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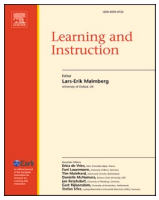

Effects of interruption on eye movements and comprehension during reading on digital devices

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ABSTRACT

The growing use of digital devices brings about interruptions during reading. The aim of the present study is to observe the consequences of an interruption on reading behavior and text comprehension when the information that is evaluated is the information that is being read at the time the interruption occurs. Eye movements (mean number of fixations, regressive fixations and mean fixation duration) were recorded while reading four long texts. Reading was interrupted by an arithmetic verification task either in the middle of a paragraph (intra-paragraph condition) or between two successive paragraphs (inter-paragraph condition). The analysis of the eye movements showed more rereading behaviors when an interruption occurred. The participants who understood the text best were also those who reread the most. The comprehension performances were not affected by the interruption, irrespective of its position (inter- or intra-paragraph). This preservation of performance is discussed in relation to LTWM theory.

1. Introduction

The growing use of digital multimedia devices has resulted in a change in our reading habits. Learning and instruction on digital device generalizes (Delgado & Salmerón, 2021). Instructional methods for teaching digital reading strategies to students are studied (Salmerón & Llorens, 2019). Also, these media seem to decrease comprehension performance compare to paper (Delgado, Vargas, Ackerman, & Salmerón, 2018). Digital devices make it possible to perform a range of different activities in parallel with that of reading (Baccino & Drai--Zerbib, 2015; Junco & Cotten, 2012; Ophir, Nass, & Wagner, 2009; Subrahmanyam et al., 2013; Tran, Carrillo, & Subrahmanyam, 2013). Consequently, reading may well be interrupted by the arrival of a message or notification. By constantly demanding our attention for the processing of other information, digital devices encourage us to interrupt the current activity so that we can undertake another one. It therefore appears to be crucial to study the extent to which interruptions can disrupt the reading process and its result, comprehension of the text.

To read and understand a text it is necessary to focus one's attention on this in order to develop a high-quality representation, which creates the link between the information taken from the text and the reader's knowledge. This representation, which is known as the situation model in the construction/integration model (C/I model, Kintsch, 1991; Kintsch, 1998; Van Dijk & Kintsch, 1983), embodies text comprehension. According to this model, the emergence in memory of the representation of the text is the result of three levels of information processing. The surface level corresponds to access to the lexicon, syntax and punctuation. At the semantic level, the subject develops propositions and associates these to create local coherence. At the referential level, participants link the elements of the different parts of the text with their own knowledge in order to achieve global coherence between the important ideas in the text and their own memory representations. Even though this model applies specifically to attentive reading (Kong, 2019), it does not specify the role of the attentional processes in text comprehension because it is based essentially on a linguistic analysis of the text. However, in order to maintain an active, continuous meaning elaboration process that functions in a cyclical way in the C/I model, readers must be able to keep their attention focused on the text, this being a prerequisite for all cognitive functions (Montel, 2016).

In psychology, attention is a multidimensional concept (Goldhammer, Moosbrugger, & Schweizer, 2007; Posner & Petersen, 1990; Schweizer, Zimmermann, & Koch, 2000). A distinction is made between selective attention, which corresponds to the ability to filter certain elements in the environment to the detriment of others (Broadbent, 2013;

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Treisman, 1964), divided attention, which defines the capacity to share resources between multiple stimuli or tasks (Kahneman, 1973; Wickens, 1981, 2002, 2008), and sustained attention, which designates the ability to stay focused on a specific task (Posner & Petersen, 1990). The model proposed by van Zomeren and Brouwer (1994) includes these various dimensions. These components are likely to play a role in the activity of reading. According to the construction/integration model (Kintsch, 1991), reading requires the ability to select the most coherent elements in order to construct the situation model without overloading the limited working memory capacities. The model identifies macro-rules for the retention of propositions within the situation model. The cognitive cost of applying these rules is not specified. It can well be imagined that the attentional filtering capabilities play a role during this stage, even if the model does not mention this. Furthermore, even if a part of the reading process is largely automated, the continuous elaboration of the situation model, like any other cognitive activity, necessarily requires the allocation and maintenance of attentional resources (Kahneman, 1973; Wickens, 2002). At the time of the interruption, insufficient resources are allocated to text processing, then the encoding of the information should be disrupted and comprehension impaired.

Glanzer et al. (Glanzer et al., 1981, 1984; Glanzer & Nolan, 1986) used interfering reading or arithmetic tasks to interrupt reading. They observed a slowing of reading on the post-interruption sentence. However, this effect was reduced if the participants were able to reread the sentence that preceded the interrupted sentence (Glanzer, Fischer, & Dorfman, 1984), if they were reminded of the thematic of the text (Lorch, 1993), or if they were given a visual image representing the scene described in the text (Schneider & Dixon, 2009). In the absence of such cues, the increase in the reading time for the post-interruption sentence served to retrieve the situation model in order to facilitate the assimilation of new information and integrate this. This form of compensation appears to be sufficient in order to maintain comprehension and no impairment of this was reported in these studies.

To evaluate the effect of the interruption on comprehension several methods have been used: questions paraphrasing sentences of the text (Glanzer et al. 1981, 1984; Schneider, 2009), verification task (Lorch, 1993), number of ideas recalled from the text (McNamara & Kintsch, 1996), number of correct response, false recognition and omission (Oulasvirta & Saariluoma, 2006), fill-in-the-blank questions (Fox, Rosen, & Crawford, 2008). The most used method is multiple choice questions (Fox et al., 2008; Bowman, Levine, Waite, & Gendron, 2010; Cane, Cauchard, & Weger, 2012; Pashler, Kang, & Ip, 2013; Tran et al., 2013; Foroughi et al., 2015, 2016; Cho, Altarriba, & Popiel, 2015). So, we choose to use multiple choice questions.

Some of these studies have provided the basis for the theoretical postulates of the *Long Term Working Memory* (LTWM) model, which predicts a direct integration of information in long-term working memory (Delaney & Ericsson, 2016; Ericsson & Kintsch, 1995) and, consequently, a preservation of the read information in the event of an interruption, even if working memory is no longer available to maintain it. Other results have provided support for this theory by showing that the interruption does not affect comprehension (Cane et al., 2012; McNamara & Kintsch, 1996), and this irrespective of the frequency of the interruption and the difficulty of the interfering task (Oulasvirta & Saariluoma, 2006). Nevertheless, more recent work conducted by Foroughi et al. seems to cast some doubt on the LTWM postulate (Foroughi et al., 2015; Foroughi, Werner, Barragán, & Boehm-Davis, 2016; Foroughi, Werner, McKendrick, et al., 2016). Under interrupted conditions, comprehension performance is preserved for explicitly written information but not for information that has to be inferred on the basis of the text (η^2p=.64) (Foroughi et al., 2015). Despite this, an impairment of performance is also observed for explicit information ($d = 0.51$) in the case of individuals with poorer working memory capacities (Foroughi, Werner, Barragán, & Boehm-Davis, 2016). According to these authors, this suggests that working memory plays a more important role in comprehension than is predicted by LTWM theory. These results should be taken with caution, since the study conducted by Cho et al. (2015) revealed no effect of interruptions ($\eta^2p < .01$) either on factual information or on information merely suggested by the text. This absence of effect could be related to a difference in the complexity of the questions used between the two studies. The study by Foroughi et al. (2015) uses questions require inferences from several pieces of information from the text, whereas the inferences required in the study by Cho et al. (2015) requires only one piece of information. Furthermore, with regard to an interrupted reading task, we may ask about the nature of the resources that determine comprehension performances by making a distinction between the working memory resources dedicated to reading (Daneman & Carpenter, 1980) and the more general resources.

