Computers in Human Behavior 74 (2017) 294–302

Contents lists available at ScienceDirect

Computers in Human Behavior

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

Facilitating information-seeking activity in instructional videos: The combined effects of micro- and macroscaffolding

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A R T I C L E I N F O

Article history:
Received 21 November 2016
Received in revised form
24 March 2017
Accepted 26 April 2017
Available online 26 April 2017

Keywords:
Information seeking
Video-based environments
MOOC
Scaffolding

A B S T R A C T

With the development of e-learning, and more specifically MOOCs, searching for information in videos is becoming a key activity in education. Many studies have focused on learning in video-based environments, but to our knowledge, they have left aside the question of search tasks. We hypothesized that information-seeking activity can be improved by adapting features of the learning environment, more particularly by providing micro- and/or macroscaffolding. To test this hypothesis, we assessed the effects of presentation during a search activity in a video-based environment. A total of 80 students were divided into four groups, then exposed to a video 1) with or without a table of contents (macroscaffolding), and 2) with or without markers in the timeline (microscaffolding). Results showed that micro- and macroscaffolding both have positive effects on search outcomes, but also that they need to be used in combination to improve search times. One possible interpretation is that, in the absence of scaffolding, users have to compensate by constructing their own mental representations of the video segmentation, which is cognitively very costly and highly time consuming.

1. Introduction

Videos are increasingly being used in learning, to the point of becoming an integral part of learning environments (Delen, Liew, & Willson, 2014; Giannakos, 2013; Kay, 2012). In parallel, the development of the Internet has considerably widened access to information (Sharit, Hernández, Czaja, & Pirolli, 2008), making it far easier to broadcast videos (Marchionini, 2003). In particular, massive online open courses (MOOCs) offer new educational opportunities, as they are accessible any time and any place (Joseph & Nath, 2013; Yadav et al., 2015). Given their impact, there is a real need to study MOOCs in the education field, for on the most popular platforms, courses can easily attract more than 500 registrations (Hew & Cheung, 2014; Koutropoulos et al., 2012). Many videos are now being created for learning purposes, and more and more research is being conducted on video-based learning (Giannakos, 2013), thus testing many of the features of this particular presentation format (e.g., Arguel & Jamet, 2009; Derry, Sherin, & Sherin, 2014; Ganier & de Vries, 2016; Schwan & Riempp, 2004). Even so, no design standards or guidelines have yet been proposed (Chen & Wu, 2015; Ilioudi, Giannakos, & Chorianopoulos, 2013). The video format has its own specific characteristics and constraints, compared with written and illustrated documents, the most important one probably being the transient delivery of the information (Wong, Leahy, Marcus, & Sweller, 2012). In order to tackle these issues, the effects of video presentation on students' activities need to be investigated, particularly those involved in learning issues. The current study focused on search activity, and exploring the benefits of providing scaffolding to users.

1.1. Information-seeking activity

1.1.1. Definition

Information seeking relies on the ability of users to locate one particular item of information among others, in order to achieve an explicit goal (Guthrie & Mosenthal, 1987). Individuals are continually searching for information, and can now do so using more and more digital devices (Dinet, Chevalier, & Tricot, 2012). Indeed, this problem-solving ability is becoming central in both professional and personal areas of life (Wopereis, Brand-Gruwel, & Vermetten, 2008). The information-seeking process can improve learning and facilitate adaptation to new issues in education (Guthrie & Mosenthal, 1987; Merkt & Schwan, 2014), and its steps (Lazonder

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http://dx.doi.org/10.1016/j.chb.2017.04.052
0747-5632/

& Rouet, 2008) have been described in several theoretical models.

1.1.2. Models of the information-seeking activity

Many theoretical models focus on describing and predicting human behavior during information searches, whether in paper or in web documents (e.g., Guthrie & Mosenthal, 1987; Kitajima, Blackmon, & Polson, 2000; Lazonder & Rouet, 2008; Puustinen & Rouet, 2009; Sharit et al., 2008; Wopereis et al., 2008). A common feature of all these models is the localization of information (or sources) and a choice that has to be made by the individual. More specifically, to define the way that an individual searches for information, Sharit et al. (2008) developed a model of the localization activity containing three subprocesses. The first subprocess is the construction of a mental representation of the problem by the searcher. The second subprocess is planning, where the individual generates a method of finding a solution, generally dividing the problem into subgoals. The third subprocess is execution, where the searcher performs the previously planned operations. The current study focused on these three subprocesses, looking at ways of making them more relevant in order to improve the information-seeking activity. One solution may be to adapt the video presentation format, in order to act upon the user's mental model and simplify the execution of the procedure.

