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Does an interactive table of contents promote learning from videos? A study on learning outcomes and behaviors

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Title:

**Does an interactive table of contents promote learning from videos? A study on
learning outcomes and behaviors**

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4 of the Declaration of Helsinki.
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Does an interactive table of contents promote learning from videos? A study on learning outcomes and behaviors

Practitioner Notes

What is already known about this topic:

- Pedagogical videos are increasingly used for learning
- According to the Cognitive Theory of Multimedia Learning, organizing incoming information is essential in learning
- In written documents, the presence of a table of contents may be seen as an organizational aid
- During information seeking tasks, interactivity of the table of contents improves localization

What this paper adds:

- Adding a table of contents in a video may promote topic recall but no content learning
- Interactive table of contents may enhance learning behaviors (such as information reviews)
- Learners mainly used the timeline, not the table of contents, to navigate the video

Implications for practice:

- When designing a pedagogical video, adding an interactive table of contents may enhance the quality of learning
- Different strategies seem to be employed by learners, some of them don't make any reviewing behavior
- Learners may underestimate the usefulness of the table of contents, so it may be necessary to encourage learners using it

Highlights:

- We studied the effect on video learning of adding a table of contents, whether it is interactive or not
- Tables of contents promoted topic recall but had no effect on content learning
- Analysis showed that interactive table of contents helped learners locate information
- Learners mainly used the timeline, not the table of contents, to navigate the video

Abstract:

Learning from videos is becoming an important part of educational activities, but video content may be difficult to process, mainly because its organization is not very salient in this medium. The learner's organization process should be enhanced by 1) displaying the structure (i.e., table of contents) in the video-based environment, and 2) proposing interactivity tools (interactive table of contents and cued timeline) to use this structure in a more efficient way. A total of 57 participants were divided into three groups (no table of contents, table of contents, and interactive table of contents) to assess the effects of displaying a structure on learning outcomes and behaviors. Results showed that tables of contents boosted topic recall, and interactivity allowed learners to perform more relevant reviewing behaviors. However, reviewing behaviors appear to be broadly timeline-driven, and learners did not actively use the interactive table of contents. No significant effect was found on other learning outcomes (i.e., content memorization and comprehension). One suggestion is that a table of contents, especially when it is interactive, can be an organizational aid during the construction of a mental model, but learners may underestimate its usefulness.

Keywords: learning, video, table of contents, interactivity, behaviors

1. Introduction

Nowadays, videos are widely used for learning purposes and are a very common presentation method (Delen et al., 2014), on massive open online courses (MOOC) platforms (Schacter & Szpunar, 2015; Yadav et al., 2015) or in flipped classrooms context (Haagsman et al., 2020; van der Meij & Böckmann, 2020) for example. According to Giannakos, Jaccheri, and Krogstie (2014), the number of studies of learning in video-based environments has grown continually since 2003. Many studies have focused on procedural learning (e.g., Arguel & Jamet, 2009; Ganier & de Vries, 2016; Schwan & Riempff, 2004), showing that learning can be enhanced by a video format, but also that a more classic presentation (i.e., printed or illustrated documents) can sometimes be better (Merkt et al., 2011).

Current design tools allow tables of contents to be inserted into video-based environments (Merkt & Schwan, 2014), but this type of presentation is still rare-as is research about it. Moreover, to our knowledge, previous studies have mainly focused

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3 on learning outcomes, and far less on learning behaviors during learning such as
4 reviewing clicks. Therefore, it is critical to understand how learners process
5 information, if video-based environments are to be adapted so that they foster learning.
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8 **1.1. Learning with tables of contents**