In the digital age, in which reading is regularly interrupted, these contradictory results require us to further investigate this issue in order to be able to identify the determinants which may possibly lead to the impairment of comprehension due to these interruptions. In this context, task-switching paradigms, which require reading to be interrupted in order to perform another task before resuming reading (Bowman et al., 2010; Fox et al., 2008; Pashler et al., 2013), provide information about the impact of more ecological interruptions (arrival of e-mails, text messages, etc.) on text reading. This interest in the impact of task-switching on reading is intrinsically linked to the boom in digital devices which is not only dedicated to reading but also permits the use of other media of various types and on which the classic reading process is modified (Baccino & Drai-Zerbib, 2015; Subrahmanyam et al., 2013). If reading is interrupted by a mail application then participants increase their reading time. However, no impairment in the comprehension of the information present in the text is observed (Bowman et al., 2010; Fox et al., 2008; Pashler et al., 2013). These works therefore also agree with the predictions of LTWM theory. The absence of an interruption effect on performance on comprehension questions does not seem to be linked to the number of media used in parallel or to the frequency of the interruptions. Indeed, the simultaneous use of multiple mail applications also has no negative impact on text comprehension. When it comes to easier texts, a beneficial effect of interruptions has been noted ($\eta^2p = .13$) (Tran et al., 2013). Nevertheless, comprehension is a real-time process and an evaluation of the extent to which the information in the text has been memorized provides a good insight into its final result but not really into the real-time construction of the situation model. In some of these studies (Bowman et al., 2010; Fox et al., 2008), the interruptions lengthened the total reading duration. This might be due to the rereading of the information read prior to the interruption or the slowing-down of the information encoding speed after an interruption, something which would reflect an impairment of the reading process. This final hypothesis is consistent with the data reported by earlier studies (Glanzer et al., 1984). The analysis of eye movements should make it possible to obtain further information on this point.

Whatever the nature of the interruption (arithmetic task, audio story, text unconnected with the thematic of the main text), the position of the interruption does not seem to be a determining factor of its impact on comprehension. Indeed, no impairment of the level of comprehension is observed irrespective of whether the interruption occurs between paragraphs (Cho et al., 2015), between sentences (Glanzer et al., 1981, 1984; Glanzer & Nolan, 1986; Lorch, 1993), or even in the middle of sentences (Cane et al., 2012; McNamara & Kintsch, 1996; Pashler et al., 2013). However, the methodology used to interrupt the text does not always make it possible to control the position of the interruption and the rereading of the interrupted text. For example, in the study by Pashler et al. (2013) which show no effect of interruption ($d = 0.12$), the interruption occurred after a certain paragraph presentation time. It is therefore difficult to know whether the subjects had all arrived at the same point in their reading at the time of the interruption because they might have read at different speeds. In the study conducted by McNamara and Kintsch (1996), the position of the interruption was controlled, but the methodology used (self-paced) did not allow the participants to read the pre-interruption part of the sentence, laking this

a very un-ecological condition. Indeed, eye movement analyses show that when they are able to do so, participants reread the part of the text located immediately before the interruption when their reading is interrupted by an audio story (Cane et al., 2012) ($\eta^2p = .67$) (or a written message (pop-up) which covers part of the text which is currently being read (Drai-Zerbib et al., 2019a, 2019b). Furthermore, the eye tracking methodology makes it possible to control the position of the interruption by means of a visual trigger positioned on a target word and which causes the text to disappear when the subject fixates this target word (Cane et al., 2012; Drai-Zerbib et al., 2019, 2019b). Despite this, no effect of the interruption on comprehension was observed. According to the authors, this also provides support for LTWM theory, which holds that it is possible to access the situation model again on the basis of a few refixed contextual cues. Nevertheless, it should be noted that the information that was read at the time of the interruption and that evaluated by the comprehension studies were not matched in these studies. The questions could refer to information located before, at the time of, or after the interruption. We think, however, that it is important for the information tested by the comprehension test to be the same information as that which is affected by the interruption.

The aim of our study was to observe whether impairments in the reading process and a decrease in comprehension performance occur following an interruption when the questions relate directly to the interrupted information. To do this, the participants read texts with or without interruption. Two conditions enabled us to control the position of the interruption relative to the information evaluated at the time of recall. In the first of these, the participants were interrupted in the middle of a sentence and were evaluated with regard to the information it contained (intra-paragraph questions). In the second, the interruption occurred between two paragraphs and the information acquired on either side of this interruption was evaluated. The questions related both to an item of information situated in the paragraph before the interruption and to an item of information situated in the paragraph after the interruption (inter-paragraph questions). By controlling the position of the interruption in this way, we expected to observe an impairment in comprehension performance in the interrupted condition, in contrast to the results obtained in the majority of other studies. The aim was not to compare performance between the intra-paragraph questions and the inter-paragraph questions. Since inter-paragraph questions require participants to combine two items of information, where the intra-paragraph questions only require one, it would not be surprising to find that they are answered less successfully. We were interested in the effect of the interruption on these two types of question.

Furthermore, in order to assess whether it is memory capacities specific to reading or more general capacities that are able to account for comprehension in a context of interrupted reading, the participants performed a specific reading span task (Daneman & Carpenter, 1980; Desmette, Hupet, Schelstraete, & Van der Linden, 1995) and an auditory-verbal working memory test (Wechsler, 2008). Indeed, it is possible that performance in an interrupted reading task is dependent on the individual's ability to switch from one task to the other. In this case, this ability would be linked to general resources and not only to resources specific to reading. These two metrics should therefore be significant predictors of performance in the comprehension test.

The recording of eye movements made it possible to observe reading behavior after the interruption. In the intra-paragraph condition, the participants could reread the part of the paragraph located before the interruption. We therefore expected this part to be fixated more in the case of an interruption than in a control condition. It should attract more fixations and longer fixation durations on the part of the text preceding the interruption and the interrupted sentence. Furthermore, the participants who perform better on the comprehension test should be those who refix the part of the paragraph situated before the interruption the most, thus testifying to the efficiency of a rereading strategy. In the event of an interruption, such strategy could help preserve comprehension. To test those hypothesis, we compared the eye movement of half of the participants who performed best on the comprehension test to those who performed worst with and without interruption. In the inter-paragraph condition, the participants could not reread the text before the interruption. Nevertheless, we expected to observe a slowing-down of the reading process for the first sentence of the post-interruption paragraph. This should be revealed by (1) more fixations on the first sentence of the paragraph and/or (2) longer fixation durations for this sentence. This would be consistent with what has been observed in other studies showing an increase in reading duration for the post-interruption sentence (Glanzer et al., 1981, 1984; Glanzer & Nolan, 1986; Lorch, 1993).

2. Method

2.1. Participants

Sample size was defined with a power calculation using *G Power* (Faul, Erdfelder, Lang, & Buchner, 2007); for a full description, see Erdfelder, Faul, & Buchner, 1996) with power (1 - β) set at 0.80 and α = 05, two-tailed. For comprehension test, this analysis revealed that on the basis of the mean, a total sample size (n = 6) would be needed to obtain statistical power at the recommended 0.80 level (Cohen, 1988). For eye movement data, this analysis showed that a total sample size (n = 24) would be needed to obtain statistical power at the recommended level. 38 students (30 females, mean age = 21.64 years; SD = 2.35) were recruited from the University campus and the surrounding community. They reported French as their first language, as well as no known dyslexic disorder. Their vision was normal or corrected-to-normal by means of contact lenses. Since three participants were excluded from the analyses due to calibration issues, our analyses relate to 35 participants (29 females). All participants gave written informed consent in accordance with the Declaration of Helsinki. Full review and approval was not required according to our Institution's guidelines and national regulations.

