



# Asking students to be active learners: the effects of totally or partially self-generating a graphic organizer on students' learning performances

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Received: 22 January 2018 / Accepted: 26 April 2019 / Published online: 13 May 2019  
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## Abstract

We compared performances on a learning task in which students ( $N=81$ ) viewed a pedagogical multimedia document without (control group) or with a readymade graphic organizer (readymade group) with performances on an active learning task where students self-generated a graphic organizer either totally (total self-generated group) or partially (partial self-generated group) while learning from the same multimedia document. According to the *generative* hypothesis, asking students to actively engage in the construction of a graphic organizer enhances their learning, owing to the generative processes (selection, organization, integration) required to perform the task. However, according to the *cognitive load* hypothesis, generating a graphic organizer can hinder students' learning, owing to the extraneous processing elicited by the task. It can nonetheless be assumed that if scaffolding is provided to students in the shape of an empty graphic organizer to fill in, these negative effects can be avoided. Results confirmed the beneficial effect of providing a graphic organizer on students' retention of the elements contained in the multimedia document (macrostructure information, hierarchical relations). Evidence in favor of the cognitive load hypothesis and against the generative hypothesis was found, as students in the total self-generated group performed more poorly on the retention and transfer tests than those in the readymade group. This negative effect on learning ceased to be observed when scaffolding was provided to students in the partial self-generated group, although they still spent more time on the document than those in the readymade group. Overall, we failed to observe any beneficial effect of generation on learning.

**Keywords** Graphic organizer · Cognitive processes · Generative processes · Learning strategies · Cognitive load · Multimedia learning

It is often stated in educational settings that students need to be *active* in order to learn effectively. In a computer-based learning environment, various instructions can be used to turn students into active learners (see Fiorella and Mayer 2016 for a review). One common

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instruction is to ask students to reproduce the document's pedagogical content in another, more meaningful format (i.e., by generating a drawing, graphic organizer or outline). However, it is still not clear how generative activities influence students' learning. It is critical to investigate the effects of readymade versus self-generated graphic organizers on students' retention and comprehension, as research indicates that these organizers enhance students' learning performance (Vekiri 2002), although very few students generate graphic organizers by themselves to improve their learning (e.g., Daher and Kiewra 2016; Fiorella and Mayer 2017; Lonka et al. 1994). We therefore assessed the effects of an active learning task on students' learning performance by asking them to totally or partially generate a graphic organizer while reading a multimedia document. We compared the performances of these two active learning groups with those of a group where students saw a readymade graphic organizer.

## Theoretical background: cognitive theory of multimedia learning

When dealing with a multimedia document composed of texts and illustrations, learners have to go through several steps in order to achieve a good understanding of it. A well-known and widely used model in educational psychology, that describes these different steps, is Mayer's *cognitive theory of multimedia learning* (2001, 2005, 2009, 2014). This model draws on three critical assumptions about the human cognitive system. First, based on Paivio's *dual coding* theory (1986), Mayer states that information can be processed via two separate channels, each encoding a specific type of information: visual/pictorial or auditory/verbal. Second, humans have only limited cognitive capacity in terms of the cognitive resources that can be allocated to information processing. Therefore, if a pedagogical document is badly designed, students' cognitive resources are wasted on irrelevant processes, leaving fewer resources for processing the presented information in depth. Mayer refers to these irrelevant processes as *extraneous processing*, which he defines as the "cognitive processing that does not support the instructional goal and is caused by poor instructional design", and which therefore has to be avoided (Mayer 2014, p. 59). The third and final assumption concerns *active processing*. According to Mayer, students need to engage in three critical cognitive processes if they are to achieve a good understanding of the information being presented. Students need to select the relevant information from a given document (*selecting* process), organize this information into coherent mental models in working memory (*organizing* process) and integrate these mental models with prior knowledge retrieved from long-term memory (*integrating* process).

This last assumption is reminiscent of the *select, organize, associate, regulate* (SOAR) method (Jairam and Kiewra 2010; Kiewra 2004), and is further emphasized in the *select-organize-integrate* (SOI) model of generative learning (Fiorella and Mayer 2015, 2016; Mayer 1996). Moreover, these cognitive processes are closely linked to Wittrock's model of *generative comprehension* (1989, 1991). This author claims that learning with understanding is a generative process that involves the reader's active generation of relational links between different parts of the text and between the text and his/her prior knowledge (1989, 1991). Moreover, these models can be related to the construction-integration model (see Kintsch 1988, 1998; Kintsch and van Dijk 1978; van Dijk and Kintsch 1983), which describes three levels of mental representation: surface structure, propositional text-base, and situation model. At the situation model level, the text's information is related to the learner's prior knowledge, which allows inferences to be drawn. In this model, the

*construction* step refers to the activation of both information from the text and the learner's prior knowledge (relevant and irrelevant). In the *integration* step, an activation spreading mechanism allows the learner to inhibit nonrelevant information and integrate relevant information to create a high-quality mental model (for a more detailed description, see McNamara and Magliano 2009).

All these models underline the critical aspects of selecting relevant items of information and relating them to each other (e.g., Kendeou et al. 2014; Kintsch and van Dijk 1978). Semantic relations are critical for learning, as they allow learners to construct a mental representation of the text's structure (see McCrudden et al. 2007, 2009). However, extracting relevant information can be particularly difficult for learners when the text is expository (e.g., Britt et al. 2014). As novice learners may have difficulty extracting macrostructure information from a text, guidance can be provided in order to facilitate this process.