1.1.3. The role of a relevant mental model

Mental models are constructed by users during their interaction with the environment (which can be a video-based environment). They represent the structure of the system and have a predictive and explanatory power (Borgman, 1986; Norman, 1983; Storey, Fracchia, & Müller, 1999). Users need mental models to anticipate their actions upon a system before they interact with it (Rowe & Cooke, 1995). Borgman (1986) specifies that if users do not spontaneously construct a mental model, they will need to rely on the provision of a conceptual model. Conceptual models are invented by teachers or designers, and represent the target system (Norman, 1983). Although they are not mental models, they can contribute to their construction. The aim of adapting the video presentation format is to accompany users in their information-seeking activity, in particular scaffolding their mental models of the video system.

1.2. Adaptation of the video presentation format

Information in videos is delivered transiently, requiring costly and continuous processing in working memory by users, and can therefore lead to a loss of relevant information (Hasler, Kersten, & Sweller, 2007; Merkt, Weigand, Heier, & Schwan, 2011). Consequently, it may be useful to focus on this inherent limitation of video presentation, in order to make them easier to overcome.

1.2.1. Avoiding a continuous flow of information: microlevel activities

To deal with the transitory aspect of the information in video-based environments, some authors recommend giving users control over the information flow (e.g., Hasler et al., 2007; Lawless & Brown, 1997; Mayer & Chandler, 2001; Schwan & Riempp, 2004). When faced with complex content, users may want to review some passages or tailor the speed of the video to their cognitive abilities (Merkt et al., 2011). Playing, pausing, rewinding and fast-forwarding a video (Delen et al., 2014) are all described as *microlevel* activities, as they control the processing of information at a local level (Merkt et al., 2011).

1.2.2. Building structural representations: macrolevel activities

When users can jump to specific parts of the video, this facilitates their navigation (Zhang, Zhou, Briggs, & Nunamaker, 2006), inevitably leading to better localization of the information (Lorch, Lemarié, & Grant, 2011). For this to happen, users have to learn how the document is structured, which is an important but costly activity (Sanchez, Lorch, & Lorch, 2001). The use of *macrolevel* features (table of contents, index, visual organizer, etc) allows this navigation to take place at a more general level than microlevel activities do (Chun & Plass, 1996; Merkt et al., 2011). Providing hierarchical cues can therefore lead to hierarchical, rather than linear, encoding of the document's structure, and to better recall of the parts or chapters of the document that are presented (Lorch et al., 2011; Sanchez et al., 2001).

1.2.3. The role of scaffolding

As indicated above, scaffolding can help to promote information-seeking activities. The various possible ways of acting upon the document, defined under the *learner control principle* (Scheiter & Gerjets, 2007), need support in order to be effective (Scheiter, 2014), and scaffolding can be offered at both micro- and macrolevels of activity. Its goal is to promote the construction of a mental model during an information-seeking activity by providing users with a conceptual model (Norman, 1983). When it takes the form of tools or structures, it supports users' understanding of the document (Azevedo & Hadwin, 2005). This guidance also helps them improve their processing skills, in particular their planning skills (Reiser, 2002, 2004). In 2014, Merkt and Schwan compared the effects of micro- and macroscaffolding during learning and search tasks. Four conditions were tested: enhanced video condition (with micro- and macroscaffolding), common video condition (with microscaffolding), noninteractive video condition, and illustrated textbook condition. Results showed that, in terms of the number of information items found, participants in the enhanced video condition outperformed those in the common video condition, who in turn outperformed those in the noninteractive video condition. However, the authors did not test the effect of macroscaffolding on its own. Moreover, while adding macroscaffolding to microscaffolding (i.e., in the enhanced video) seemed to promote searching activity, only the presence of an index appeared to be predictive of performance, and no effect of table of contents was found. In line with this research, the current study was designed to ascertain the specific effects of micro- and macroscaffolding during information-seeking activity.

1.3. The current study

The current experiment was designed to study the potential effects of micro- and macrolevel scaffolding on information seeking in a video-based environment, as well as their interaction when they referred each other. Here, *microscaffolding* took the form of markers along the video's timeline that were intended to foster microlevel activities and thence control over the information flow. *Macroscaffolding* took the form of a table of contents that was intended to foster macrolevel activities and thence general navigation. We assumed that the failure of previous research in this area to demonstrate an effect of table of contents (see Merkt & Schwan, 2014) stemmed from the way the scaffolding was presented. The table of contents was not near the video, and users had to click on a button next to the video to display it. The spatial contiguity principle (e.g., Ginns, 2006; Mayer, 2005) states that learning is enhanced when related sources or documents are displayed near to each other on the screen. We can therefore assume that it applies to information-seeking activity in the same way as it does to a learning activity, and that different sources of information (here, levels of scaffolding) should refer to each other within the video-based environment.

Regarding the three subprocesses described by Sharit et al.