9 **1.1.1. Multimedia learning**

10 Mayer (2014b) defines multimedia learning as the construction by individuals of
11 mental representations from words (printed or oral) and pictures (e.g., illustrations,
12 videos). According to his cognitive theory of multimedia learning (CTML; Mayer,
13 2014a), learning is a sense-making activity, in which the multimedia material serves as
14 a cognitive aid. Three central consecutive processes are described in the CTML. The first
15 process is the **selection** of relevant information, where the learner needs to identify
16 which information is important in the educational document. Second, the learner must
17 **organize** the selected information into verbal and pictorial models in working memory.
18 Third, these models are **integrated** with the learner's prior knowledge to elaborate a
19 mental model. Moreover, the CTML makes three assumptions: 1) each learner has two
20 separate channels for processing verbal/auditory or pictorial/visual information; 2) only
21 a limited amount of information can be processed in each channel at any one time; and
22 3) the learner needs to actively engage in the processes to select the relevant incoming
23 information, organize it into mental representations, and integrate these
24 representations with prior knowledge. Thus, the construction of a mental model of the
25 studied document is a central notion in the CTML.
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40 The notion of *mental model* is common to several learning models (e.g., Kintsch,
41 1998; Mayer, 2014a; Narayanan & Hegarty, 1998; Schnotz, 2014). According to Doyle
42 and Ford (1998)'s definition, a mental model is an internal representation of an external
43 system. It contains the key parts or steps of this system, as well as the links between
44 its different elements (Mayer, 2014a). In the context of learning in a video-based
45 environment, the video content can be regarded as the studied system. The quality
46 and relevance of the learner's mental model have impact on comprehension and
47 memorization performances. Comprehension is directly linked to the construction of a
48 relevant mental model (Hegarty, 2014; Mayer, 2014b), while memorization consists of
49 information storage and retrieval by the learner. According to the CTML (Mayer,
50 2014a), the incoming information is selected, organized and integrated into a mental
51 model. Then, easily recover the information in memory, which means having good
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3 performance in a memorization task, should imply the learner to retrieve information
4 previously organized. To conclude, comprehension and memorization performances
5 depend on the quality of the mental model and the steps taken to build it.
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8 According to the literature, adding a table of contents could be a way to facilitate
9 the processes of organization since it emphasizes the content's structure (de Koning
10 et al., 2009; Glynn & di Vesta, 1977). However, many studies have been led on such
11 aids inserted in a text whereas they can also be used in video-based environments (de
12 Koning et al., 2009; Wang et al., 2020).
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17 **1.1.2. Tables of contents as organizational signals**

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19 Tables of contents, or outlines, are generally considered under the more general
20 term of "signals", including also headings, overviews or summaries (Lemarié et al.,
21 2008). Concerning headings, their effect inside a written text has already been
22 explored in many studies (e.g., Loman & Mayer, 1983; Lorch et al., 2011, 2013; Mayer
23 et al., 1984, Experiment 2; Sanchez et al., 2001). Their presence has generally been
24 found to help learners recall more topics covered in the document. In studies
25 conducted by Krug and collaborators (1989), headings and tables of contents' effects
26 were distinguished. In two experiments, both headings and tables of contents had
27 positive effect on memorization (for similar results on memorization and
28 comprehension, see also Colliot & Jamet, 2018). In a third experiment, the authors
29 showed that tables of contents are particularly efficient on content's organization
30 knowledge, while learning therefore particularly depends on how well the incoming
31 information is organized (Mayer, 2014a). More, according to Amadiou and Salmerón
32 (2014), in a hypertext environment, the presence of an organizational overview (i.e.,
33 concept map) can facilitate the elaboration of learners' mental models and their
34 navigation through the document.
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46 **1.2. Tables of contents in videos**

47 **1.2.1. Specificities of video format**

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49 According to the literature, the video format may be better for learning than static
50 pictures (e.g., Arguel & Jamet, 2009; Ayres et al., 2009; Höffler & Leutner, 2007), but
51 the general superiority of video over other formats is debatable (Merkt et al., 2011),
52 and it can have either no positive effect or even a negative one (e.g., Ganier & de
53 Vries, 2016; Michas & Berry, 2000, Experiment 1). One major advantage of videos is
54 that they can represent temporal change via dynamic content (Lowe & Schnotz, 2014;
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3 van der Meij & van der Meij, 2014). A meta-analysis conducted by Höffler and Leutner
4 (2007) therefore showed a general benefit of animated content over static pictures.
5 Furthermore, videos are usually accompanied by oral information (van der Meij & van
6 der Meij, 2014). As we saw in the previous section, according to the CTML (Mayer,
7 2014a; see also Paivio, 1990), learners have two distinct but parallel cognitive
8 channels for processing verbal/auditory or pictorial/visual information. As each channel
9 has a limited capacity, presenting information that elicits both channels, instead of
10 relying on just one, may increase available working memory capacity (Kalyuga et al.,
11 1999; Low & Sweller, 2014). However, the benefits of video may not outweigh the
12 specific disadvantages of this format. First, the transitory aspect of the information that
13 is delivered may be too demanding for learners' cognitive capacity (Bétrancourt et al.,
14 2003; Doolittle et al., 2015; Hasler et al., 2007). Videos provide a continuous flow of
15 information that can overcome learners' processing capacities (Höffler & Leutner,
16 2007; Merkt et al., 2011). Second, in printed educational documents, understanding
17 the structure of the text (e.g., identifying topics or chapters), is essential for text
18 processing and learning, but cognitively costly for learners (Sanchez et al., 2001).
19 However, whereas it is possible to gain an overview of a printed text, the organization
20 of a video's content is neither explicit nor easy to find (van der Meij & van der Meij,
21 2014). Then, in videos, one specific constraint is the difficulty that learners have
22 accessing specific information, compared with the ease of finding a paragraph in a
23 paper document : the content is delivered in a linear way, meaning that to find a specific
24 item of information, learners have to navigate the video until they locate it (Dongsong
25 Zhang et al., 2006). For these reasons, learners have difficulty organizing the incoming
26 information. They are not aware of the video's structure and need help to navigate the
27 video at global and local levels (Cojean & Jamet, 2017). Then, the presence of a table
28 of contents presenting content's organization may be particularly useful in video-based
29 environments.