One of the eight learning strategies identified by Fiorella and Mayer (2015) as promoting generative learning is *mapping* (see also Fiorella and Mayer 2017). This strategy consists in converting the presented text into a spatial arrangement of words that are linked together, as with the generation of a graphic organizer (2015). Mapping is thus regarded as an *organizational* strategy, as students need to turn the material into a more meaningful form (e.g., Amadiou and Tricot 2015; Weinstein 1987; Weinstein et al. 2011). If students are asked to generate a graphic organizer, it should not only engage them in a selecting process, insofar as they have to select the relevant information to include in the graphic organizer, but also in an organizing process, as they have to build hierarchical relations between the relevant items of information included in the organizer. However, while this generative activity (i.e., creation of a graphic organizer) can promote students' active involvement in learning and enhance their understanding (i.e., *generative hypothesis*) it can also require considerable effort from them in the process (i.e., *cognitive load hypothesis*). Thus, if this task appears too difficult for students and demands too many cognitive resources, it may have a detrimental effect and impair learning by increasing extraneous processing and consuming students' limited cognitive resources.

## Viewing versus self-generating a graphic organizer while learning from a multimedia document

*Graphic organizers* are defined as "spatial arrangements of words intended to represent the conceptual organization of a text" where "relations among elements are indicated by the spatial arrangements of the elements on the page, and the graphic organizer represents the conceptual organization of a text" (Stull and Mayer 2007, p. 810). A graphic organizer added to a multimedia document can therefore be regarded as a visual aid that shows the learner the main items of information in the text and the hierarchical relations between these items. Numerous studies have yielded evidence that graphic organizers benefit learning (e.g., Kiewra et al. 1999; Robinson and Kiewra 1995; Robinson and Schraw 1994). For instance, Robinson and Schraw (1994, Exp. 1) showed that learning from a text followed by a graphic organizer, as opposed to learning from a text followed by the same text, improves students' retention of interconcept relations. For their part, Robinson and Kiewra (1995; Exp.1) found that adding graphic organizers to a text induced students to learn more coordinate relations.

These positive effects were further emphasized in a study conducted by McCrudden et al. (2009), who reported that students learning a text followed by a specific graphic

organizer (i.e., causal diagram) achieved higher transfer scores and holistic causal comprehension scores than those learning the text followed by the same text. The benefits of adding a graphic organizer to a multimedia document, demonstrated by these studies, can be explained by the fact that, by acting as a visual aid, the graphic organizer greatly facilitates the selecting and organizing processes required by students for a good understanding of the document. Nevertheless, when learners have access to a readymade graphic organizer, they do not have to select and organize the information it contains by themselves.

Learners can be forced to become actively engaged in the selecting and organizing processes by instructing them to self-generate a graphic organizer for all the information presented in the document they have to read. In a study conducted by Colliot and Jamet (2018a), students had to learn from a multimedia document either by viewing the document on its own (control group), by viewing an author-provided graphic organizer presented statically throughout the document or step-by-step alongside it (static readymade group and sequential readymade group), or by self-generating a graphic organizer while reading the document (self-generated group). In line with reports of positive effects of graphic organizers in the literature, Colliot and Jamet found that adding an author-provided graphic organizer enhanced students' learning performances, compared with those of a control group. By contrast, their study showed that self-generating a graphic organizer, as opposed to viewing a readymade one, hindered students' retention scores for elements represented in the graphic organizer (macrostructure information and hierarchical relations). The generative activity also hindered their comprehension performance, as measured through transfer questions. Results were the same when the graphic organizer was replaced with a hierarchical outline (Colliot and Jamet 2018b).

These recent results extended those obtained by Stull and Mayer (2007). In their study, students either viewed the document only, viewed the document accompanied by 27 author-provided graphic organizers, or self-generated several graphic organizers while learning from the document. The authors reported a detrimental effect of the generative activity on students' learning performances regarding transfer scores. No difference was observed for the retention test. These results therefore supported the cognitive load hypothesis whereby generating a graphic organizer hinders students' learning because of the extraneous processing induced by the task, and went against the generative hypothesis whereby this generative activity promotes active learning by fostering students' engagement in generative processes and deep learning.

If the generative task of constructing an entire graphic organizer requires too much effort from the students, it can be made easier with scaffolding. Instead of asking students to generate a whole graphic organizer, they can be asked to fill in an empty one. Stull and Mayer (2007) did just this in their second and third experiments, where students had to complete 18 or 10 graphic organizer templates. Although the detrimental effects still appeared on transfer problems for the self-generated group, favoring the cognitive load hypothesis, these negative effects may have been due to the high number of graphic organizers used in the study. This may have prevented students from having a single representation of all the main items of information in the text and their interconnections to rely on. In a more recent study conducted by Ponce and Mayer (2014), students either received the text alone (control group), a text with highlighted keywords, a text where students had to highlight the keywords themselves, a text accompanied by a readymade graphic organizer, or a text where students had to fill in an empty graphic organizer. Results showed that any study aids added to the text improved students' performances on a memory test, but the two graphic organizer groups outperformed the three other groups on the summary test. Furthermore, contrary to the results obtained by Stull and Mayer (2007) and consistent

with Ponce and Mayer's interactivity hypothesis, students who actively filled in the graphic organizer scored higher on the memory test than those who were provided with a ready-made graphic organizer. Moreover, mapping can be a challenging activity for less experienced learners (Hilbert and Renkl 2008). Hence, Gurlitt and Renkl (2008, 2010) showed that less experienced learners benefit more from a mapping task where they only have to label lines that are already provided, instead of having to create the lines as well as label them. Thus, a less demanding task can be more beneficial for students' learning performances than a more demanding one (see also Chang et al. 2001).

## Overview of the present study

As previous observations of students' learning when they were asked to perform a generative activity had yielded mixed results, we set out to deepen current knowledge about the effects of one specific generative activity (i.e., generating a graphic organizer) on aspects of students' learning performances. The purpose of the present study was therefore to compare the effects on students' learning of a learning task, where students viewed a multimedia document accompanied by a readymade graphic organizer (readymade group), and an active learning task, where students were asked to self-generate a graphic organizer either totally (total self-generated group) or partially (partial self-generated group). The present study also aimed to extend previous findings on the effects of graphic organizers on learning obtained in nondigital learning environments.