(2008), we assumed that scaffolding would serve as a conceptual model, and thus support mental representations. As for the other two subprocesses (planning and execution) we assumed that they would be facilitated in two ways by scaffolding: use of an enhanced mental model and direct use of the cues provided. These concrete actions upon a video-based environment can be placed under the heading of *interactivity*, and have already been shown to alleviate users' difficulties in a video browsing task (Zhang et al., 2006). If no conceptual model is provided (or only an incomplete one, where there is only one level of scaffolding), users need more time to construct their own mental model and thus improve their performances. Once the mental model has been created, performances should become just as good as those made possible by the provision of a conceptual model. We therefore decided to take a closer look at this dynamic aspect, by introducing a temporal analysis. To this end, participants were asked nine questions whose answers were all in the video.

We made a series of predictions, based on six hypotheses:

Hypothesis 1. Success: Participants with micro- or macroscaffolding would perform the task better than participants without any scaffolding, especially when there were two levels of scaffolding. Moreover, when there was only micro- or macroscaffolding, or even no scaffolding at all, performances for each question would improve over time, reflecting the construction of a relevant mental model.

Hypothesis 2. Response time: Participants with micro- or macroscaffolding would spend less time seeking information than participants without any scaffolding. This effect would be greater for participants with two levels of scaffolding. Moreover, when there was only micro- or macroscaffolding, or even no scaffolding at all, the amount of time spent on each question would decrease over time, for the same reason that performances would improve (Hypothesis 1).

Hypothesis 3. Relevance of the first click: For each search activity (i.e., for each question in the task), participants with micro- or macroscaffolding would make more relevant first clicks (nearer the target segment) than participants without any scaffolding. This effect would be greater for participants with two-level scaffolding. Moreover, when there was only micro- or macroscaffolding, or even no scaffolding at all, the relevance of the first click would increase over time, reflecting the construction of a mental model.

Hypothesis 4. Perceived difficulty: Participants with micro- or macroscaffolding would perceive the task to be less difficult than participants without any scaffolding. This effect would be greater for participants with two-level scaffolding.

Hypothesis 5. Perceived control: Participants with microscaffolding would have more perceived control than participants without microscaffolding.

Hypothesis 6. Number of recalled chapters: Participants with macroscaffolding would recall more chapters of the video than participants without macroscaffolding, owing to the presence of a table of contents.

2. Method

2.1. Participants

A total of 80 students (59 women, 21 men) from the University of Brittany (France) volunteered to take part in the study. Their mean age was 21.33 years ($SD = 3.05$). They were recruited via advertisements posted across the university. All of them received a cinema ticket for their participation. The experiment was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Materials and experimental design

The video we used was taken from the Canal U website (http://www.canal-u.tv/). Its topic was *water in the universe* (Doressoundiram, 2012), and it lasted about 13 min. According to the website, the video was thematically segmented into 12 chapters.

We designed a specific learning environment to display this video (see Fig. 1). A timeline below the video allowed participants to browse it with the mouse as much as they wanted. We used a 2×2 factorial design: the video either had or did not have a table of contents (macroscaffolding), and the timeline either did or did not display markers (12 sections corresponding to the chapters; microscaffolding). Next to the computer screen, each participant had a tablet, on which the nine questions for the information-seeking activity were presented. A timer above the question indicated how much time was left to answer. Each question was limited to 5 min, and the countdown was launched as soon as the question appeared. A button below the question allowed participants to skip to the next question if they answered in less than 5 min. The nine questions were presented in a counterbalanced order, in groups of three questions, thus forming three different orders of presentation (1-2-3, 2-3-1 and 3-1-2). Counterbalancing these questions allowed us to analyze a time factor for some variables. Answers were written on nine different sheets of paper placed on the desk. The nine questions were followed by a post-task questionnaire displayed on the computer screen. Questions about perceived difficulty and control were presented in a random order. Participants were randomly assigned to one of the four experimental groups. In the control condition ($n = 19$), participants could use the timeline to browse the video, and could stop the video at any given time (see Fig. 1). No table of contents or makers on the timeline were available. There was, however, an indicator of the video's running time and total duration. The participants in the microscaffolding condition ($n = 19$) were exposed to the same material as those in the control condition, but benefitted from markers on the timeline (see Fig. 1). These markers segmented the timeline into 12 sections corresponding to the 12 chapters, although participants were not given the headings of these sections. The participants in the macroscaffolding condition ($n = 20$) were again exposed to the same material as those in the control condition, but were given a table of contents on the left side of the video (see Fig. 1). All 12 chapters were represented, but there was no reference to them in the timeline. Nor was it possible to click on a specific chapter to directly access it at the corresponding point in the video. In the two-level scaffolding condition ($n = 22$), the video was presented with both table of contents and corresponding markers in the timeline (see Fig. 1). To ensure that they referred to each other, numbers were assigned to each chapter and were displayed below each corresponding segment in the timeline.