2.2. Linguistic material

We used procedural texts, in which information describing a process is represented in a set of actions or phenomena organized, and for which interruptions could seriously interfere with comprehension. Indeed, if the information structure is disturbed by the interruptions, and the order of the information is lost, it might lead to a failure to well understand the process described.

Four procedural texts written in French were adapted from encyclopedia articles. The topics of the text concern the production process of 4 aliments, maple syrup, beer, cheese and coffee. Each consisted of 8 paragraphs and contained a mean of 1051 words presented in Times New Roman font, size 14. The texts were presented on the screen with double line spacing and justified.

Each participant read three texts containing 2 intra-paragraph interruptions and 2 inter-paragraph interruptions, as well as a fourth text which did not contain any interruption (control text). In order to counterbalance the text interruption conditions four lists were created using *ExperimentCenter 3.7*. The position of the interruption in the interrupted texts also varied between lists, this allowed us to test all the positions intra-paragraph and inter-paragraph of the four texts.

Comprehension was evaluated by means of 48 multiple-choice questions (α = 0.70) created by the experimenters (see, appendix A). For each of the 4 texts, those questions matched 12 information. Half of these related to an item of information located between the third and fifth line of a paragraph (intra-paragraph questions). The other half required the readers to combine information located in two successive paragraphs of the text (inter-paragraph questions). The participants had to select a response out of the four proposed. Some of the incorrect responses contained information taken from the text. To give the correct response, the participants did not require prior knowledge on the topic, but it was necessary to establish a relation between a proposition and the

context defined by the question.

For the 3 interrupted texts, each participant had to answer 36 questions, but only 12 were matched with the information targeted by interruptions, including 6 intra-paragraph and 6 inter-paragraph questions. The remaining 24 filling questions consisted of 12 intra-paragraph questions and 12 inter-paragraph questions for information that was not targeted by interruptions in the list to which the participant belonged. These questions were kept 1) in order that the participants see all the questions 2) to have the same number of questions in the control text and the interrupted texts, and 3) to ensure that the participants did not recognize that the information to be remembered was always located at a point of interruption. This made it possible to prevent them from developing a strategy for memorizing this information. They also answered 12 questions for the control text, including 6 intra-paragraph and 6 inter-paragraph questions.

2.3. Apparatus

The eye movements were monitored using the SMI RED 250 system with a sampling rate of 250 Hz. A head and chin rest stabilized the head. The 9-point calibration was accepted for an error of less than 0.5°. The fixations were extracted using the *BeGaze* 3.7™ software running a velocity-based algorithm with a minimum angle of 40°/s. The stimuli were presented on a high-resolution 22″ screen (1920*1080) using the *Experiment Center* 3.7™ software.

2.4. Interrupting task

The interrupting task was an arithmetic task requiring the participants to check a series of four additions presented after each interruption. They were instructed to indicate whether the answer was correct (e.g., 48 + 24 = 72? True/False).

2.5. Explanatory variables

We used two pre-tests to determine whether working memory resources specific to reading or more general working memory resources are related to comprehension performance. The reading span test (Daneman & Carpenter, 1980) in its adapted French version (Desmette et al., 1995) made it possible to collect the reading span ($\alpha = 0.71$). The digit span *subtest* from WAIS-IV (Wechsler, 2008) made it possible to collect an indicator of auditory-verbal working memory (auditory-verbal span).

2.6. Experimental checks

The difficulty of the texts and the participants' prior knowledge of the topics covered were evaluated as Post-test on a 5-point Lickert scale after each of the texts had been read. For the difficulty the scale ranged from 1 "no difficulty" to 5 "very difficult", for the prior knowledge the scale ranged from 1 "No knowledge" to 5 "exhaustive knowledge".

2.7. Procedure

After giving their written consent, the participants completed a demographic questionnaire and the pre-tests. There was then a 10-min pause before the reading task was performed. The participants sat 60 cm from the screen and eye tracker. Each participant was assigned to one of the four lists in order to counterbalance the position of the interruptions in the texts. Thus, each participant read all the texts and saw both interruptions intra-paragraph and inter-paragraph, and the control text was not always the same. The order of presentation of the texts within the lists was automatically randomized by the *Experiment Center 3.7*™ software. Before presentation of each of the texts, calibration was repeated in order to avoid an offset of the eye movement position errors during the experiment. The participants read one paragraph at a time and pressed the spacebar to move on to the next. They were free to read them at their own speed but could not go back once they had moved on to the next paragraph. After reading each of the four texts, the participants answered the 12 questions.

The interruptions were triggered as follows: in the intra-paragraph condition, by means of a visual trigger set to 150 ms when the participant's gaze arrived at a target area; in the inter-paragraph condition, when the participant pressed the spacebar to move on to the next paragraph) (Fig. 1). Following an intra-paragraph interruption, the participants resumed their reading as they wished in the interrupted paragraph. Following an inter-paragraph interruption, they started reading again at the next paragraph. The visual trigger in the middle of the paragraph was retained in the control and inter-paragraph conditions and made it possible to mark the data for subsequent analysis. Intra-paragraph Interruptions could be inside paragraphs 1, 2, 3, 4, 5 and 6. Inter-paragraph interruptions could be between paragraphs 1 and 2, 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7.

To analyze the eye movements, three areas of interest (AOIs) were defined in order to extract the oculometric data using the *BeGaze* 3.7™ software (Fig. 2). A first AOI (AOI 1) was located in the part of the paragraph before the interrupted sentence. This allowed us to collect the eye movements in the part of the paragraph that was read before the visual trigger was activated and thus to infer whether or not the subject read the same part again. A second AOI (AOI 2) was located at the interrupted sentence. This AOI allowed us to compare the eye movements for this sentence as a function of interruption condition. Furthermore, in the event of an interruption, it made it possible to determine the relation between the eye movements for this sentence, which contained the target information, and the comprehension performance. Both AOI 1 et 2 were used to extract information in the intra-paragraph condition. A third AOI (AOI 3) was defined on the first sentence of each paragraph as of the second. This allowed us to compare the eye movements when the participant started to read a paragraph as a function of interruption condition. AOI 3 were used in to collect data in the inter-paragraph condition.

It is important to note that for AOIs 1 and 2, we focused our analyses only on the eye movements collected after activation of the visual trigger. We did not analyze the data before this point of transition. Comparing the eye movements between the control condition and the interruption condition for these two parts of the text, following activation of the *trigger,* is sufficient to observe the effect of the interruption.