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1.2.2. Previous studies

In videos, the presence of organizational signals such as tables of contents has mostly been investigated during information-seeking activity. Overall, results are in favor of a positive impact of tables of contents. In a study by Merkt and Schwan (2014), participants who could access the table of contents and index found significantly more requested information than participants who only saw the ordinary video. Similar results were found by Cojean and Jamet (2017) when they compared information-

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3 seeking performances in video-based environments 1) with or without a table of
4 contents, and 2) with or without timeline segmentation. The presence of a table of
5 contents led to more video chapters being recalled after the task, but only the combined
6 presence of a table of contents and segmentation allowed individuals to find more
7 requested facts in the video. The authors concluded that in a video-based environment,
8 tables of contents must be accompanied by segmentation, if the efficiency of the
9 organizational signals is to be improved.

15 During learning, and when individuals can navigate through the video as they want,
16 they can choose to review specific information. This reviewing activity can be
17 considered as similar to an information-seeking task. To sum up, providing a table of
18 contents should improve the organization of incoming information. As organization is
19 a key process of the construction of a relevant mental model (Mayer, 2014a), it should
20 improve learning. Adding interactivity (i.e., control over the information that is
21 displayed; Scheiter & Gerjets, 2007) with references to the timeline (i.e., segmentation)
22 should enhance the location of specific items of information. This would be beneficial,
23 especially when learners want to review some of the information.

31 Few studies focused on learning outcomes. Research led by Merkt (Merkt et al.,
32 2011; Merkt & Schwan, 2014) compared the effects of different video formats. Overall,
33 results showed no significant difference between a video with a table of contents or an
34 index (i.e., enhanced video) and a video without (i.e., ordinary video). However, in
35 these studies, learners did not have access to the table of contents and the index on
36 the same screen as the video. When they clicked to see the signals, the video
37 disappeared. The potential issue with this separated presentation format is that it could
38 generate a split-attention effect (i.e., the individual needs to process information from
39 two separate sources and mentally integrate it). This effect is negative for learning
40 (Ayres & Sweller, 2014). In a recent study led by Li, Huang, and Tsai (2019), three
41 conditions were compared: video with no signaling devices, with heading tags in the
42 timeline, and with heading tags and a table of contents. As for studies in written
43 documents, topic recall was enhanced by structuring signals headings or headings with
44 a table of contents). However, the effect of a table of contents itself was not
45 investigated. In the same way, to our knowledge, no previous study had focused on
46 analyzing learning behaviors, especially when an interactive table of contents is
47 provided.

2. The current study

This study was designed to define the contribution of a table of contents to learning outcomes in a video-based environment. We formulated two main hypotheses: 1) interactive table of contents with associated segmentation particularly facilitates the location of information during review activities; and 2) the presence of a table of contents enhances the organization of the information selected from the video during learning, thereby improving learning outcomes. A series of predictions were made:

Hypothesis 1. Learning behaviors: Previous studies on information-seeking in videos had indicated that an interactive table of contents (i.e., with chapter segmentation in the timeline and direct access to each chapter from the table of contents) facilitates the location of information in a video-based environment (e.g., Cojean & Jamet, 2017, 2018; Merkt & Schwan, 2014). Interactive table of contents presumably encourages review behaviors. According to Nilsson and Mayer (2002), a way to estimate the efficiency of information location process is to measure the number of clicks made : fewer clicks would reflect a more relevant activity. More specifically, without any table of contents or with a noninteractive table of contents, participants would exhibit random location behaviors, making more and shorter reviews before they access the information are seeking. By contrast, participants with an interactive table of contents would make a smaller number of clicks during the review activity, reflecting more precise information location in the video (Hypothesis 1a). Moreover, participants with an interactive table of contents would spend more time on each review (i.e., after each click) than participants with a noninteractive table of contents or no table of contents at all, as the information would be a more relevant match for the information being sought (Hypothesis 1b). This means more relevant review activity.

