Computers in Human Behavior 80 (2018) 354–361

Contents lists available at ScienceDirect

Computers in Human Behavior

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

Full length article

How does adding versus self-generating a hierarchical outline while learning from a multimedia document influence students' performances?

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ARTICLE INFO

Article history:
Received 4 September 2017
Received in revised form
22 November 2017
Accepted 23 November 2017
Available online 24 November 2017

Keywords:
multimedia learning
Cognitive processes
Generative learning activity
Hierarchical outline
Advance organizer
Cognitive load

ABSTRACT

The present study investigated the effects of a visual aid (i.e., hierarchical outline) on students' multimedia learning. We expected the presence of this aid to improve students' learning from a multimedia document, by making the relevant information more salient and explicitly highlighting the text's structure. We postulated that asking students to self-generate an outline during learning would involve them in generative processing (selection and organization), thereby promoting effective learning (*generative hypothesis*). However, the generation activity might prove too demanding and overload students' cognitive capacity, thus impairing their learning (*cognitive load hypothesis*). When we compared the learning of students who viewed a readymade outline, generated one themselves, or studied a text with no outline at all, we found that providing an outline enhanced students' retention and transfer performances compared with the control group. Contrary to the generative hypothesis and consistent with the cognitive load hypothesis, the group who self-generated a hierarchical outline performed more poorly on the retention and transfer tests than those who viewed a readymade one.

1. Introduction

Most multimedia pedagogical documents contain outlines depicting the topics presented in each section. These outlines consist of visual displays identifying the topics and their hierarchical relationships. Put another way, they list the main concept and the subordinate concepts, including only the most important text information, and convey hierarchical concept relations (Glynn, Britton, & Muth, 1985; Robinson & Kiewra, 1995, p. 455). Adding an outline to a text can promote students' learning. It acts as a visual aid, emphasizing key elements of the text, and because students no longer need to maintain the main items of information in working memory to process the document, it frees up their cognitive resources. The literature on generative activity raises the question of whether it is better for learning to view a readymade outline or a self-generated one. If students self-generate an outline while reading, instead of viewing one that is provided, will it hinder their learning, because of the cognitive demands imposed on working memory, or improve their learning, because they are more involved in the cognitive processes required for a good understanding?

1.1. The benefits of emphasizing a text's structure

Outlines are provided close to textual signals such as headings, overviews or summaries. These signals are critical for learning, as they emphasize the conceptual structure or organization of a given passage (Glynn & Di Vesta, 1977; Loman & Mayer, 1983) and direct students' attention toward the signaled elements, thereby increasing their retention (e.g., Mayer, Dyck, & Cook, 1984). Moreover, signals direct students' attention to important aspects of textual structure and guide their processing of complex relations between text concepts (Lemarié, Lorch, Eyrolle, & Virbel, 2008, p. 39; Lorch, Lemarié, & Grant, 2011b). A broad range of research has shown the benefits of textual signals on students' performances (e.g., Britton, Glynn, Meyer, & Penland, 1982; Cauchard, Eyrolle, Cellier, & Hyönä, 2010; Hyönä & Lorch, 2004; Lorch & Lorch, 1995, 1996; Lorch, Chen, & Lemarié, 2012; Lorch, Lemarié, & Chen, 2013; Sanchez, Lorch, & Lorch, 2001). When Lorch, Lorch, and Inman (1993) studied the effects on learning of signaling a

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https://doi.org/10.1016/j.chb.2017.11.037
0747-5632/

text's topic structure by adding headings, overviews and summaries, they showed that students exhibited better topic recall than those who studied a nonsignaled version of the text. The same results were found in a more recent study conducted by Surber and Schroeder in 2007.

All the headings and subheadings of a text can be included in an outline and provided alongside an expository text to represent the overall text's topic structure. According to signal available relevant accessible (SARA) theory (Lorch, Lemarié, & Grant, 2011a,b; Lemarié, Lorch, & Péry-Woodley, 2012; Lemarié et al., 2008), outlines can serve several information functions that influence students' text processing, such as organizing (showing hierarchical relationships), labeling and identifying topics. In 1995, an interesting study conducted by Robinson and Kiewra (Exp. 2) compared three study materials: text only, text plus outlines, and text plus graphic organizers. Results demonstrated that students studying with organizers or outlines learned more of the represented facts than those who viewed the text on its own. However, the outline group did not differ from the text-only group on hierarchical relations scores. Adding an outline to a text has also been shown to improve the learning performances of children who are poor comprehenders and summarizers (Rossi, 1990). A more recent study tested the effects on learning of providing two different learning aids (Bui & McDaniel, 2015). Students studied an audio-lecture either with a skeletal outline, an illustrative diagram, or no learning aid at all. Authors showed that providing an outline was a useful learning aid, as it improved students' performance on a free recall test, compared with those of the control group, independently of their structure-building ability. Furthermore, the outline led students to take more notes containing more important ideas than the control group. Thus, as suggested by Bui and McDaniel (2015, p. 130), when provided, "outlines can free up cognitive resources otherwise devoted to extracting the organization of the propositions to construct a more complete mental model". To elaborate a coherent mental model of a multimedia document composed of texts and diagrams, students need to select the main information in the text and organize it into a mental representation that will then have to be integrated with their prior knowledge (e.g., Fiorella & Mayer, 2016). Therefore, students must devote cognitive resources to these critical cognitive processes in order to achieve a good understanding of the multimedia document.