Based on the literature, and given that graphic organizers facilitate selection and organization processes by showing the main ideas in the text and their interrelations, our first hypothesis was that adding a readymade graphic organizer to a multimedia document improves students' learning performance, compared with those of controls who view the same multimedia document on its own (i.e., text only group). We therefore predicted that the readymade group would outperform the control group on a retention test for elements represented in the graphic organizer, namely macrostructure information (Hypothesis 1a) and hierarchical relations (Hypothesis 1b), as well as on a transfer test (Hypothesis 1c). An additional prediction was that the control group would spend less time on the overall document than the readymade group (Hypothesis 1d). On top of reading the text, students in this group would need to process the graphic organizer and relate the information it contained to the pedagogical document.

In the light of previous studies showing that totally self-generating a graphic organizer impairs learning, compared with using a readymade one (e.g., Colliot and Jamet 2018a; Stull and Mayer 2007), we predicted that the readymade group would outperform the total self-generated group on the retention of elements represented in the graphic organizer, namely macrostructure information (Hypothesis 2a) and hierarchical relations (Hypothesis 2b). In accordance with the cognitive load hypothesis, we also expected the readymade group to perform better than the total self-generated group on the transfer test (Hypothesis 2c). The total self-generated group would also spend more time on the document, owing to the generative activity (Hypothesis 2d) and would report greater perceived difficulty of the learning material (Hypothesis 2e). No hypothesis was formed concerning comparisons between the control group and the total self-generated group, owing to confounded effects (GO and generation).

When the generative task was simplified by only asking students to fill in the empty boxes of a graphic organizer (i.e., partial self-generated group), we assumed that these

students would be more deeply engaged in selection and organization processes, leading them to exhibit better learning performances than the readymade group on the retention test for elements represented in the graphic organizer, namely macrostructure information (Hypothesis 3a) and hierarchical relations (Hypothesis 3b). We also expected them to achieve higher transfer scores (Hypothesis 3c), owing to the reduction in extraneous processing and the expected increase in generative processes (generative hypothesis).

Finally, we formed hypotheses regarding the learning performances of students in the total self-generated group compared with those in the partial self-generated group. With the decrease in extraneous generation constraints, we expected the partial self-generated group to have more cognitive resources to allocate to deep information processing, and therefore predicted that they would achieve higher retention scores than the total self-generated group for the elements represented in the graphic organizer, namely macrostructure information (Hypothesis 4a) and hierarchical relations (Hypothesis 4b), as well as higher transfer scores (Hypothesis 4c). We also expected them to spend less time than the total self-generated group on the overall document (Hypothesis 4d) and to report less perceived difficulty (Hypothesis 4c).

## Method

### Participants

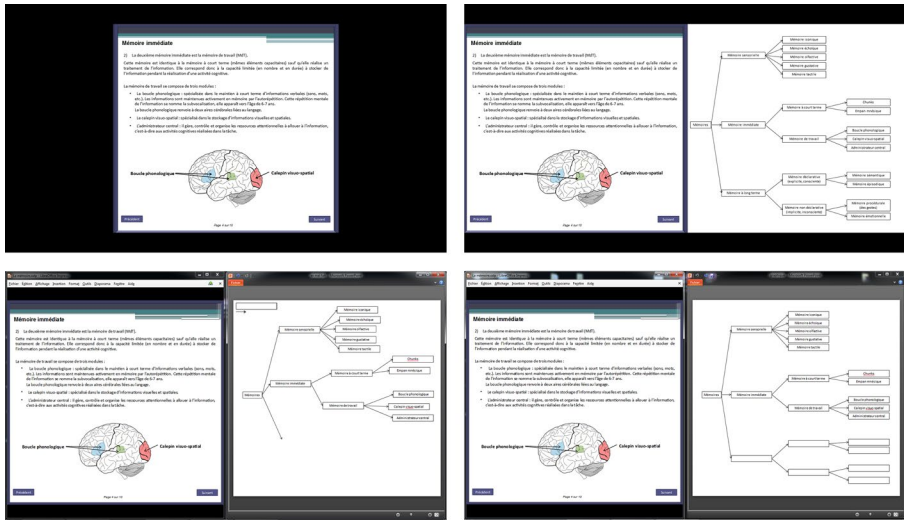
A total of 81 French psychology undergraduates (72 women, 9 men; mean age = 19.88,  $SD = 1.59$ ) took part in the study on a voluntary basis. The experiment was conducted in accordance with the principles of the Declaration of Helsinki. An informed consent form was given to all the participants. All of them agreed to the study conditions described in the informed consent form and signed it. The participants were randomly assigned to one of the four conditions of the study (see Fig. 1). Two of the groups either viewed a multimedia document on its own (control group,  $n = 20$ ) or with a readymade graphic organizer (readymade group,  $n = 20$ ). The two other groups were asked to generate a graphic organizer while reading the same multimedia document, either totally (total self-generated group,  $n = 20$ ) or partially (partial self-generated group,  $n = 21$ ).

To ensure that they were novice learners, all participants completed a pretest probing their prior knowledge about the topic of the study. This pretest comprised five open-ended questions with a total possible score of 8 points. As none of the participants scored more than 50% on the test, none had to be excluded from the analyses ( $M = 44\%$ ,  $SD = .72$ ). The choice of this criterion was based on Jamet (2014). No significant difference was observed on this pretest,  $F(3, 77) = .763$ ,  $p = .518$ .

### Computer-based learning environment (CBLE)

#### Video tutorials

Four video tutorials, each using the same pedagogical content, were created for the four groups. Two of these tutorials showed students a multimedia document about the phases of mitosis either with (readymade group; duration: 3 min 32 s) or without (control group; duration: 3 min 27 s) a readymade graphic organizer. The other two tutorials showed the self-generated groups how to use the editing tool to create (total self-generated group;



**Fig. 1** Screenshots of the displays for the control group (top left), readymade group (top right), total self-generated group (bottom left), and partial self-generated group (bottom right)

duration: 4 min 7 s) or complete (partial self-generated group; duration: 3 min 56 s) the graphic organizer.