2.3. Measures

2.3.1. Interest in the topic and perceived competence (control variables)

Two questions were administered before the task, to check that interest and perceived individual competence on the topic were evenly distributed across the conditions. Participants indicated the degree to which they were interested in the topic on an 11-point scale ("*On a scale of 0 to 10, how interested are you in this topic?*") and how competent they felt ("*On a scale of 0 to 10, how competent*

Fig. 1. Screenshot of the video-based environment in the control (1), microscaffolding (2), macroscaffolding (3), and two-level scaffolding (4) conditions.

do you feel on this topic?").

2.3.2. Successful responses

Responses were deemed to be correct when participants noted the information they sought and the point in the video at which they found it. Responses were deemed not to be correct when participants noted another item of information than the one they should have been searching for and/or the wrong point in the video. A missing response was also deemed to be incorrect.

2.3.3. Response times

We used a screen recorder to analyze the duration of each information search by participants. Response times were calculated from when participants started searching (first click) to when they found the information (pause button). Information search time was limited to 5 min per question.

2.3.4. Relevance of the first click

The screen recorder meant we had access to the location of the first click participants made during each search. We noted on an 11-point scale how far (number of segments between the target segment and clicked one) the participant was initially from the segment containing the response. If the participant clicked on or very close to the target segment (i.e., low initial error rate), we took this as an indicator of high relevance.

2.3.5. Perceived difficulty and control

Perceived difficulty and perceived control were assessed with items adapted from studies of these concepts (Kraft, Rise, Sutton, & Røysamb, 2005; Trafimow, Sheeran, Conner, & Finlay, 2002). We used three perceived difficulty items (e.g., "I found this information-seeking activity difficult", "Searching for information was easy"). We also used three perceived control items (e.g., "I had full control over this information seeking activity", "I felt a lack of control during the search activity"). Participants indicated the degree to which they agreed to these statements on a 7-point Likert scale. Cronbach's alphas were .81 for the perceived difficulty items used in this study, and .75 for the perceived control items.

2.3.6. Number of chapters recalled

After the information-seeking activity, participants were asked to name the 12 parts discussed in the video. For those in the macroscaffolding and two-level scaffolding conditions, this constituted a memory task, as the table of contents had remained visible throughout the information-seeking activity. For those who were in the control and microscaffolding conditions, and who had not been shown the table of contents, it was more of an inferential task. The number of recalled chapters (whether they were right or wrong) was extracted as an indicator of macrostructure.

2.4. Procedure

Participants were greeted, then installed at a desk. First, they answered the questions about their interest in the topic of *water in the universe* and their perceived competence (pre-task questionnaire). The experimenter then explained the instructions to them (answer the questions by searching in the video) and described the material (table of contents and/or markers on timeline in experimental groups). All participants were informed of all the measures that would be carried out, and were told that they were free to leave the experiment whenever they wanted. The experimenter then launched the screen recorder. The participants were asked to wear headphones to listen to the video. They started the task whenever they wanted, by clicking on the touchpad to make the first question appear. They then had 5 min to answer each question using the video. When they found the answer and its point in the video, they wrote it on the corresponding sheet of paper. They could then go on to the next question. If they did not find the answer in 5 min, the next question automatically appeared. The participants therefore did not write an answer on the corresponding sheet of paper, and continued the task with the new question. At the end of the nine questions, the experimenter stopped the video and administered an online post-task questionnaire. This comprised three perceived difficulty items, three perceived control items, a question about chapter recall, and two demographic questions (sex, age). Finally, once the participants had finished this questionnaire, the experimenter gave each one a cinema ticket to thank them for their participation.

3. Results

3.1. Control variables

The aim of the pre-task questionnaire was to ensure that the participants in the four experimental conditions did not differ on their prior interest in and perceived competence on the video topic.

Analyses of variance (ANOVAs) revealed no significant differences between experimental conditions on either interest, $F(3, 76) = 1.133$, $p = 0.341$, or perceived competence, $F(3, 76) = 0.290$, $p = 0.833$.

3.2. Search task

3.2.1. Prerequisites for data analysis

To analyze the data from the search task, we chose to distinguish between responses and failures. A failure was defined as not finding the answer to a question within 5 min. We used a chi-square test to determine whether the number of failures differed across conditions (see Table 1 for descriptive statistics). Results showed a significant difference, $\chi^2(3, N = 720) = 17.182$, $p < .001$. Descriptive statistics indicated that the participants failed less often when they benefitted from two-level scaffolding. To explore response times, we removed the failures from the data and focused on the successful searches.