Hypothesis 2. Learning outcomes: We predicted that participants with a table of contents would recall the topics presented in the video (i.e., overall structure and content's organization) in a more precise manner (Hypothesis 2a). As the learners' mental models would be constructed from a representation of the video's content, and especially from organization process, their learning of the document would be better in the presence of a table of contents. Participants who were given a table of contents would perform better on content memorization (Hypothesis 2b) and comprehension (Hypothesis 2c) tasks than participants with no table of contents. Also, participants with an interactive table of contents would be better at memorization (Hypothesis 2d) and

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3 comprehension (Hypothesis 2e) than participants with a noninteractive table of
4 contents, as they would be able to navigate the video more easily and have more
5 relevant reviewing activities.
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8 More, learners in video-based environments may implement non-efficient
9 strategies, such as making very few pauses (e.g., Biard et al., 2017; Hasler et al.,
10 2007). In the current study, interactions with the video (i.e., use of pause button and
11 description of reviewing activities) will be analyzed to identify strategy patterns among
12 learners.
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16 **2.1. Method**

17 **2.1.1. Participants**

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19 Participants were 57 students (45 women, 12 men; mean age = 20.06 years,
20 $SD = 2.15$). They all received a cinema ticket in exchange for their participation. The
21 experiment was conducted in accordance with the principles of the Declaration of
22 Helsinki.
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27 **2.1.2. Materials and experimental design**

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29 The video-based environment featured an 18-minute video taken from the INSERM
30 website¹. This video was about dyslexia (Moret & Hermann, 2009). It was modified to
31 create three experimental conditions. In all three conditions, learners could freely
32 navigate the video, using the timeline. The learning task was limited to 30 minutes. A
33 button next to the video allowed learners to go to the post-task questionnaire when
34 they wanted. This questionnaire probed knowledge (memorization and
35 comprehension) and topic recall.
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41 Participants were randomly divided between the conditions. In the no table of
42 contents condition ($n = 19$), the video-based environment contained the video with a
43 timeline that learners could navigate. A pause button was also available, together with
44 displays indicating the video's total duration and running time (see Figure 1). Learners
45 in the table of contents condition ($n = 19$) were given the video with a table of contents.
46 This table of contents presented the 14 chapters of the video, but it was not possible
47 for learners to click on the title to access the corresponding moments in the video (see
48 Figure 1). In the interactive table of contents condition ($n = 19$), learners could click on
49 a timeline with markers corresponding to the 14 chapters of the video (see Figure 1).
50 They could also click on a chapter in the table of contents to access it in the video.
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¹ <https://www.images.inserm.fr/fr/asset/fullTextSearch/search/dyslexie/page/1>