**Learning material**

The learning material consisted of an introductory slide, an instruction slide, nine to-be-learned content slides, and a final slide where students could click on a button to proceed to the learning test or another one to review the content slides. Each content slide comprised an explanatory text (150–200 words) dealing with the different human memory systems and their functioning, and a schematic picture illustrating the location of these memory systems in the brain. Together, the content slides totaled 1500 words and nine schematic pictures. Depending on the condition, the multimedia document was either centered onscreen (control condition) or on the left of the screen, with either the readymade graphic organizer or an editing tool enabling the two self-generated groups to create or complete the graphic organizer on the right (see Fig. 1).

The graphic organizer represented the three-level hierarchical structure of the multimedia document. It contained 21 labels (macrostructure information; 3 labels at Level 1, 9 at Level 2, and 9 at Level 3) and 21 links (i.e., hierarchical relations). Students in the total self-generated group had to click and drag empty boxes, located at the top of the editing tool window, to create the graphic organizer structure. They also had to type items of macrostructure information in these empty boxes and link these items with arrows they had to drag and drop between the boxes. The partial self-generated group had to fill in an empty graphic organizer that already featured the document’s hierarchical structure. Students in this group only had to type macrostructure information in the empty boxes. For each group, the learning material was learner-paced, with each slide featuring a Previous and a Next button. For the final slide, students had the choice between clicking on a Previous button or clicking on a button to go to the learning test. No cues were given to students for creating

or completing the graphic organizer, meaning that they had to identify the main ideas to include in the organizer on their own.

## Measures

### Prior knowledge test and demographic data

Before viewing the document, participants were first asked to complete a pretest assessing their prior knowledge about the different human memory systems and how they function. Students answered five open-ended questions (e.g., “What is the span of short-term memory?”) with a total possible score of 8 points. The scoring of each question depended on the expected number of answers. For each participant, we summed the points earned for each question (range 0–8). We then calculated the mean total score for each group. This test also collected demographic data (age and sex).

### Perceived difficulty of the learning document

After the learning phase, students were asked to rate three items (“Learning with this document was difficult”, “It was difficult to learn with this document”, “I found that learning with this document was hard”) probing the perceived difficulty of the learning material on a 9-point Likert-like scale ranging from 1 (*Do not agree at all*) to 9 (*Totally agree*). For each participant, we averaged the ratings of the three items (range 1–9). We then calculated the mean perceived difficulty for each group. These items were adapted from several studies (e.g., DeLeeuw and Mayer 2008; Moreno et al. 2010; Moreno and Valdez 2005; Paas 1992). Cronbach’s alpha for this scale ( $\alpha = .895$ ) suggested very good internal consistency and reliability.

### Learning test

The learning test comprised 45 questions divided into two parts: a retention test composed of 39 open-ended questions; and a transfer test composed of six transfer problems. We calculated the total number of points scored on each test and the mean score for each group. Each question in the learning test was scored 1 point for a correct answer (min = 0, max = 45). The 39 questions in the retention test were divided up as follows:

- Represented information: 19 open-ended questions about the information contained in the organizer.
  - Macrostructure, namely the main ideas in the text (12 questions, e.g., “Which kind of memory stores our procedural knowledge and motor skills?”; score range 0–12),
  - Hierarchical relations between these main ideas (7 questions, e.g., “Declarative memory is made up of how many parts?”; score range 0–7) These questions assessed students’ retention of the general organization of the content,
- Nonrepresented information: 20 questions about the information that was not contained in the organizer.
  - Microstructure, namely the details of the text, (12 open-ended questions, e.g., “How long is information stored on average in short-term memory?”; range 0–12),



- Pictorial information, illustrations contained in the document (8 multiple-choice questions, e.g., “In the picture above, which number refers to the amygdala? 1, 2, 3, 4 or Don’t know”; range 0–8).

In the six transfer problems, students had to apply what they had just learnt from the multimedia document to new situations (e.g., “Owing to brain injuries, patient HM cannot retrieve old memories and acquire new knowledge. However, his cognitive performance and his general knowledge about the world are preserved. Which declarative long-term memory is affected in this case? Which brain structure is affected in this case?”). A second researcher coded 33% of participants’ responses to check interrater reliability. The two raters agreed on 146 of these 150 answers (97.3% interrater agreement).

## Learning time

We recorded the learning time spent on the entire multimedia document for each participant. This time was measured from the point when the students each started to read the document to the point when they clicked on the “I am ready to answer the learning test” button in the final slide. When participants clicked on this button, the learning test appeared.

## Instructions

In each group, students were given the following instructions: “At the end of your reading, you will have to answer a learning test made up of questions about the information displayed in this document. You will therefore have to learn this information in order to be able to answer the learning test.” In the readymade group, students were further informed that a graphic organizer containing all the main ideas in the text would be displayed alongside the document. In the total self-generated group, students were given the following additional instructions: “While learning the information contained in the multimedia document, you will have to create a graphic organizer containing all the main ideas in the document from scratch, using the editing tool on the righthand side of the screen”. The additional instructions given to students in the partial self-generated group were slightly different: “While learning the information contained in the multimedia document, you will have to insert all the main ideas of the document in the empty boxes of a graphic organizer, using the editing tool on the righthand side of the screen.” Students in the control group did not receive any additional instructions.

The pedagogical document featured three main headings, which helped students to create the first level of the organizer. No other cues were provided in the document. In the partial self-generated group, students were also instructed to learn the information contained in the multimedia document and at the same time to identify the main ideas in the text and use them to fill in the empty boxes in the organizer that was provided.