2.8. Eye tracking data filtration

The ocular data was visually inspected from the scanpaths, to ensure that there were no inconsistencies in the recordings, this lead to the elimination of 3 participants whose position of the eyes did not coincide with the lines of texts. From the total of fixations made by the participants on our AOIs ($n = 22{,}462$) we eliminate all the fixations below 100 ms and superior to 679 ms (which correspond to the mean duration of all the fixations plus 2.5 *SD* of all the fixations durations). In total 2477 fixations had been removed (9.2% of 22,462). In order to eliminate a possible effect linked to differences in sentence length, we calculated the mean number of fixations per character (number of fixations in an area of interest divided by the number of characters it contained) and the mean fixation duration per character (total fixation duration in an area of interest divided by the number of characters it contained). These values make it possible to eliminate the variability linked to the sentence length, while retaining the variability linked to the differential processing of the text in the case of an interruption. Finally, in order to identify the regressive fixations involving one and the same sentence in AOIs 2 and 3, we took as our starting point the position on the horizontal axis of the fixations given by the *BeGaze* 3.7 software. As the texts were read from left to right, and as the AOIs 2 and 3 are positioned only on a single line of text, the position of the fixation N on the horizontal axis (X) must be superior to the position of the fixation N-1 on this axis, unless

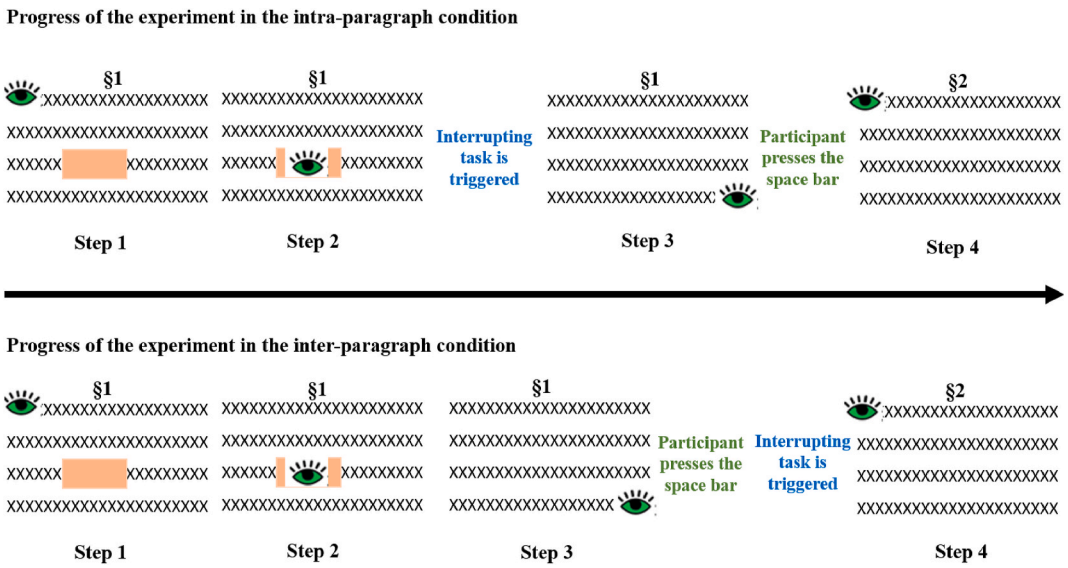

Fig. 1. Progress of the experiment for an intra-paragraph interruption (up) and inter-paragraph interruption (down). This is an example for §1 and §2. Whatever the condition, the participants started to read the texts (step 1) until they arrived at a *visual trigger* (step 2) area located between the third and fifth line. This area is represented here by a red rectangle but was not identifiable as such by the participants. In the intra-paragraph interruption condition, the interfering task was automatically triggered when the subject fixated the *trigger*, whereas in the control condition, activation of the trigger made it possible to mark the data. Once the participants had finished reading §1 (Step 3), they pressed the spacebar to move on to §2 (Step 4). In the control and intra-paragraph conditions, the participants moved directly on to §2, whereas in the inter-paragraph condition, pressing the spacebar first triggered the arithmetic task which they had to complete before being able to move on to §2. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

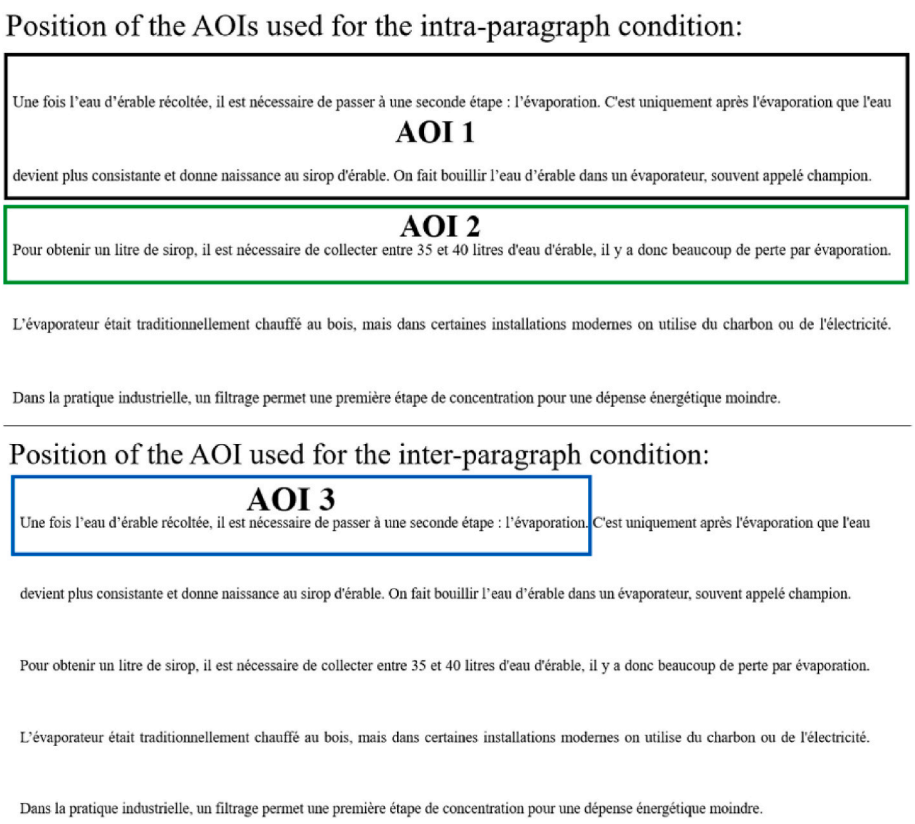

Fig. 2. Positioning of the AOIs in a paragraph. On the top, AOIs 1 and 2, were used to compare the intra-paragraph interruption conditions. They correspond respectively to the part of the text preceding the interrupted sentence and the target sentence in which the interruption is liable to occur. Below, AOI 3 corresponds to the first sentence of the paragraph. This made it possible to compare the inter-paragraph interruption conditions.

it's a regressive fixation (i. e. a fixation from right to left in system where reading take place from left to right). A fixation N was considered to be regressive if its position on this axis (given in pixels) came before that of fixation N-1. We choose to focus our analysis on the mean number of fixation per character, the mean number of regressive fixation per character, and the mean fixation duration per character. Previous

studies (Rayner, Chace, Slattery, & Ashby, 2006) has shown that duration and number of fixations are sensitive to text difficulty, and linked to high level comprehension process, and we believe that the interruptions could affect those process.

2.9. Analysis

The analyses were performed using the JAMOVI software, v1.1.9.0. For linear mixed model we used the package GAMLj. Correlation matrix between the relevant data are provided in appendix C.

2.9.1. Analysis on comprehension

To test if the presence of interruptions within the texts influenced comprehension, the error rates for all the questions relating to the interrupted texts and the control text were compared with a linear mixed model with participant, texts, and the lists used to counterbalance our conditions as random factors, and interruption (interrupted texts vs. control text) as intra-subject fixed factor.