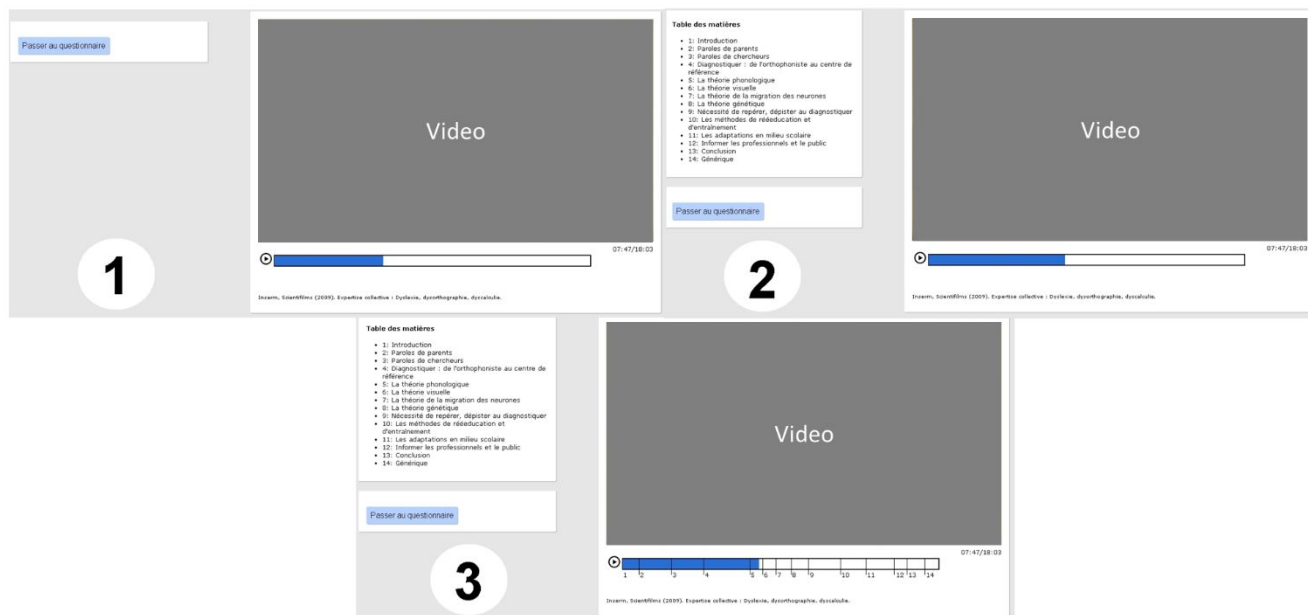


Figure 1. Screenshots of the video-based environment in the (1) no table of contents, (2) table of contents, and (3) and interactive table of contents conditions

2.1.3. Measures

Control variables

Before starting the learning task, participants were informed that the video would be about dyslexia. They were then asked to indicate on 11-point Likert scales the extent of their interest in this topic (“On a scale of 0 to 10, how interested are you in this topic?”) and their degree of perceived knowledge (“On a scale of 0 to 10, how competent do you feel on this topic?”). We used these two measures to check that interest and perceived competence were evenly distributed across the experimental conditions.

Learning behaviors

A screen recorder² was used to precisely measure the strategies employed by the participants. **Learning times** were calculated from when the learner launched the video to when he/she clicked on the post-task questionnaire button (or the pause button before going to the post-task questionnaire). Learning time was limited to 30 minutes. All the participants could make **pauses** while viewing the video. The number of times they used the pause button was also calculated. Relevance of the review activity was assessed in two ways: **number of clicks** on the timeline to retrieve information to review; and **time spent** revising each retrieved item of information. Data

² Flashback by Blueberry Software, <https://www.flashbackrecorder.com/fbhome/>

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3 were collected from the screen recorder. Review activities were defined as reviewing
4 an item of information that had already been seen.
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6 **Learning outcomes**

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8 To assess **organization recall**, participants were asked in the post-task
9 questionnaire to name the 14 topics introduced in the video. These could correspond
10 to the chapters set out in the table of contents, when available. The number of correct
11 chapters (or main ideas presented in corresponding chapters) was calculated for each
12 participant. Concerning content learning, participants had to answer 14 **memorization**
13 questions (e.g., “Are the dyslexic children part of a homogeneous group?”) and five
14 **comprehension** questions (e.g., “Some dyslexics read each word as a new one,
15 assembling the letters one by one. Others only read words by retrieving them directly
16 from the lexicon, and have a great deal of trouble reading new words. To which theory
17 does each of these behaviors correspond?”). Answers to the memorization questions
18 were explicitly supplied in the video, unlike answers to the comprehension questions.
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27 **2.1.4. Procedure**

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29 Participants were individually greeted and then seated at a desk with a computer
30 and headphones. They then completed a consent form in two copies (one for the
31 experimenter and one for the participant) that described all the measures that would
32 be carried out. A pre-task questionnaire was administered, in which participants
33 answered questions about their prior interest and perceived competence on the topic
34 of dyslexia. In the task, they were instructed to learn as much of the information
35 presented in the video as possible. The experimenter warned participants that they
36 would have a maximum of 30 minutes to learn the video, and that questions would be
37 asked at the end of the task. The screen recorder was then launched and participants
38 started whenever they wanted. A clock was available on the screen, and after 25
39 minutes of learning, the experimenter informed individuals that there was only 5
40 minutes left. All participants but one went on to the post-task questionnaire before the
41 30 minutes were up. The lone participant who kept on learning for the whole of the
42 allotted time was asked by the experimenter to stop and proceed to the questionnaire.
43 The post-task learning questionnaire contained 14 memorization questions and five
44 comprehension questions in random order. Participants had to answer all the
45 questions, but the answer could be “I don’t know”. They then answered one question
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about topic recall, and two demographic questions (sex, age). To thank the participants for their participation, the experimenter gave each one a cinema ticket.

3. Results

3.1. Control variables

Analyses of variance (ANOVAs) revealed no significant differences between the experimental groups on either prior interest, $F(2, 54) = 0.76$, $p = .472$, $\eta^2_p = .03$, or perceived competence, $F(2, 54) = 0.17$, $p = .846$, $\eta^2_p = .01$ (see Table 1 for descriptive statistics).