All nine questions were presented to each participant, meaning that the independence assumption was violated (Field, Miles, & Field, 2012). We therefore used linear mixed models (Gueorguieva & Krystal, 2004), a statistical method that takes into account the nonindependence of data into account. To assess the effect of a variable in the mixed models, we compared nested models. More specifically, for each tested effect, we compared two models: one without the variable (i.e., baseline model) and one with the variable (more complex model with more degrees of freedom) (see, for example, Baayen, Davidson, & Bates, 2008). To assess the contribution of each variable, we measured the difference in deviance (chi square) between these two nested models. The significance threshold for p values was set at $\alpha = 0.05$. For each dependent variable, we tested the main effects of microlevel scaffolding, macrolevel scaffolding, and their additive and interaction effects, as well as the additive and interaction effects of question rank. For example, to measure the effect of microlevel scaffolding on success, we compared two models: one that included no predictor, and one that included the microscaffolding variable. If the latter significantly reduced the deviance ($p < .05$), it was considered to be the better one (i.e., this independent variable had a significant influence on the dependent variable). Every model included random effects of question and participant, to take the nonindependence of the data into account (Baayen et al., 2008).

3.2.2. Response success

Concerning task scores, each question was coded either 0 (wrong answer) or 1 (right answer). We therefore used logistic regression to process these binomial data (Field et al., 2012), whereas for response times and relevance, we used linear regression. Results showed a significant effect of macroscaffolding, $\chi^2(1, N = 720) = 9.3575$, $p = 0.002$, on success rate, but no significant effect of microscaffolding, $\chi^2(1, N = 720) = 3.4779$, $p = 0.062$. Results also showed an additive effect of micro- and macroscaffolding, $\chi^2(2, N = 720) = 13.0474$, $p = 0.001$, but no interaction between these two levels, $\chi^2(1, N = 720) = 2.0789$, $p = 0.149$. Given that there was no main effect of microscaffolding, in order to confirm the additive effect of microscaffolding on macroscaffolding, we compared the macro-effect (i.e., main effect of macroscaffolding) and micro-macro effect (i.e., additive effect of macro- and microscaffolding) models. We failed to find a significant contribution of microscaffolding to macroscaffolding, $\chi^2(1, N = 720) = 3.6898$, $p = 0.055$. Descriptive statistics showed that success seemed to be greater in the two-level scaffolding condition than in the three others (see Fig. 2).

To go one step further, we analyzed how the success rate changed over time, according to question rank. More specifically, we analyzed the success rate according to condition and question rank, ranging from 1 (first question presented) to 9 (last question presented). We compared the macro-effect model (selected as the best fit for the macroscaffolding effect), additive model (i.e., additive effect of question rank) and interaction model (i.e., interaction effect of question rank). Results showed an additive effect of question rank, $\chi^2(1, N = 720) = 4.8036$, $p = 0.028$, as well as an interaction between macro scaffolding and question rank, $\chi^2(1, N = 720) = 6.7257$, $p = 0.010$. Descriptive statistics showed that the success rate increased over time and with question rank, and that the difference between the two-level scaffolding condition and the other three conditions seemed to disappear over time (see Fig. 2).

3.2.3. Response times

We analyzed the response times for each of the nine questions, in order to identify differences between conditions. Results showed that microscaffolding, $\chi^2(1, N = 659) = 7.365$, $p = 0.007$, and macroscaffolding, $\chi^2(1, N = 659) = 12.572$, $p < .001$, each had a significant effect on response times. They also revealed an additive effect of micro- and macroscaffolding, $\chi^2(2, N = 659) = 20.575$, $p < .001$, as well as an interaction between these two levels, $\chi^2(1, N = 659) = 14.538$, $p < .001$. Descriptive statistics indicated that response times were shorter in the two-level scaffolding condition than in the three others (see Fig. 3).

We also analyzed how the amount of time allocated to the search activity changed in the course of the task. We compared the scaffolding interaction model (selected as the best fit for micro- and macroscaffolding effects), additive model (i.e., additive effect of question rank) and double interaction model (i.e., interaction effect of question rank). Results showed an additive effect of question rank, $\chi^2(1, N = 659) = 34.214$, $p < .001$, as well as an interaction between the two levels of scaffolding and question rank, $\chi^2(3, N = 659) = 11.078$, $p = 0.011$. Descriptive statistics showed that response times decreased over time and with question rank, and that the difference between the two-level scaffolding condition and the other three conditions seemed to disappear over time (see Fig. 3).

3.2.4. Relevance of the first click

As the error rate was assumed to reflect relevance, we ran analyses on the distance between the target segment and the clicked one. Results showed that microscaffolding, $\chi^2(1, N = 720) = 5.9198$, $p = 0.015$, and macroscaffolding, $\chi^2(1, N = 720) = 15.586$, $p < .001$, each had a significant effect on the error rate. They also revealed an additive effect of micro- and macroscaffolding, $\chi^2(2, N = 720) = 22.1337$, $p < .001$, as well as an interaction between these two levels, $\chi^2(1, N = 720) = 6.5117$, $p = 0.011$. Descriptive statistics indicated that the error rate was lower in the two-level scaffolding condition than in the three others (see Fig. 4).