To test whether the comprehension of the information was disrupted depending on the location of the interruption, the error rates for the interrupted texts were recalculated without the 24 fillers questions, only on the basis to the 12 questions relating to information targeted by the interruption according to the list of the participant. We then used a linear mixed model with participant, texts, and the lists used to counterbalance our conditions as random factors, and interruption (interruption vs. control) and position (intra-paragraph vs. inter-paragraph) as intra-subject fixed effect.

2.9.2. Analysis between explanatory variable and comprehension in interrupted texts

In order to determine whether working memory capacities are predictive of the error rate for the interrupted texts, we conducted a multiple regression analysis with reading span and the standard score on the WAIS-IV subtest as predictors of the error rate.

2.9.3. Analysis on eye-tracking data

The analysis of the eye movements related to three measures: the mean number of fixations per character, the mean number of regressive fixations per character, and the mean fixation duration per character (in milliseconds) for the AOIs in question (*cf.* Fig. 2).

In order to take account of the participants' level of comprehension during the eye movement analysis, we distinguished between two comprehension level groups relative to the median of the total error rate for the questions (0.46). The participants with a score lower than the median were the *"high comprehenders" (N = 17)*, and those with a score higher than the median were *"low comprehenders" (N = 18)*. The *"low comprehenders"* had a significantly higher error rate than the *"high comprehenders"*, t (33) = 8.74, $p < .001$ and $d' = 2.96$.

For each AOI, the eye movements were analyzed using linear mixed model (LMM), with subjects, trials, and the lists to counterbalance our conditions as random factors, and both comprehension level (*"high comprehenders* vs. *"low comprehenders"*) as inter-subject fixed effect, and interruption (Interruption vs. No interruption) as intra-subject fixed effect.

3. Results

3.1. Interrupting task

The mean error rate of 5.6% (SD = 5.8%) on the interfering task indicates that the arithmetic task was performed correctly and did not cause any difficulties.

3.2. Explanatory variables

Daneman and Carpenter's Test (1980)*:* The mean reading span was 3.3 (SD = 0.80). This is consistent with the data from the studies used to elaborate this test (Daneman & Carpenter, 1980; Desmette et al., 1995).

*Subtest from WAIS IV, auditory-verbal working memory span***:** For the digit span, the raw scores were converted to standard scores in accordance with the WAIS-IV protocol. The mean standard score of 9.58 (SD = 2.58) was close to what was found in the calibrated test (10).

The correlation analysis with a *Pearson's R* showed that the two metrics were correlated, with $r = 0.55$, $p < .001$.

3.3. Experimental checks

The participants rated the texts for difficulty and prior knowledge on Lickert scales from 1 to 5. They rated the texts as being moderately difficult (M = 2.96; SD = 0.78) and also declared that they had almost no prior knowledge of the topics addressed (M = 1.32; SD = 0.58). The participants did not declare more prior knowledge for the control text (M = 1.37, SD = 0.69) than for the interrupted texts (M = 1.30, SD = 0.28), with t (34) = 0.58, p = .56, d' = 0.10. The subjects did not judge the interrupted texts more difficult (M = 2.96, SD = 0.55) than the control texts (M = 2.94, SD = 0.64 with t (34) = 0.14, p = .90, d' = 0.02.

3.4. Comprehension

3.4.1. Differences between interrupting conditions

The participants answered seriously to the comprehension questions. Indeed, the questions were in the form of multiple-choice questions with 4 possible answers, with only 1 right answer. This gives a theoretical percentage of error of 75% if the participants answer at random to all the questions. We compared this theoretical percentage of error, to the reals percentages of error, for both the inter-paragraph and intra-paragraph questions. Their performances were sufficiently different from chance (75%), with a mean error percentage of 53% for the inter-paragraph questions, t (34) = −10.6, $p < .001$, and 36% for the intra-paragraph questions, t = −16.20, $p < .001$.

We compared the error rate for the control text questions to the interrupted texts questions. The error rate corresponding to the questions for the texts with interruptions was lower than for the questions on the text without interruption, with b = - 0.05, 95% CI [- 0.09, 0.00], t = - 1.91. (see, Fig. 3).

We then compared error rates for the inter-paragraph questions targeted by interruption, the inter-paragraph questions of the control text, the intra-paragraph questions targeted by interruption and the intra-paragraph questions of the control text (see, Fig. 4). The error rate

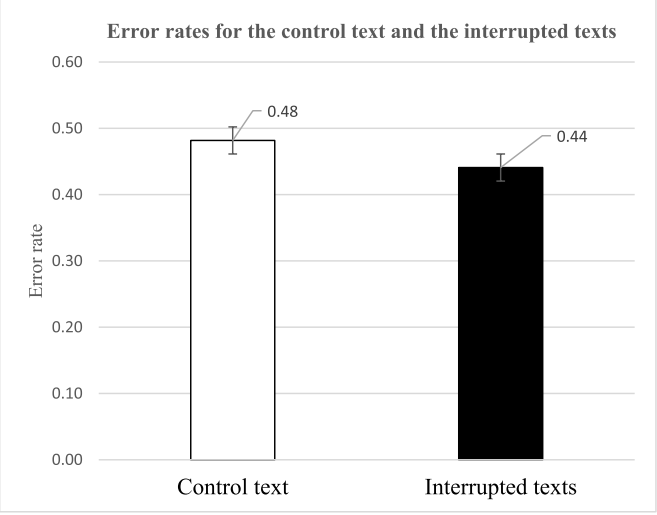

Fig. 3. Error rates for questions of the control text and the interrupted texts. The error bars correspond to the standard error.

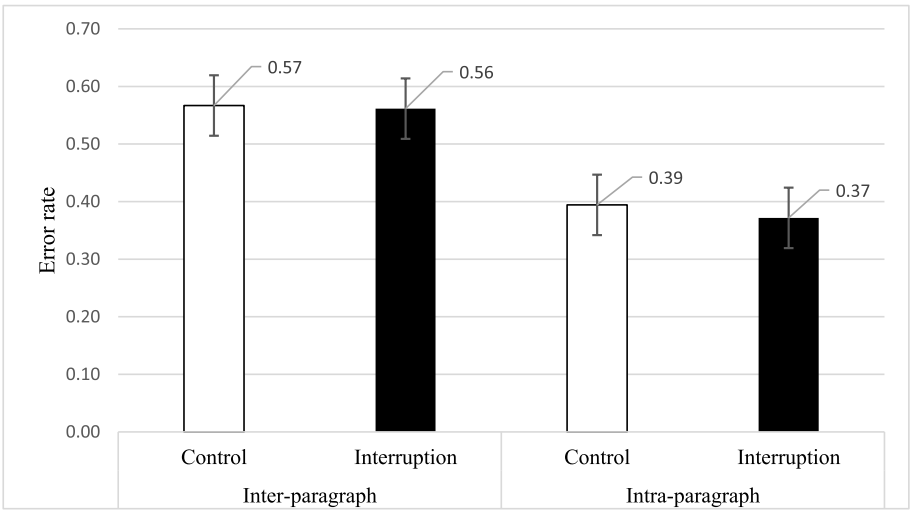

Fig. 4. Error rates for the inter-paragraph questions targeted by interruption, the inter-paragraph questions of the control text, the intra-paragraph questions targeted by interruption and the intra-paragraph questions of the control text. The error bars correspond to the standard error.

was lower for the intra-paragraph than for the inter-paragraph questions, with $b = -0.18$, 95% CI [- 0.27, −0.10], $t = -4.18$. By contrast, and contrary to our expectations, when the questions related to information whose reading really had been interrupted, the error rate in the case of an interruption did not differ significantly from that without interruption, $b = -0.01$, 95% CI [- 0.10, 0.07], $t = -0.30$. There was no interaction between the type of question and the interruption, $b = -0.02$, 95% CI [- 0.19, 0.15], $t = -0.22$.