Table 1. Descriptive statistics for prior interest and perceived competence

Condition	Prior interest		Perceived competence	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
No table of contents	7.00	1.37	3.42	1.80
Table of contents	6.58	1.35	3.05	2.22
Interactive table of contents	7.11	1.45	3.32	2.00

3.2. Learning behaviors

An ANOVA was conducted on learning times. Results revealed no significant effect of condition, $F(2, 54) = .27$, $p = .763$, $\eta^2_p = .05$ (see Table 2 for descriptive statistics). On average, learners spent 23 minutes and 04 seconds viewing the video.

Table 2. Descriptive statistics for learning time

Condition	Learning time (s)	
	<i>M</i>	<i>SD</i>
No table of contents	1397.37	219.52
Table of contents	1401.21	233.48
Interactive table of contents	1354.58	194.67

All the learners could make pauses while they were viewing the video. Although we had not formulated any hypothesis beforehand on the effects of tables of contents on pause behaviors, for the purposes of strategy description, we felt it might be useful to compare these behaviors between the experimental conditions. Comparison showed that 29.82% of learners ($n = 17$) used the pause button (31.58% ($n = 6$) in the no table of contents condition, 31.58% ($n = 6$) in the table of contents condition, and 26.32%

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3 (n = 5) in the interactive table of contents condition. A chi-square analysis showed no
4 differences between conditions, $\chi^2(1, N = 57) = 0.17, p = .920$. Concerning the number
5 of pauses participants made ($M = 0.53, SD = 1.02$ in the no table of contents condition;
6 $M = 0.42, SD = 0.69$ in the table of contents condition; $M = 0.42, SD = 0.84$ in the
7 interactive table of contents condition), an ANOVA showed no differences between
8 conditions, $F(2, 54) = .10, p = .910, \eta^2_p = .00$. The 17 learners who used the pause
9 button made a total of 26 pauses ($M = 1.53, SD = 0.87$; 10 in the no table of contents
10 condition, eight in the table of contents condition, and eight in the interactive table of
11 contents condition). The presence of a table of contents may not have influenced
12 pause behaviors.
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22 We also explored consultation strategies. We expected the presence of a table of
23 contents to have a positive effect on learning outcomes, and interactive table of
24 contents to be beneficial especially for reviewing. Review activities consisted in clicks
25 on the timeline or on the interactive table of contents in order to see an item of
26 information again. According to the chi-square analysis, there were no differences in
27 terms of strategies across the experimental conditions, $\chi^2(6, N = 57) = 2.02, p = .918$
28 (see Table 3 for descriptive statistics). Results indicated that 10.53% of learners
29 watched the video without making any review clicks at all, while 5.26% made review
30 clicks during the first viewing of the video, but none thereafter. For the rest of the
31 learners (i.e., 84.21%), we identified two phases: a learning phase, followed by a
32 reviewing phase. The reviewing phase began after the learner had viewed the whole
33 video once. A total of 61.40% ($n = 35$) only reviewed information after a full first viewing
34 of the video. The remaining 22.81% made review clicks during the first viewing of the
35 video, as well as during a reviewing phase after watching the video from beginning to
36 end.
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Table 3. Descriptive statistics for learning strategies

Condition	No reviews at all		Reviews during first viewing only		Reviews only after first viewing		Reviews during and after first viewing	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
No table of contents	1	5.26	1	5.26	12	63.16	5	26.32
Table of contents	3	15.79	1	5.26	10	52.63	5	26.32
Interactive table of contents	2	10.53	1	5.26	13	68.42	3	15.79

Concerning reviewing behaviors, we collected two types of data to measure the quality of the review activity: number of clicks on the timeline to review some part of the video content; and mean time spent reviewing information after each click (i.e., total review time divided by number of review clicks).

An ANOVA on total review time showed no significant main effect of condition, $F(2, 54) = .46$, $p = .632$, $\eta^2_p = .02$. On average, participants spent 5 minutes and 35 seconds reviewing the video content (see Table 4 for descriptive statistics). This corresponds to 24.19% of total learning time.

An ANOVA on the number of clicks showed a significant difference between groups, $F(2, 54) = 4.11$, $p = .022$, $\eta^2_p = .13$. Pairwise post hoc tests (with Bonferroni adjustment) were performed. Significant differences emerged between the interactive table of contents condition and both the table of contents condition ($p = .013$), and the no table of contents condition ($p = .021$). Participants in the interactive table of contents condition made fewer review clicks than those in the other conditions (see Table 4 for descriptive statistics).