## Procedure

Participants were first greeted and told about the different steps of the study. They were also informed of the study duration (approx. 1 h) and were told that they would have to complete a learning test focusing on information presented in a document after they had viewed it. All the participants signed a consent form before starting the study. They

then filled in the pretest collecting demographic data and their prior knowledge about the topic. Participants were randomly assigned to one of the four conditions and watched the video tutorial associated with that condition. After answering any questions they had, we launched the BBFlashBack software to record the amount of time spent on the document and the creation or completion of the graphic organizer in the two self-generated groups. Students were told that no note taking was allowed during the learning phase and no documents would be allowed when performing the learning test. After studying the multimedia document, participants provided the perceived difficulty ratings and completed the learning test. No time limit was set for any of the tests.

## Results

### Preliminary analysis

We began by running analyses of variance (ANOVAs) to test the effects of each condition on the different dependent variables. We found significant differences for both the retention test (macrostructure information, hierarchical relations and microstructure information) and the transfer test (see Table 1). Analysis also revealed a significant difference between the four groups on perceived difficulty ratings. As all our hypotheses concerned specific differences, we then conducted planned comparisons.

### Does emphasizing the text's structure with a readymade graphic organizer improve students' learning performances?

We conducted planned comparisons between the control group and the group who viewed a readymade graphic organizer alongside the document. Consistent with Hypotheses 1a and 1b, analyses revealed that the readymade group significantly outperformed the control group on the retention of elements represented in the graphic organizer: macrostructure information,  $t(77)=3.248, p=.003$ , and hierarchical relations,  $t(77)=2.808, p=.009$ . The readymade group also outperformed the control group on the retention of microstructure information,  $t(77)=2.612, p=.013$ . Moreover, students who viewed the readymade graphic organizer while learning the multimedia document scored significantly higher on the transfer test than the control group,  $t(77)=3.461, p=.001$ , thus validating Hypothesis 1c (see Table 1). Planned comparisons did not, however, confirm Hypothesis 1d, as there was no significant difference between the control group and the readymade group on the amount of time spent learning from the document,  $t(77)=.611, p=.545$ . Furthermore, no difference was found between the readymade group and the control group on perceived difficulty,  $t(77)=1.427, p=.162$ .

### Does asking students to totally self-generate a graphic organizer while reading improve their learning more than viewing a readymade graphic organizer?

Consistent with Hypotheses 2a and 2b, analyses revealed that the readymade group significantly outperformed the total self-generated group on the retention of elements represented in the graphic organizer: macrostructure information,  $t(77)=3.856, p=.001$ , and hierarchical relations  $t(77)=2.976, p=.006$ . They also outperformed the total

**Table 1** Mean scores, standard deviations and differences between the four conditions on the learning test, perceived difficulty ratings, and learning times

Retention test	Control <i>M (SD)</i>	Readymade <i>M (SD)</i>	Total self-generated <i>M (SD)</i>	Partial self-generated <i>M (SD)</i>	<i>F</i> statistic <i>df=77</i>	<i>p</i> value	$\eta^2$
<b>Represented information</b>							
Macrostructure/12	7.09 (2.82)	9.63 (1.97)	6.30 (3.44)	9.19 (2.24)	7.42	< .001	.224
Hierarchical relations/7	5.40 (1.64)	6.55 (.83)	5.45 (1.43)	6.38 (1.07)	4.53	.006	.150
<b>Non-represented information</b>							
Microstructure/12	6.85 (2.76)	8.80 (1.88)	6.45 (2.14)	8.31 (2.04)	5.23	.002	.169
Pictorial information/8	5.45 (1.93)	5.90 (1.97)	5.45 (2.35)	5.86 (1.56)	.32	.810	.012
Transfer problems/6	1.73 (1.68)	3.60 (1.70)	1.78 (1.99)	3.17 (1.58)	5.90	.001	.187
Perceived difficulty	4.18 (1.82)	3.37 (1.80)	4.60 (1.99)	3.60 (1.53)	3.26	.026	.113
Learning times (min)	18.42 (7.41)	22.28 (6.29)	31.00 (9.12)	26.70 (6.72)	10.52	< .001	.291

self-generated group on the retention of microstructure information,  $t(77)=3.690$ ,  $p=.001$ . Moreover, consistent with Hypothesis 2c, those who viewed the readymade graphic organizer performed better on the transfer test than those who had to totally self-generate a graphic organizer,  $t(77)=3.077$ ,  $p=.004$ .

Students in the total self-generated graphic organizer group spent more time on the learning document than the readymade group,  $t(77)=3.514$ ,  $p=.001$ , thus validating Hypothesis 2d. As predicted by Hypothesis 2e, analysis of the perceived difficulty ratings revealed that students in the total self-generated group rated the learning document as more difficult than those in the readymade group,  $t(77)=2.056$ ,  $p=.047$ .

### Complementary analyses

We analyzed the quality of the graphic organizers that the students totally self-generated. These qualitative analyses consisted in counting the number of main ideas contained in each organizer (out of the 21 main ideas displayed in the readymade organizer), and counting the number of correct hierarchical relations contained in each organizer. When an arrow linked two concepts in the right direction, it was coded as a correct hierarchical relation.

Qualitative analyses of the totally self-generated graphic organizers indicated that they were of a high quality, as 90% of the students correctly included all 21 main ideas. Furthermore, 85% accurately reproduced the document's hierarchical structure (hierarchical relations indicated by arrows). One of the 21 arrows was omitted by one student, and two by another student.

Regarding learning performances, when we compared the total self-generated group with the control group, we failed to find any difference on the learning test, indicating that totally self-generating a graphic organizer was neither beneficial nor detrimental to students' learning performances (all  $ps > .30$ ).

### Does asking students to partially self-generate a graphic organizer (filling in empty boxes) while reading improve their learning more than asking them to view a readymade graphic organizer?

Contrary to Hypotheses 3a and 3b, there were no significant differences between the readymade group and the partial self-generated group on the retention of elements represented in the graphic organizer, namely macrostructure information,  $t(77)=.630$ ,  $p=.532$ , and hierarchical relations,  $t(77)=.568$ ,  $p=.574$ . There were also no significant differences on the retention of elements that were not represented on the graphic organizer, namely microstructure information,  $t(77)=.763$ ,  $p=.450$ . Moreover, no differences were found on the transfer test between these two groups,  $t(77)=.897$ ,  $p=.375$ , invalidating Hypothesis 3c.