3.4.2. Relation between explanatory variables and comprehension in interrupted texts

The linear model was marginally significant, $F(2, 32) = 3.02$, $p = .06$ et $R^2 = 0.16$. Only the standard score on the WAIS-IV subtest was a significant predictor of the error rate, $t(32) = -2.73$, $p < .05$ and $\beta = -0.02$. The reading span did not predict the error rate at a significant level, $t(32) = 0.47$, $p = .63$ and $\beta = -0.01$. It therefore seems that general working memory resources are related to comprehension performance in the event of an interruption, but not reading span.

3.5. Eye movements

3.5.1. Intra-paragraph analyses

In the intra-paragraph condition, the rereading behaviors are revealed by the mean number of fixations and the mean fixation duration per character on AOI 1 (part of the text read before the interruption) and AOI 2 (sentence in which the interruption occurred) (cf. Fig. 2). Fig. 5 presents the number of fixations per character as a function of the interruption condition and the comprehension level for these two AOIs. The mean number of regressive fixations per character was also analyzed for AOI 2.

For AOI 1, the number of fixations was greater in the interruption condition, $b = 0.05$, 95% CI [0.04, 0.05], $t = 12.13$ (see Table 1, appendix B). The fixation duration was also longer in the case of an interruption, $b = 11.57$, 95% CI [9.52, 13.51], $t = 11$. (see Table 2, appendix B). The presence of the interruption also resulted in more fixations on AOI 2, $b = 0.06$, 95% CI [0.05, 0.07], $t = 9.02$, and more regressive fixations, $b = 0.02$, 95% CI [0.01, 0.02], $t = 6.99$ (see Tables 1 and 3, appendix B). The fixation duration on AOI 2 was also longer in the interrupted condition, $b = 12.82$, 95% CI [9.42, 16.23], $t = 7.38$ (see

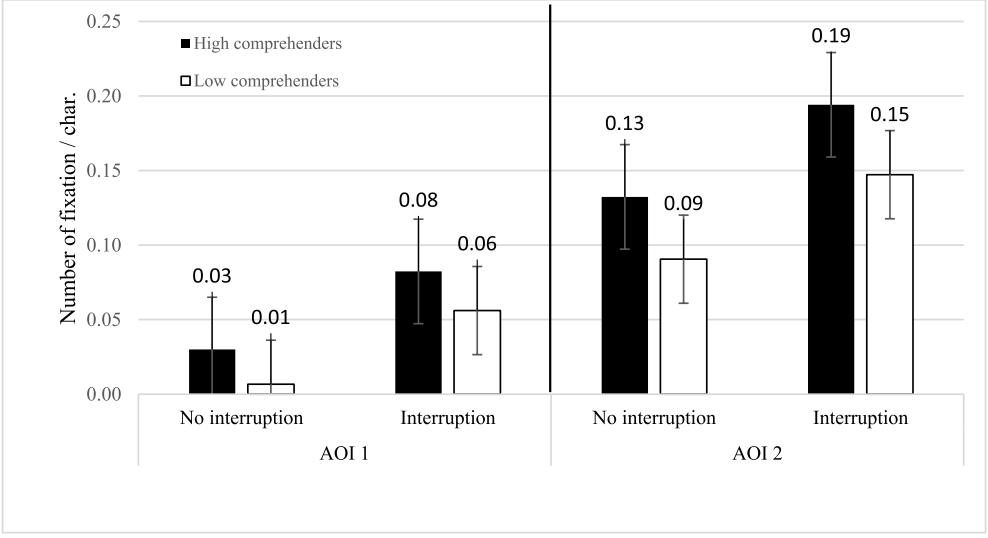

Fig. 5. Number of fixations per character for AOI 1 and AOI 2 as a function of interruption condition and comprehension level (High or low comprehenders). The error bars correspond to the standard error.

Table 2, appendix B). Overall, this data conforms to our expectations and shows a more pronounced rereading behavior in response to an interruption, with more gaze fixations and longer fixation durations for the interrupted sentence and the portion of the text that preceded it.

Comparing the number of fixations, as well as the fixation duration on AOI 1, as a function of the comprehension levels provides information about the usefulness of the rereading strategy. In line with our expectations, the comprehension level had an impact on the number of fixations performed: the *"low comprehenders"* made less fixations than the *"high comprehenders"*, $b = -0.02$, 95% CI [- 0.05, 0.00], $t = -1.93$ (cf. Fig. 5). Nevertheless, no interaction effect between the presence of an interruption and the comprehension level was observed, $b = 0.00$, 95% CI [- 0.02, 0.01], $t = -0.28$. No effect of comprehension levels on fixation duration was observed, $b = -5.08$, 95% CI [−10.78, 0.63], $t = -1.75$. There was no interaction between the comprehension level and the presence or absence of an interruption, $b = 0.89$, 95% CI [- 4.98, 3.20], $t = -0.43$.

The same pattern was observed for AOI 2 in which the interruption occurred: the *"low comprehenders"* made less fixations ($M = 0.24$, $SD = 0.07$) than "*high comprehenders*" ($M = 0.33$, $SD = 0.13$), $b = -0.05$, 95% CI [- 0.08, - 0.01], $t = 2.77$. Nevertheless, no interaction effect between the presence of an interruption and the comprehension levels was observed, $b = -0.01$, 95% CI [- 0.03, 0.02], $t = -0.39$. The *"low comprehenders"* also made more regressive fixations per characters ($M = 0.05$, $SD = 0.03$) than the "*high comprehenders*" ($M = 0.08$, $SD = 0.05$), $b = -0.02$, 95% CI [- 0.03, - 0.01], $t = -3.35$. However, no interaction effect between the presence of an interruption and the comprehension levels was observed, $b = -0.00$, 95% CI [- 0.01, 0.01], $t = -0.94$. The fixation duration was shorter among the "*low comprehenders"* ($M = 63$ ms, $SD = 20$) than *"high comprehenders"* ($M = 81$ ms, $SD = 32$), $b = -8.99$, 95% CI [- 17.74, - 0.18], $t = -2.00$. There was no interaction between the presence of an interruption and the comprehension level, $b = -0.16$, 95% CI [- 6.97, 6.65], $t = -0.05$. As expected, this data suggests that the "*high comprehenders"* made more fixations, and in particular regressive fixations, than the "*low comprehenders*", thus showing the effectiveness of a rereading strategy, irrespective of whether or not the reader is interrupted.

3.5.2. Inter-paragraph analysis

In order to observe whether an interruption affects the way a new paragraph is started, the mean number of fixations and regressive fixations per character and the mean fixation duration per character for the first sentence of the paragraphs (AOI 3) were analyzed as a function of interruption condition and comprehension level.