Concerning mean review times, an ANOVA revealed a significant effect of condition, $F(2, 54) = 9.48$, $p < .001$, $\eta^2_p = .26$. Post hoc tests showed significant differences between the interactive table of contents condition and both the table of contents condition ($p < .001$) and the no table of contents condition ($p = .001$). On average, learners with an interactive table of contents spent more time on each review (i.e., after each review click) than learners in the other experimental conditions (see Table 4 for descriptive statistics).

Table 4. Number of review clicks, total review time, and time per review

Condition	Total review time (in s)		Number of reviews (clicks)		Time per review (in s)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
	No table of contents	352.68	235.05	22.32	27.77	21.40
Table of contents	356.21	219.53	23.63	19.58	17.48	15.21
Interactive table of contents	295.68	196.25	7.00	5.63	53.38	43.75

Finally, we analyzed the location of the review clicks. In the no table of contents and table of contents conditions, clicks were only possible on the timeline. However, in the interactive table of contents condition, learners could click either on the timeline or on the table of contents to directly access the corresponding chapter. In the interactive table of contents condition, although the instruction identified both ways of interacting with the content, 90.23% of the review clicks were made on the timeline (9.77% on the table of contents). Only three learners (15.79%) clicked at least once in the table of contents.

3.3. Learning outcomes

For topic recall, the number of correct chapters recalled was calculated for each participant. It was indicated that there were 14 chapters to recall. An answer was considered as correct if it corresponded to a main idea presented in a chapter. To calculate the number of recalled chapters' score, if a chapter was represented many times, it was scored as only one chapter recalled. An ANOVA showed significant differences between the groups, $F(2, 54) = 10.89, p < .001, \eta^2 = .29$. Pairwise post hoc tests revealed significant differences between the table of contents and no table of contents conditions ($p = .003$), as well as between the interactive table of contents and no table of contents conditions ($p < .001$).

We also attributed a Levenshtein distance score to each participant. The Levenshtein distance corresponds to the minimum cost of transforming one sequence into another, through actions such as insertion, substitution or suppression (Yujian & Bo, 2007). It was calculated from the number and order of ideas recalled by each participant. Scores could range from 0 (i.e., equivalent to the initial sequence of topics presented in the video) to 14 (i.e., great many modifications to the initial sequence). An ANOVA showed significant differences between the groups, $F(2, 54) = 15.51,$

$p < .001$, $\eta^2 = .36$. Pairwise post hoc tests revealed significant differences between the table of contents and no table of contents conditions ($p = .001$), as well as between the interactive table of contents and no table of contents conditions ($p < .001$).

According to the descriptive statistics (see Table 5), learners recalled the chapters and their organization better when they could see the structure (i.e., table of contents), whether or not it was interactive.

Table 5. Descriptive data for topic recall

Condition	Number of recalled chapters (max. 14)		Topic recall (Levenshtein distance)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
No table of contents	3.42	2.55	12.32	1.49
Table of contents	6.68	3.86	9.00	3.25
Interactive table of contents	8.26	3.25	7.37	3.25

Concerning the memorization score, the ANOVA revealed no significant effect of condition, $F(2, 54) = 2.03$, $p = .141$, $\eta^2_p = .07$ (see Table 6 for descriptive statistics).

Concerning the comprehension score, the ANOVA revealed no significant differences between the groups, $F(2, 54) = .80$, $p = .456$, $\eta^2_p = .01$ (see Table 6 for descriptive statistics).

Table 6. Descriptive data for memorization and comprehension scores

Condition	Memorization score (max. 15)		Comprehension score (max. 5)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
No table of contents	8.55	2.20	1.58	1.15
Table of contents	7.18	2.17	2.00	1.15
Interactive table of contents	7.76	1.92	2.00	1.26

4. Discussion

The aim of the present study was to pinpoint the effects of video table of contents on learning outcomes. The main hypothesis was that, in video-based environments, the presence of a table of contents enhances the organization of incoming information into a relevant mental model and thus improves learning. We expected table of contents to enhance recall of the overall structure, and interactive table of contents to permit more precise information location in the video during learning.