We analyzed how the error rate changed over time depending on question rank. We compared the scaffolding interaction model (selected as the best fit for micro- and macroscaffolding effects), additive model (i.e., additive effect of question rank) and double interaction model (i.e., interaction effect of question rank). Results revealed an additive effect of question rank, $\chi^2(1, N = 720) = 43.637$, $p < .001$, as well as an interaction between the

Table 1
Descriptive statistics for information-seeking failures.

Condition	n	% (condition)	% (total)
Control	22	12.866	3.056
Microscaffolding	20	11.696	2.778
Macroscaffolding	15	8.333	2.083
Twolevel scaffolding	4	2.020	.556

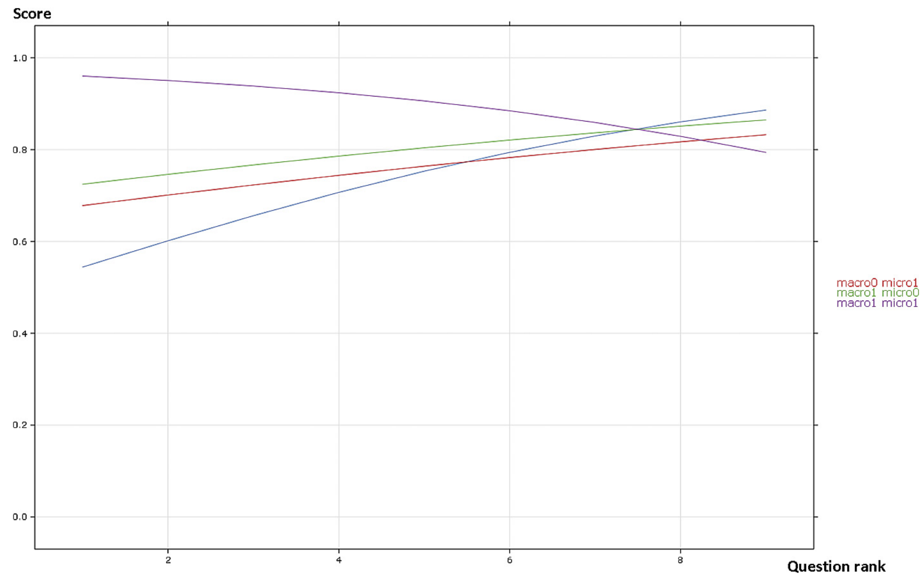

Fig. 2. Diagram showing response success rate according to question rank in the four experimental conditions.

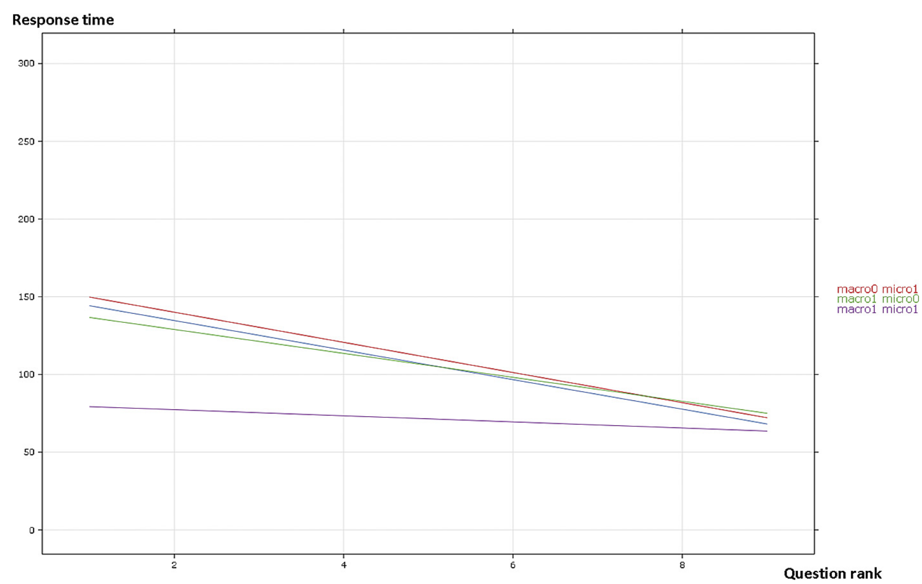

Fig. 3. Diagram showing response times (in s) according to question rank in the four experimental conditions.

two levels of scaffolding and question rank, $\chi^2(3, N = 720) = 14.778$, $p = 0.002$. Descriptive statistics indicated that the error rate decreased over time and with question rank, and relevance therefore seemed to increase over time. Moreover, the difference between the two-level scaffolding condition and the other three conditions disappeared over time (see Fig. 4).