Planned comparisons failed to reveal any difference between the readymade group and the partial self-generated group on the perceived difficulty of the learning document,  $t(77)=.611$ ,  $p=.545$ . These two groups did, however, differ significantly on the amount of time spent on the document,  $t(77)=2.169$ ,  $p=.036$ , with the partial self-generated group spending more time on it than the readymade group.

## Complementary analyses

Qualitative analyses indicated that all the students in the partial self-generated group accurately filled in the empty boxes of the graphic organizer. They all inserted the 21 main ideas in the empty boxes of the organizer.

Furthermore, the partial self-generated group outperformed the control group on the same learning measures as the readymade group did. When we compared the partial self-generated group with the control group, we found significant differences on the learning test, with the partial self-generated group outperforming controls on both the retention of macrostructure information,  $t(77)=2.572$ ,  $p=.014$ , and hierarchical relations,  $t(77)=2.260$ ,  $p=.031$ . No difference was found for the retention of microstructure information,  $t(77)=1.952$ ,  $p=.059$ . Students in the partial self-generated group also outperformed the control group on the transfer test,  $t(77)=2.747$ ,  $p=.009$ .

### Is asking students to partially self-generate a graphic organizer better than asking them to totally self-generate one?

Planned comparisons were conducted between the total self-generated group and the partial self-generated group. Consistent with Hypotheses 4a and 4b, the partial self-generated group outperformed the total self-generated group on the retention of elements represented in the graphic organizer, namely macrostructure information,  $t(77)=3.242$ ,  $p=.003$ , and hierarchical relations,  $t(77)=2.348$ ,  $p=.025$ . They also achieved higher retention scores for microstructure information,  $t(77)=2.887$ ,  $p=.006$ . As predicted by Hypothesis 4c, the partial self-generated group achieved significantly higher transfer scores than the total self-generated group,  $t(77)=2.398$ ,  $p=.022$ . Contrary to Hypothesis 4d, we failed to find a significant difference between the two groups regarding the amount of time spent on the learning document,  $t(77)=1.731$ ,  $p=.092$ . Finally, consistent with Hypothesis 4e, the partial self-generated group reported less perceived difficulty of the learning material,  $t(77)=2.789$ ,  $p=.008$ , than the total self-generated group.

## Discussion

### Theoretical and empirical contributions

The present study addressed four research questions. Our first question concerned the effects of adding a readymade graphic organizer to a multimedia document. In line with previous studies, results showed that adding a graphic organizer that depicted the main items of information contained in the document and their interrelations improved students' learning performances (e.g., Robinson and Kiewra 1995; Vekiri 2002), compared with a control group who studied the multimedia document on their own. More specifically, it improved not only students' retention of the elements represented in the graphic organizer (i.e., macrostructure information and hierarchical relations), but also their retention of elements that were not represented in the graphic organizer (i.e., microstructure information). Furthermore, as indicated by the transfer scores, students who viewed the readymade graphic organizer achieved a better understanding of the document than those in the control group. These results provide further evidence of the positive effects of graphic

organizers on learning (e.g., Kiewra et al. 1999; Robinson and Schraw 1994) and extend findings about these effects in nondigital learning environments. As graphic organizers show the most important items of information and their interrelations, they greatly facilitate the selecting and organizing processes for students, acting as a visual aid for them to build a coherent mental model of the information being presented.

We were particularly interested in evaluating the effects of being behaviorally active in a learning task on students' learning performances. Hence the second research question addressed the effects of viewing a readymade graphic organizer versus totally self-generating one on students' learning. Consistent with previous studies reporting detrimental effects of self-generating a graphic organizer on learning (e.g., Stull and Mayer 2007), our results revealed that totally self-generating a graphic organizer hindered students' learning in terms of the retention of elements that were either represented (macrostructure information and hierarchical relations) or not represented (microstructure information) in the graphic organizer. Moreover, results showed that the readymade group outperformed the total self-generated group on transfer problems.

In line with the findings of Stull and Mayer (2007) and Colliot and Jamet (2018a, b), our results supported the cognitive load hypothesis but not the generative hypothesis. One possible explanation is that the generative task required too much effort from students. Therefore, as revealed by the perceived difficulty ratings, students had to expend considerable cognitive effort on performing the task and did not have enough cognitive resources left to try and make sense of the information being presented. Thus, even though complementary analyses showed that the students generated high-quality graphic organizers, they failed to benefit from them because of the task demands in terms of time requirements and perceived difficulty. Moreover, mapping strategies can be difficult to learn and implement, especially for novice learners, whose performances are particularly reliant on properly planned and controlled map construction (Hilbert and Renkl 2005, 2008). Moreover, as stated in the Introduction, extracting relevant information can be difficult when the text is expository (e.g., Britt et al. 2014). In the present study, it was difficult to distinguish between the effects stemming from text variables (regarding its inherent difficulty and its structure) and those stemming from the learners' characteristics (working memory capacity, prior knowledge about the content). Future studies will need to assess how these variables influence the generation effect.

Notwithstanding, when students are given an easier generative task where they have to self-generate a linear graphic organizer (i.e., hierarchical outline) instead of a spatial one (i.e., tree diagram), the same detrimental effects are observed on their learning performances (Colliot and Jamet 2018b). However, these results need to be viewed with caution, as no difference was found on the learning test between the control group and the total self-generated group. The total self-generation of a graphic organizer did not enhance learning compared with the control group, and significantly increased the amount of time spent learning from the document. Therefore, the control group was more efficient than the total self-generated group.

