedagogical document are discussed in the following section.

1.2. Adding graphic organizers to pedagogical documents to improve learning

Stull and Mayer (2007, p. 810) defined graphic organizers (e.g., concept maps, knowledge maps, outlines) as spatial arrangements of words, indicating relations between concepts, that are intended to represent the conceptual organization of texts. Graphic organizers can be regarded as organizational signals, emphasizing key items of information and their interrelations. Signals in a text (e.g., headings, overviews or summaries) can emphasize its conceptual structure and organization (Loman & Mayer, 1983), direct students' attention toward signaled items, and enhance their retention (e.g., Mayer, Dyck, & Cook, 1984). Emphasizing a text's structure with a graphic organizer has therefore proved to enhance students' learning. In a study conducted by Robinson and Kiewra (1995; Exp. 1), students received either a text only, a text with outlines, or a text with graphic organizers. Results showed that students in the graphic organizers group learned more coordinate relations than those in the outlines or text-only groups. In a second experiment, students studied during a 1-h reading session (graphic organizers, outlines, or text only) followed by a 15-min review period after 1 day. Results revealed that studying with graphics or outlines, rather than with the text on its own, led to better recall of the represented facts. Moreover, students who studied with graphic organizers performed better on hierarchical relations, coordinate relations and the application of new knowledge. Graphic displays have therefore proved to be effective learning tools for readers (e.g., Kiewra, Kauffman, Robinson, Dubois, & Stanley, 1999; McCrudden, Schraw, & Lehman, 2009; Robinson & Schraw, 1994; see also Vekiri, 2002, for a review). Besides, graphic displays have also proved useful with hypertexts, as they can help students organize macrostructure information and build a coherent mental representation (e.g., Amadieu & Salmerón, 2014; Amadieu, Van Gog, Paas, Tricot, & Mariné, 2009; Potelle & Rouet, 2003). Graphic organizers allow learners to focus on the main information in the text and the way it is organized.

However, for them to be useful, graphic organizers need to be effectively processed by students during learning. Several studies have tested the effects of guiding students' attention toward a graphic organizer on learning. For instance, in their study, Kloster and Winne (1989) used a tracing method to force students to process a graphic organizer. While reading a text with an organizer, students had to write the code of the matching organizer section next to each paragraph, thus linking information in the text to the organizer. Authors found that students had difficulty linking the information from the organizer to the text. Moreover, results indicated that students who obtained high trace scores also performed better on the achievement test. Based on this experiment, Moore and Scevak (1994) studied the efficiency of one specific type of graphic organizer (i.e., tree diagram) on comprehension. Students had to read a social studies text either without a tree diagram, with a tree diagram that could be used optionally, or with a tree diagram that they were forced to process. Even though higher trace scores were related to better comprehension, results showed that students who were forced to process the diagram achieved lower overall and detailed comprehension scores than those who were provided with the diagram but not instructed to process it. The authors surmised that their method was too intrusive for students. The efficiency of a graphic organizer may therefore depend on the way students process it and its intrinsic difficulty. If students manage to relate the information contained in a text to a graphic organizer, then their performance improves (Kloster & Winne, 1989; Moore & Scevak, 1994). Therefore, when they are presented simultaneously with a text, graphic organizers need to be provided with guidance.

One way of facilitating connections between a text and a graphic organizer is to present the organizer step by step alongside the corresponding parts of the text. The advantage of a step-by-step presentation over a static one is that it makes the documents easier to process, by increasing the salience of the key information appearing on the screen (e.g., Bétrancourt, Dillenbourg, & Montarnal, 2003; Jamet, Gavota, & Quaireau, 2008). Moreover, research has shown that a sequential presentation is an effective way of directing students' attention toward the items of information as and when they appear, and of leading them to exhaustively explore the visual source (Fleury & Jamet, 2014). As regards graphic organizers, two studies have demonstrated that students studying with a sequential presentation significantly outperform those studying with a static presentation on retention (Blankenship & Dansereau, 2000) and comprehension (Jamet & Arguel, 2008) questions. Mayer's model suggests that the best way of fully engaging students in the processing of a graphic organizer is to ask them to self-generate one while studying a pedagogical document.

1.3. Asking students to self-generate a graphic organizer while studying: effects on learning performances

Generating a graphic organizer can promote selection and organization processes. First, it can be regarded as an organization