The number of fixations on the first sentence of the paragraphs (AOI 3) did not vary as a function of interruption condition, $b = 0.00$, 95% CI [- 0.02, 0.01], $t = -0.32$ (see Table 1, appendix B). The results relating to the number of regressive fixations were identical, $b = 0.00$, 95% CI [00, 0.01], $t = -1.09$ (see Table 3, appendix B). The effect of comprehension level also appeared to be non-significant, in terms of both the number of fixations, $b = -0.01$, 95% CI [- 0.05, 0.02], $t = -0.87$ and the number of regressive fixations per character, $b = -0.01$, 95% CI [- 0.02, 0.01], $t = -1.10$. No interaction between the presence of an interruption and the comprehension level was observed for either measure, $b = 0.00$, 95% CI [- 0.03, 0.03], $t = -0.15$ and $b = 0.00$, 95% CI [- 0.01, 0.01], $t = -0.06$ respectively. Finally, there was no significant effect for the fixation durations, which varied neither as a function of interruption condition (see Table 2, appendix B), $b = 1.87$, 95% CI [- 5.67, 1.93] $t = -0.97$, nor as a function of comprehension level, $b = -0.80$, 95% CI [- 10.60, 8.99] $t = -0.16$. The interaction was also non-significant, $b = -2.10$, 95% CI [- 9.70, 5.51] $t = -0.54$. Contrary to our expectations, the interruption therefore did not affect the reading process when participants started a new paragraph.

4. Discussion

This study evaluated the consequences of interrupting the digital reading of a text for individuals who had declared they had no knowledge of the subject matter addressed. The effect of interruptions was studied between paragraphs as well as within paragraphs (Pashler et al., 2013). The intra-paragraph questions were constructed by matching the evaluated information with the information read when a visual trigger was activated (Cane et al., 2012). The inter-paragraph questions were constructed on the basis of the information located on either side of an interruption that occurred between two paragraphs. By designing our questions in this way, we expected to demonstrate a disruptive effect of interruptions which had not been observed in other studies (e.g. Cane et al., 2012; Cho et al., 2015; Fox et al., 2008; Glanzer et al., 1984; Pashler et al., 2013). At the same time, we also evaluated general working memory (Wechsler, 2008) and working memory specific to reading (Daneman & Carpenter, 1980; Desmette et al., 1995) in order to determine the best predictor of comprehension performance in the presence of interruptions. Finally, the eye movement analysis enabled us to study how participants resumed reading when they were able to go back over the text which they had already read after the interruption (intra-paragraph condition). It also enabled us to observe how readers started paragraphs that had or had not been preceded by an interruption when they did not have the opportunity to go back over the text (inter-paragraph condition).

The comprehension performances were slightly better for the set of questions relating to the interrupted texts than for the questions relating to the uninterrupted texts. This result is somewhat surprising. Indeed, the majority of earlier studies showed no effect of interruption on the recall of text information (Bowman et al., 2010; Cane et al., 2012; Cho et al., 2015; Fox et al., 2008; Glanzer et al., 1981, 1984; Oulasvirta & Saariluoma, 2006; Pashler et al., 2013), and a small number of studies (Foroughi et al., 2015; Foroughi, Werner, McKendrick, et al., 2016) found an interruption-related impairment of performance. To our knowledge, only one study (Tran et al., 2013) revealed an improvement of comprehension when participants responded to messages while reading simple texts. According to these authors, the interruption rendered more complex a task perceived as unstimulating and in which the participants' attention tended to wane, thus making it possible to bring about a reinvestment of attentional resource on the part of the participants. This reasoning can be compared to the inverse U-curve for vigilance proposed by Yerkes and Dodson (1908) (see also, Unsworth & Robison, 2016), who suggested that performances are better for an intermediate level of vigilance induced solely by a task that is neither too simple nor too complicated. It would seem that this is the case in our study, in which the participants evaluated the texts as being of an intermediate level of difficulty. It might be possible to test this hypothesis by continuously measuring the physiological markers of changes in vigilance during the reading of an interrupted text.

If we compare only performance on the questions relating to the information that was locally interrupted with performance on the control text, the presence of an interruption had no significant effect on the error rate. This result is contrary to our expectations because the very aim of constructing questions that targeted the interrupted information was to observe an impairment of comprehension performance. In this, our study continues in the line of research which has shown no effect of interruptions on comprehension (Bowman et al., 2010; Cane et al., 2012; Cho et al., 2015; Fox et al., 2008; Glanzer et al., 1984; McNamara & Kintsch, 1996; Oulasvirta & Saariluoma, 2006; Pashler et al., 2013). Two explanations may account for these observations. On the one hand, they are consistent with the predictions of the long-term working memory model, which holds that once information has been read, it is directly integrated into the situation model in LTM and therefore protected against degradation (Delaney & Ericsson, 2016; Ericsson & Kintsch, 1995). On the other, the rereading behaviors, which were more marked when reading was interrupted mid-paragraph, might explain

why performance was preserved in this condition. This explanation cannot account for the situation when the interruptions occurred between the paragraphs because the participants were not able to reread the paragraph that preceded the interruption.

Unlike in the study conducted by Cane et al. (2012), we did not observe any ceiling effect in the comprehension test. The intra-paragraph questions were answered more successfully than the inter-paragraph questions irrespective of the presence of an interruption. There is nothing surprising about this because the inter-paragraph questions were more difficult: they made it necessary to identify two items of information whereas the intra-paragraph questions only required the identification of a single item. Nevertheless, interruptions did not affect comprehension differently as a function of the two types of question.

The eye movement analysis confirmed that whenever it was possible, the readers tended to reread the part of the text that preceded the interruption (Cane et al., 2012). In our study, the character rereading markers (greater number and duration of fixations) were observed when the readers were able to go back over the text they had already read. This behavior might indicate a rereading strategy intended to retrieve contextual cues in order to re-access the situation model, as proposed by Cane et al. (2012). This strategy seems to be effective since there was no difference in performance, irrespective of whether the readers were interrupted, for the questions relating to information located in the middle of a paragraph during reading. Rereading the interrupted sentence and the part of the paragraph that precedes it would therefore seem to compensate for the consequences of an interruption. Furthermore, there is indeed a relation between rereading behaviors and comprehension performance, since the *"high comprehenders"* were also those who most frequently read these parts of the text, irrespective of whether an interruption was present. However, it is also possible that rereading behaviors serve simply to identify one's location in the text (Baccino & Pynte, 1994). Indeed, when participants are not able to reread the text, this does not lead to a greater impairment in comprehension performance, which should be the case if rereading is necessary for the recovery of the situation model. Nevertheless, it should be noted that the questions were not constructed in the same way in the condition in which the participants were able to read the texts and in the condition in which they were not able to do so. It would be interesting to perform a study in which this parameter is controlled.

When the interruption occurred between two paragraphs, it did not modify the reading behavior for the first sentence of the post-interruption paragraph. This result contrasts with those of earlier studies (Glanzer et al., 1981, 1984) which found an increase in reading time for the post-interruption sentence. However, in these experiments, the sentence at which the participants resumed their reading after the interruption belonged to the same body of text as the one that preceded it. To understand it, it was therefore necessary to reactivate the contextual information contained in the preceding sentence. This is not necessarily the case when the interruption occurs between two paragraphs. In effect, when the subject starts a new paragraph, it is not necessary to reactivate the information present in the previous paragraph in order to understand it. This explains why we observed no difference in fixation duration when the interruption occurred between the paragraphs. It would also be interesting to observe the eye movements of participants able to reread the pre-interruption paragraph. If the information in the pre-interruption paragraph is not necessary in order to understand the post-interruption paragraph, we should not observe any rereading behavior.

Moreover, our study shows that general working memory capacities are a better related to comprehension performance in the event of an interruption than reading span. Even though reading span is intended to evaluate working memory dedicated to reading, it is possible that in an interrupted reading task, the general working memory capacities underpin the alternation or superimposition of the tasks and permit good comprehension performance. This could be explained by the fact that the WAIS-IV subtest used to evaluate general working memory capacities also accounts for the ability to maintain the vigilance and concentration that play a role in text comprehension (Commodari & Guarnera, 2005). Despite this relation between working memory and comprehension, we did not observe differences between levels of digit span on eye-movements.