3.3. Post-task questionnaire

3.3.1. Perceived difficulty

A 2 × 2 ANOVA revealed main effects of both microscaffolding, $F(1, 76) = 11.53$, $p = 0.001$, $\eta^2_p = 0.13$, and macroscaffolding, $F(1, 76) = 7.08$, $p = 0.010$, $\eta^2_p = 0.09$, as well as an interaction between the two, $F(1, 76) = 5.04$, $p = 0.028$, $\eta^2_p = 0.06$ (see Table 2 for descriptive statistics). The data showed that users had lower perceptions of task difficulty, but only when the two levels of scaffolding were combined.

3.3.2. Perceived control

A 2 × 2 ANOVA revealed a main effect of microscaffolding, $F(1, 76) = 12.66$, $p < .001$, $\eta^2_p = 0.14$, but no main effect of macroscaffolding, $F(1, 76) = 3.12$, $p = 0.082$, and no interaction between the two, $F(1, 76) = 0.27$, $p = 0.605$ (see Table 2 for descriptive statistics). The data showed that users only perceived themselves to have more control over the task when they benefitted from microscaffolding.

3.3.3. Number of recalled chapters

A 2 × 2 ANOVA revealed a main effect of macroscaffolding, $F(1, 76) = 10.77$, $p = 0.002$, $\eta^2_p = 0.12$, but no main effect of microscaffolding, $F(1, 76) = 2.58$, $p = 0.112$, and no interaction between the two, $F(1, 76) = 0.00$, $p = 0.990$ (see Table 2 for descriptive statistics). The data showed that users only recalled a greater number of chapters when they benefitted from macroscaffolding.

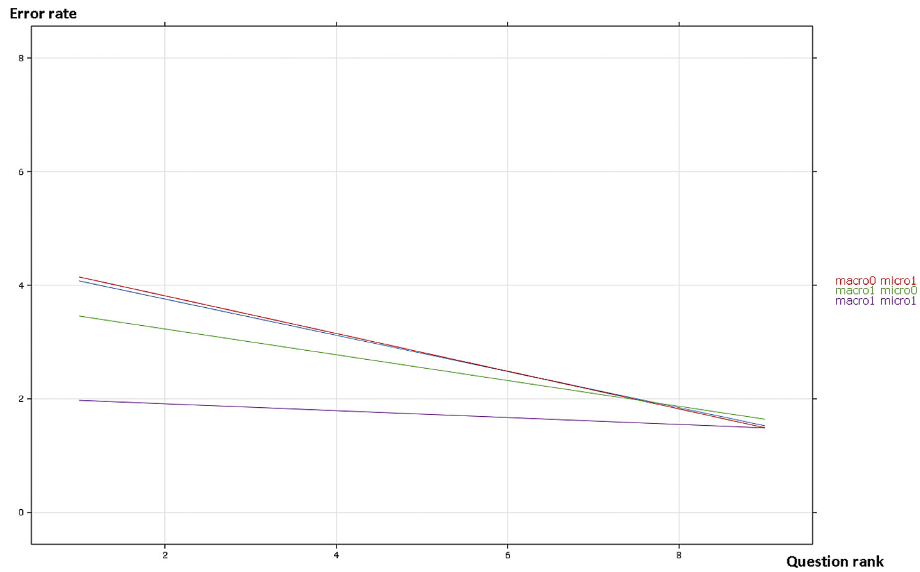

Fig. 4. Diagram showing error rate according to question rank in the four experimental conditions.

Table 2
Descriptive statistics for perceived difficulty, perceived control and number of recalled chapters.

Condition	Perceived difficulty		Perceived control		Recalled chapters	
	M	SD	M	SD	M	SD
Control	8.737	2.600	13.211	3.780	4.684	1.945
Microscaffolding	8.053	3.613	16.158	2.566	5.579	2.244
Macroscaffolding	8.550	3.456	14.800	3.286	6.500	2.328
Twolevel scaffolding	4.909	1.875	17.000	3.101	7.409	3.217

4. Discussion

The present study was designed to identify the effects of micro- and macroscaffolding, both separately and in interaction, during information-seeking activity. Our hypotheses were that the scaffolding of microlevel and/or macrolevel activities helps users to construct a relevant mental model of the document, thereby facilitating the search for specific information. For this to happen, we assumed that scaffolding improves the efficiency, accuracy, and relevance of the search activity, mainly by increasing control, facilitating use and/or making the document's structure more salient.