The third research question addressed the effects of viewing a readymade graphic organizer versus partially self-generating one on students' learning. When the generative task was facilitated by providing students with an empty graphic organizer to fill in, the negative effects on learning disappeared, such that the differences observed between the readymade group and the total self-generated group ceased to be significant when the readymade group was compared with the partial self-generated group. As indicated in Table 1, the learning performance of students in the partial self-generated group were very close to those of students in the readymade group on the retention and transfer tests. Thus, alleviating the

task's demands left more cognitive resources for students to deeply process the document, probably allowing them to reach the same level of understanding as those who viewed the readymade graphic organizer. Nevertheless, students in the partial self-generated group still spent more time on the learning document than those in the readymade group, without outperforming them in the learning test. Hence, contrary to the results reported by Ponce and Mayer (2014), our results do not support the notion that being actively involved in the task of completing an empty graphic organizer has a positive generation effect on learning.

The fourth and final research question compared the effects on learning of two types of graphic organizer self-generation: total self-generation versus partial self-generation. When we compared these two groups, learning outcomes revealed that alleviating the generative task by providing students with empty boxes to fill in greatly improved their performances for both represented (macrostructure information, hierarchical relations) and non-represented elements (microstructure information). The partial self-generated group also outperformed the total self-generated group on transfer problems. Furthermore, when we reduced the complexity of the task, the former reported less perceived difficulty than the latter. These results indicate that the scaffolding we used effectively reduced the extraneous processing induced by the task, but not sufficiently to foster generative processes.

### Limitations and future directions

In the present study, students had to generate a graphic organizer while reading a multimedia document. This experimental context may have generated a double-task situation, as students needed not only to learn the document but also to self-generate a graphic organizer. The detrimental effects of self-generation reported in the literature may be due to this double-task situation. Here, contrary to our hypotheses, even if generation was facilitated by providing students with an empty graphic organizer, no positive effects of the active learning task were observed. Moreover, qualitative analyses indicated that students self-generated high-quality graphic organizers and did not report higher perceived difficulty in the partial self-generated condition. Therefore, the absence of results may stem not from the efforts required by the task, but from the double-task situation that was induced. Students may have been too focused on the generation task to try and make sense of the material that was presented. Therefore, future studies should endeavor to separate the generation task from the learning task. This could be done by asking students to complete the graphic organizer first, and then to learn the multimedia document. Another possible explanation is that students were not active enough in the self-generative task. When students were asked to totally self-generate a graphic organizer, the task required too much effort from them (drag and drop the boxes, the arrows, etc.) and consequently hindered their learning. By contrast, when they were asked to fill in an empty graphic organizer (partial self-generated group), the task proved to be easy and not sufficiently engaging, as it simply required them to print the main items of information contained in the text in the empty boxes. This active task may not have involved the students sufficiently in the generative processes, as they may just have copied the information into the boxes without trying to use and make sense of the graphic organizer they were generating. Thus, future studies should avoid this possible lack of students' engagement in the task by preventing them from simply copying the information from the text. This could be done by asking them to generate a graphic organizer without having the text alongside it.

Moreover, it is critical to distinguish cognitive engagement from behavioral engagement (Mayer 2014). Students can behaviorally engage in the learning task by creating a visual

aid (Fredericks et al. 2004; Skinner and Belmont 1993), but this does not mean that they are cognitively engaged in the deep processing of information and in self-regulated learning strategies (Fredricks et al. 2004; Fredricks and McColskey 2012). Conversely, even if students seem behaviorally passive in their learning, they may be highly cognitively engaged in the learning task.

Viewing or self-generating a graphic organizer did not influence students' retention of pictorial information. This result may be due to the fact that the graphic organizers used in the present study only emphasized verbal information. Therefore, future studies should investigate the effects on students' learning performance of using graphic organizers intended to promote not only text and picture processing, but also text and picture integration. Moreover, eye-tracking technology could be used to see how students' attention is partialled out between the graphic organizer and the content slides. An eye-tracking study could allow us to measure the amount of time spent on each area of interest and the way students study the document (e.g., When do they generate or view the graphic organizer? How many transitions do they make between these areas of interest?), and to relate this information to students' learning performance.

Furthermore, the results reported here were yielded by an immediate learning test. However, it is critical to assess students' learning with a delayed learning test, as these results may change over time. We would expect students engaged in any active learning task where relatively little effort was required to perform the generative task to outperform those in a more passive learning group on a delayed learning test.

## Conclusion

To sum up, the present study extended research findings about the effects of graphic organizers on students' learning performances. It showed that (1) adding a graphic organizer to a multimedia document improves students' learning performances, (2) totally self-generating a graphic organizer, as opposed to viewing a readymade one, hinders students' learning (*cognitive load hypothesis*), and (3) when scaffolding is provided, the detrimental effects of self-generation on learning disappear, with students who partially self-generate a graphic organizer achieving the same learning performances as those who view a readymade one. On top of having no beneficial effects on learning, the generative activity also increased the overall time students spent on learning the document. Thus, although generative activities might be expected to have positive effects, the results of the present study showed no positive effects on learning of being behaviorally active by partially or totally generating a graphic organizer.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

- Amadiéu, F., & Tricot, A. (2015). Les facteurs psychologiques qui ont un effet sur la réussite des étudiants. *Recherche et Pratiques Pédagogiques en Langues de Spécialité - Cahiers de l'APLIUT*, XXXIV(2).