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3 Tables of contents did not influence overall review time. Nevertheless, it did have
4 impact on the nature of reviewing behaviors. Participants made fewer clicks on the
5 timeline in the interactive table of contents condition. This confirmed Hypothesis 1a,
6 and was consistent with the literature: an interactive table of contents (i.e., links
7 between structure and timeline, and direct access to chapters) facilitated navigation of
8 the video (Cojean & Jamet, 2017). Moreover, on average, learners spent more time on
9 each review (i.e., after each click) with interactive table of contents than without it. This
10 could reflect the quality of the review activity. Participants may have spent more time
11 on each review because these reviews were more relevant. Hypothesis 1b was
12 therefore validated.
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20 Results showed that participants who could refer to the table of contents recalled
21 the topics set out in the video and their organization significantly more accurately than
22 participants without table of contents did. This result is in accordance with the results
23 of previous studies that focused on printed documents rather than videos (e.g., Hyönä
24 & Lorch, 2004; Lorch et al., 2013; Lorch & Lorch, 1996). Hypothesis 2a was therefore
25 validated. No significant differences were found between the groups for content
26 memorization and comprehension. In a study conducted by Li, Huang, and Tsai (2019)
27 in video-based environment, the same pattern of results was observed: structuring
28 (i.e., table of contents and headings in the timeline) increased topic recall but no
29 content learning. Hypotheses 2b, 2c, 2d and 2e were therefore not validated, even
30 though our second main hypothesis predicted that the presence of a table of contents
31 would promote the organization process and video content learning. Although topic
32 recall was effectively enhanced by the presence of a table of contents, no significant
33 effect of table of contents was observed on memorization and comprehension in this
34 study. One possible explanation is that learners only used this scaffolding at quite a
35 late stage in the task: more than 70% of the participants did not make any review clicks
36 during their first viewing of the video. This result must be relativized: not clicking on the
37 timeline to review an item of information does not mean that learners did not process
38 information from the table of contents. It only suggests that they did not use the table
39 of contents in an active manner: they may have processed the information, but only
40 superficially. Moreover, when the table of contents was interactive, learners made very
41 little use of it, and mostly relied on the timeline to navigate the video. The presence of
42 a table of contents allowed participants to better recall the main ideas presented in the
43 video, and interactive table of contents allowed them to undertake more efficient
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3 reviewing activities. So, although learners may benefit from table of contents, they may
4 have poor self-regulation of knowledge and the structuring source may be
5 underestimated and underused. Some results of the current study provide additional
6 information about behaviors and strategies in this respect. Finally, few learners
7 pressed the pause button, and when they did, they made very little use of it. This is
8 consistent with previous results in the literature (Biard et al., 2017; Hasler et al., 2007).
9 One possible explanation is that when learners are not familiar with the topic being
10 presented, they do not know when to pause the video (Wouters et al., 2007). Learning
11 therefore seems to have been enhanced by table of contents, but only for signaled
12 information (i.e., main ideas in the table of contents). This result is consistent with
13 previous results in the literature (e.g., Hyönä & Lorch, 2004; Lorch, 1989; Lorch et al.,
14 2013). Asking students questions before a video should enhance their learning of
15 unsigned information (Carpenter & Toftness, 2017).
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25 One of the limitations of the present study was the measure of review activity
26 quality, but this could be improved by collecting complementary data. For example,
27 eye-tracking could shed light on navigation strategies (e.g., Hannus & Hyönä, 1999;
28 Hyönä et al., 2002; Johnson & Mayer, 2012; Potocki et al., 2017; van Gog & Scheiter,
29 2010; Dexiang Zhang et al., 2019), while think-aloud protocols (Greene et al., 2015)
30 could be used to identify the learner's search goal at each click on the timeline (e.g.,
31 Fernandez & Jamet, 2017; Hinojosa et al., 2018). Finally, this study was conducted
32 in a laboratory, and learning behaviors might have been different in a naturalistic
33 setting. The ecological character of the learning task with or without table of contents
34 could be improved in future studies: effect of note taking, long-term learning, or
35 presentation of the video during a real course (e.g., MOOC).
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45 **5. Conclusion**

46 The aim of the present study was to identify the effects of displaying a table of
47 contentson video-based learning. Two specific effects were observed: the presence of
48 a table of contents enhanced organizational recall; and interactive table of contents
49 facilitated relevant reviewing behaviors. Overall, the use of interactive table of contents
50 resulted in more relevant learning activity. The hypothesis that tables of contents,
51 especially interactive ones, promote learners' organization processes was therefore
52 confirmed. Nevertheless, no significant effect of table of contents was found on either
53 content memorization or comprehension. Results suggest that learners did not make
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3 sufficient use of the table of contents because they were not aware of their difficulties.
4 Giving them additional information about their knowledge would have helped them
5 adopt the appropriate strategy (i.e., using the table of contents as an organizer of
6 incoming information in memory). Future studies could focus on the effect of questions
7 before learning as a metacognitive aid. The objective would be to encourage learners
8 to actively use and benefit from the table of contents in a video.
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