Regarding response success, results showed a significant effect of macroscaffolding, but no microscaffolding effect. Participants provided more correct responses when they benefitted from macrolevel scaffolding (i.e., table of contents) than when they did not, but no advantage came with microscaffolding, partly validating Hypothesis 1. Results on response times according to condition showed that two-level scaffolding helped to reduce the amount of time allocated to the search. Overall, participants with micro- and macroscaffolding spent less time on the information-seeking activity than the others. This was consistent with Hypothesis 2. The same pattern could be observed for the error rate for the first click on each question. Results showed that participants made smaller errors (i.e., more relevant, closer to the target segment) when they benefitted from two-level scaffolding than when they did not, thus validating Hypothesis 3. Concerning these three variables, results highlighted the beneficial effects on information-seeking activity of scaffolding documents. Macrolevel scaffolding helps to improve the accuracy of the response, and when the two levels of scaffolding are combined, they improve search efficiency and relevance. These results build on previous ones (i.e., Merkt & Schwan, 2014), by demonstrating the superiority of two-level scaffolding on video (i.e. enhanced video) over other video formats. Another original feature of this study is that it sheds new light on changes in users' performances across the task. We assumed that scaffolding has these beneficial effects because it provides the searcher with a *ready-to-use* conceptual model of the video content. Tables of contents and related markers on the timeline make it easier to locate and access information. In the case of the response success score, unlike microscaffolding, macroscaffolding carried meaningful information, which could be the reason why it was the only level that contributed to semantic success. More generally, when a scaffolding level was missing, or when there was no scaffolding at all, in order to make sense of the document, users had to develop their own mental model-more specifically, a mental representation of the missing level of scaffolding in the video. This construction could be the reason for the disparity between performances, and explain why there was no longer any difference by the end of the task. Once the construction was complete, searchers could use it as their own mental scaffolding. We therefore made two assumptions: 1) the proposed scaffolding serves as a conceptual and external model for the user, and is immediately usable for information-seeking activity, thus improving performances; 2) in the absence of scaffolding, searchers construct their own internal representations of the video-based environment, such that they eventually perform just as well as they would have done had they benefitted from scaffolding. This construction process is cognitively costly, as seen with the results on perceived difficulty, confirming Hypothesis 4.

Furthermore, adding microscaffolding to a video-based environment significantly improves the feeling of having control over the situation, in accordance with Hypothesis 5 and with previous research (e.g., Delen et al., 2014; Merkt et al., 2011). Finally, the number of recalled chapters improved with macro-scaffolding, confirming Hypothesis 6, as well as previous studies of hierarchical cues and their impact on text recall (e.g., Lorch et al., 2011; Sanchez et al., 2001). These results shed light on the specific features of these scaffolding levels. While microscaffolding was used to navigate within the video, macroscaffolding supplied information about its content. The activity of searching for information is clearly, therefore, a complex and two-level activity. These two levels were mostly complementary, and their combined presence had a significant impact on information-seeking performances. The construction of relevant mental models by the searchers themselves can overcome the difficulties they encounter in the absence of scaffolding, but it is more costly in terms of time and cognitive demands. Scaffolding helps users to achieve success at their first try, when they would otherwise only have performed correctly many questions later.

Nonetheless, this study had several limitations. First, only university students took part. They could be regarded as information-seeking *experts*, and it would be interesting to test the effects of scaffolding on children who have not yet encountered information-seeking demands in video-based environments. Second, although our main assumption concerned participants' mental models, we did not directly measure their construction over time. Several authors have described ways of measuring mental models during a task without relying solely on performance scores (e.g., Azevedo, Cromley, & Seibert, 2004; He, Erdelez, Wang, & Shyu, 2008; Marchionini, 1989).

5. Conclusion

Our results indicate that micro- and macrolevels play an important role in information-seeking activity. We had previously noticed that a common step in all theoretical models in this field is the localization of information. The two components of localization appear to be identifying the information being sought and navigating within the video to find it, respectively promoted by macro- and microscaffolding. Concretely, these results allow us to make several recommendations about the design of video-based environments when they are used for information-seeking activity. The presence of the two levels of scaffolding (i.e., segmentation of the timeline and table of contents) enables users carry out their task in a less costly, quicker and more efficient manner.

We can also assume that scaffolding provides an external representation of the video-based environment, and that without scaffolding searchers have to construct mental models by themselves. To confirm this hypothesis, future studies will have to focus on measuring this mental model construction, without relying solely on the performance score and without altering the information-seeking activity. It would be interesting to analyze how this construction changes over time and how effectively the constructed mental model compensates for the absence of scaffolding. Finally, if the information-seeking activity results in the construction of an operational mental model, we can assume that this improves learning (Johnson-Laird, 1983; Norman, 1983). So, in future works, it would also be interesting to measure incidental learning during information seeking activity. Adding an information-seeking step in the learning process could therefore enhance learners' representations and increase the saliency of the relevant information.

Author note

The authors certify that there was no financial or personal interest that could have influenced their objectivity in this study.

Acknowledgments

This work was supported by the CominLabs laboratory of excellence funded by the French National Research Agency (ref. ANR-10-LABX-07-01).

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