1.2. SOI model of generative learning: a theoretical framework

The cognitive processes critical to students' understanding are described in Mayer (2014)'s select-organize-integrate (SOI) model. The SOI model is derived from this author's cognitive theory of multimedia learning (CTML) for multimedia documents (Mayer, 2001, 2005, 2014), which in turn relies on three assumptions: learners have dual channels for processing visual and auditory information, they have limited cognitive capacity available for information processing and they engage themselves in active processing. This last assumption is based on the idea that learners actively engage in three cognitive processes during learning: selection, organization, and integration. The SOI model relies on these same three cognitive processes and describes how they allow meaningful learning to occur (Mayer, 2014). When they read or listen to a given instruction (processed in sensory memory) learners have to select the relevant information (processed in working memory) and organize it into a coherent mental representation, which then has to be integrated with their prior knowledge and experiences retrieved from long-term memory to construct a coherent mental model (Mayer, 1989, 2009, 2014; Fiorella & Mayer, 2015). Learners' performances ultimately depend on their use of and engagement in these cognitive processes (Fiorella & Mayer, 2016). The SOI model can be likened to Wittrock's framework (1974, 1989, 1992). As well as motivation, attention and memory, Wittrock (1989, 1991) identifies *generation* as a critical component for understanding in his model of generative comprehension, describing it as a process of comprehension where learners establish relations between the items of information that are presented, and between these items and their prior knowledge (i.e., organization and integration processes). According to this model, if students are highly engaged in a generative activity, they will deeply process the overall information that is presented to them. One way of stimulating generative processes is to ask students to construct headings and subheadings while reading (Wittrock, 1989), as this requires selection and relational processes, and is thus regarded as deep processing (Amadieu, Lemarié, & Tricot, 2017). For instance, students can be asked to generate a hierarchical outline composed of headings and subheadings. This construction process should focus students' attention not only on the relevant information contained in the document - thereby fostering their selection processes - but also on the relationships between the different concepts that are presented-thereby fostering their organization processes. Creating an outline can be regarded as an *elaboration learning strategy*, and more precisely as an *organization learning strategy*, as learners need to turn the information they have been given into a more meaningful form (Weinstein & Mayer, 1983; Weinstein, Acee, & Jung, 2011). Nevertheless, constructing a hierarchical outline can prove too demanding a generative task, overloading students' limited capacity. This cognitive overload arises from the extraneous processes described by Mayer, as the cognitive processing is not related to the instructional goal (Mayer, 2014, p. 40). Accordingly, if this construction task requires a large amount of cognitive resources because of extraneous processes, it may offset the benefits of the generative act and hinder learning.

1.3. Generating an outline while reading

According to generative learning theory (Fiorella & Mayer, 2015, 2016), based on the SOI model and Wittrock's work, active engagement in learning, as opposed to passive learning, should improve students' performances. If students are given a task where they have to select the main items of information presented in a document and organize them according to their hierarchical relations (generative processing), their learning performances should benefit from this activity. Students' understanding of scientific texts relies on their ability to extract the macrostructure information (Kintsch & Van Dijk, 1978; Lorch, Lorch, & Matthews, 1985) and link this information together. One generative task that may promote these processes is outline construction. According to Stull and Mayer's definition (2007), outlines can be regarded as graphic organizers, as they show the conceptual organization of a text even if the spatial arrangement is less salient than that of a concept map or tree diagram.

A study conducted by Stull and Mayer (2007) compared students' learning across three groups: text only, text plus author-provided graphic organizers, and text plus self-generated graphic organizers. Their results supported the cognitive load hypothesis, as the construction task increased extraneous cognitive processing and reduced generative processing, and went against the generative hypothesis whereby constructing these organizers encourages generative processing (Stull & Mayer, 2007, p. 810). The generation activity hindered students' performances on a transfer test, although it had no effect on a retention test compared with the group that had author-provided organizers. Furthermore, students in the self-generated group spent more time studying the document. This study was recently replicated by Colliot and Jamet