- Britt, M. A., Richter, T., & Rouet, J. F. (2014). Scientific literacy: The role of goal-directed reading and evaluation in understanding scientific information. *Educational Psychologist, 49*(2), 104–122.
- Chang, K. E., Sung, Y. T., & Chen, S. F. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning, 17*(1), 21–33.
- Colliot, T., & Jamet, É. (2018a). Does self-generating a graphic organizer improve students' learning? *Computers & Education, 126*, 13–22.
- Colliot, T., & Jamet, É. (2018b). How does adding versus self-generating a hierarchical outline while learning from a multimedia document influence students' performances? *Computers in Human Behavior, 80*, 354–361.
- Daher, T. A., & Kiewra, K. A. (2016). An investigation of SOAR study strategies for learning from multiple online resources. *Contemporary Educational Psychology, 46*, 10–21.
- DeLeeuw, K. E., & Mayer, R. E. (2008). A comparison of three measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load. *Journal of Educational Psychology, 100*(1), 223–234.
- Fiorella, L., & Mayer, R. E. (2015). *Learning as a generative activity: Eight learning strategies that promote understanding*. Cambridge: Cambridge University Press.
- Fiorella, L., & Mayer, R. E. (2016). Eight ways to promote generative learning. *Educational Psychology Review, 28*(4), 717–741.
- Fiorella, L., & Mayer, R. E. (2017). Spontaneous spatial strategy use in learning from scientific text. *Contemporary Educational Psychology, 49*, 66–79.
- Fredricks, J. A., & McColskey, W. (2012). The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. *Handbook of research on student engagement* (pp. 763–782). Boston: Springer.
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109.
- Gurlitt, J., & Renkl, A. (2008). Are high-coherent concept maps better for prior knowledge activation? Differential effects of concept mapping tasks on high school vs. university students. *Journal of Computer Assisted Learning, 24*(5), 407–419.
- Gurlitt, J., & Renkl, A. (2010). Prior knowledge activation: How different concept mapping tasks lead to substantial differences in cognitive processes, learning outcomes, and perceived self-efficacy. *Instructional Science, 38*(4), 417–433.
- Hilbert, T. S., & Renkl, A. (2005). Individual differences in concept mapping when learning from texts. In B. G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the 27th annual conference of the Cognitive Science Society* (pp. 947–952). Mahwah, NJ: Erlbaum.
- Hilbert, T. S., & Renkl, A. (2008). Concept mapping as a follow-up strategy to learning from texts: What characterizes good and poor mappers? *Instructional Science, 36*(1), 53–73.
- Jairam, D., & Kiewra, K. A. (2010). Helping students soar to success on computers: An investigation of the SOAR study method for computer-based learning. *Journal of Educational Psychology, 102*(3), 601–614.
- Jamet, E. (2014). An eye-tracking study of cueing effects in multimedia learning. *Computers in Human Behavior, 32*, 47–53.
- Kendeou, P., Van Den Broek, P., Helder, A., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research & Practice, 29*(1), 10–16.
- Kiewra, K. A. (2004). *Learn how to study and SOAR to success*. Upper Saddle River: Prentice Hall.
- Kiewra, K. A., Kauffman, D. F., Robinson, D., DuBois, N., & Staley, R. K. (1999). Supplementing floundering text with adjunct displays. *Journal of Instructional Science, 27*, 373–401.
- Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review, 95*(2), 163–182.
- Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York: Cambridge University Press.
- Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*(5), 363–394.
- Lonka, K., Lindblom-Ylänne, S., & Maury, S. (1994). The effect of study strategies on learning from text. *Learning and Instruction, 4*(3), 253–271.
- Mayer, R. E. (1996). Learning strategies for making sense out of expository text: The SOI model for guiding three cognitive processes in knowledge construction. *Educational Psychology Review, 8*(4), 357–371.
- Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.
- Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 3–48). New York: Cambridge University Press.

- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press.
- Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 43–71). New York: Cambridge University Press.
- McCrudden, M. T., Schraw, G., Lehman, S., & Poliquin, A. (2007). The effect of causal diagrams on text learning. *Contemporary Educational Psychology*, 32(3), 367–388.
- McCrudden, M. T., Schraw, G., & Lehman, S. (2009). The use of adjunct displays to facilitate comprehension of causal relationships in expository text. *Instructional Science*, 37(1), 65–86.
- McNamara, D. S., & Magliano, J. (2009). Toward a comprehensive model of comprehension. *Psychology of Learning and Motivation*, 51, 297–384.
- Moreno, R., & Valdez, A. (2005). Cognitive load and learning effects of having students organize pictures and words in multimedia environments: The role of student interactivity and feedback. *Educational Technology Research and Development*, 53(3), 35–45.
- Moreno, R., Reislein, M., & Ozogul, G. (2010). Using virtual peers to guide visual attention during learning: A test of the persona hypothesis. *Journal of Media Psychology*, 22(2), 52–60.
- Paas, F. G. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, 84(4), 429–434.
- Paivio, A. (1986). *Mental representations: A dual-coding approach*. Oxford: Oxford University Press.
- Ponce, H. R., & Mayer, R. E. (2014). An eye movement analysis of highlighting and graphic organizer study aids for learning from expository text. *Computers in Human Behavior*, 41, 21–32.
- Robinson, D. H., & Kiewra, K. A. (1995). Visual argument: Graphic organizers are superior to outlines in improving learning from text. *Journal of Educational Psychology*, 87(3), 455–467.
- Robinson, D. H., & Schraw, G. (1994). Computational efficiency through visual argument: Do graphic organizers communicate relations in text too effectively? *Contemporary Educational Psychology*, 19, 399–415.
- Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, 85(4), 571–581.
- Stull, A. T., & Mayer, R. E. (2007). Learning by doing versus learning by viewing: Three experimental comparisons of learner-generated versus author-provided graphic organizers. *Journal of Educational Psychology*, 99(4), 808–820.
- Van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension* (pp. 11–12). New York: Academic Press.
- Vekiri, I. (2002). What is the value of graphical displays in learning? *Educational Psychology Review*, 14(3), 261–312.
- Weinstein, C. E. (1987). Fostering learning autonomy through the use of learning strategies. *Journal of Reading*, 30(7), 590–595.
- Weinstein, C. E., Acee, T. W., & Jung, J. (2011). Self-regulation and learning strategies. *New Directions for Teaching and Learning*, 2011(126), 45–53.
- Wittrock, M. C. (1989). Generative processes of comprehension. *Educational Psychologist*, 24(4), 345–376. [https://doi.org/10.1207/s15326985ep2404\\_2](https://doi.org/10.1207/s15326985ep2404_2).
- Wittrock, M. C. (1991). Generative teaching of comprehension. *The Elementary School Journal*, 92(2), 169–184.

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