When reading is performed on digital media, interruptions are omnipresent and our study suggests that their impact on comprehension may not be particularly critical. This is positive considering their increasing use as a learning medium. However, the interruptions that we used were very different from those likely to occur in a digital reading environment. No-one breaks off their reading to perform an arithmetic task and a future study could therefore make use of more ecological interruptions. Furthermore, we only used a single type of interruption, whereas a variety of interruptions generally occur when reading on digital equipment. In addition, we tested the effect of interruption only on procedural texts. In these texts, the organization of the information is structured sequentially. It is possible that this structure helps to realize that a step is missing for the process to be consistent. Being aware that a piece of information is missing could encourage one to make an effort to retrieve it in memory, or to reread the text to find it when it is possible. To our knowledge, no study has attempted to compare the effect of interruptions on comprehension and eye movements depending on the nature of the text. Such a study could reveal whether the structure of the text modulates the effect of the interruption on reading. Finally, this study examines reading interruptions in adults who have already automated the reading process. The results could be different in individuals whose acquisition of reading process is in progress, and a study on this population has not yet been carried out to our knowledge.

5. Conclusion

In conclusion, our study shows that, in procedural texts, when we compare the information evaluated by the comprehension test and that which is being read at the time the interruption occurs, there is no impairment in comprehension performance. When the interruption occurs in the middle of a paragraph, this preserved performance can be explained by the subject's rereading behavior, as revealed by an eye movement analysis. In our study, the participants were all unfamiliar with the subject matter addressed. It would be interesting to study the consequences of interruptions as a function of readers' level of expertise in the topics presented in the text.

CRediT authorship contribution statement

Guillaume Chevet: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Thierry Baccino:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Lucas Marlot:** Investigation. **Annie Vinter:** Writing – review & editing. **Véronique Drai-Zerbib:** Conceptualization, Methodology, Writing – original draft, Formal analysis, Visualization.

Appendix A: Examples of paragraph and questions related to them

Intra-paragraph question:

The first method of heating is the decoction. A part of the content of the vat is removed and brought to a boil before being reincorporated, this is

called a soak, not to be confused with steeping. Several soaks are performed in order to gradually increase the temperature of the vat. This heating technique is used for bottom fermentation, although in reality it can also be used for top fermentation. The second technique, which is commonly called stepwise infusion, consists of adding very hot water at regular intervals. Finally, the last method is the simple infusion: water is heated and added to the malt. After heating, the brewing process ends with the extraction of the "primary wort" by filtering in another tank, called a "filter tank". The remaining residue, consisting of filtered malt grains that are no longer needed, is removed. The wort is the liquid at the base of the beer and is used for the following steps.

What is the name of the second heating method described in the text?

· Simple infusion
· Decoction
· Stepwise infusion
· Boiling

Inter-paragraph question:

The production of beer begins with malting. This step consists in reproducing the natural development of the barley grain so that it produces certain enzymes necessary to transform the starch into simple sugars, which are used for the alcoholic fermentation. The malting process itself is divided into four stages. First the soaking, which consists, during a little 10 h to immerse the barley in water. Then the germination, which, as its name indicates it, is the period during which the barley will begin to germinate. Especially, it is during the germination that barley will produce enzymes, in particular amylase. This stage lasts about 50 h and gives birth to what is called green malt.

The penultimate stage of malting is called kilning. It consists of drying the green malt in an air kiln at a temperature of 40 °C for about 30 h. The moisture content of the grain drops from 45% to 4%. This decrease has the effect of stopping the development of the grains. The fire is a rise in temperature during heating where it reaches between 85 °C and 105 °C for one to 4 h in the oven. The more the grain is heated, the more it dehydrates and darkens. This step is crucial because it is the duration of the "fire" that will determine the color of the beer. Similarly, the humidity level will affect the caramel aroma. Finally, malting ends with degerming, which consists in separating the malt from the roots that have grown.

During the malting process, in between which stages does germination take place?

· The soaking and heating
· The soaking and kilning
· The heating and brewing
· The heating and fermentation

Appendix B: Tables of means and standard deviations for eye-tracking datas

Table 1
Number of fixation per character as a function of the interrupted condition and the presence of an interruption

	AOI 1		AOI 2		AOI 3	
	Control	Interruption	Control	Interruption	Control	Interruption
M	.02	.07	.11	.17	.16	.16
SD	.03	.05	.04	.08	.5	.07

Table 2
Duration **of fixation per character (ms) as a function of the interrupted condition and the presence of an interruption**

	AOI 1		AOI 2		AOI 3	
	Control	Interruption	Control	Interruption	Control	Interruption
M	4.4	15.5	29.7	42.5	43.7	42.2
SD	7.1	13.2	10.0	20.5	12.7	20.2

Table 3
number of regressive fixation per character as a function of the interrupted condition and the presence of an interruption

	AOI 2		AOI 3	
	Control	interruption	Control	Interruption
M	.02	.04	.03	.03
SD	.02	.03	.02	.03

Appendix C: Correlation between variables

Correlation Matrix between the pre-tests scores, eye movements, and error rates for the intra-paragraph condition

Correlation Matrix between the pre-tests scores, eye movements, and error rates for the intra-paragraph condition

	Digit span	Reading span	Nfix_AOI1 control	Nfix_AOI1 interruption	Tfix_AOI1 control	Tfix_AOI1 interruption	Nfix_AOI2 control	Nfix_AOI2 interruption	NfixReg_AOI2 control	NfixReg_AOI2 interruption	Tfix_AOI2 control	Tfix_AOI2 interruption	Error rate intra-control	Error rate intra-interruption
Digit span	—													
Reading span	.55***	—												
Nfix_AOI1_control	.15	-.01	—				.81***	.44**						
Nfix_AOI1_interruption	.04	.16	.58***	—			.57***	.64***						
Tfix_AOI1_control	.04	-.06	.84***	.46**	—									
Tfix_AOI1_interruption	-.01	.10	.52**	.98***	.35*	—								
Nfix_AOI2_control	.22	.13	.81***	.57***	.62***	.51**	—							
Nfix_AOI2_interruption	.08	.09	.44**	.64***	.311	.63***	.69***	—						
NfixReg_AOI2_control	.26	.11	.68***	.56***	.47**	.52**	.90***	.69***	—					
NfixReg_AOI2_interruption	.17	.07	.36*	.53***	.22	.53**	.65***	.92***	.76***	—				
Tfix_AOI2_control	.07	-.07	.78***	.51**	.61***	.49**	.94***	.66***	.85***	.62***	—			
Tfix_AOI2_interruption	-.04	.01	.39*	.64***	.28	.65***	.60***	.98***	.61***	.90***	.62***	—		
Error rate intra-control	-.33	-.34*	-.42*	-.20	-.23	-.16	-.22	-.06	-.13	.07	-.07	.02	—	
Error rate intra interruption	-.25	-.09	-.37*	-.18	-.15	-.17	-.42*	-.17	-.28	-.17	-.34*	-.11	.31	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix between the pre-tests scores, eye movements, and error rates for the inter-paragraph condition

Correlation Matrix between the pre-tests scores, eye movements, and error rates for the inter-paragraph condition

	Digit span	Reading span	Nfix_AOI3 control	Nfix_AOI3 interruption	NfixReg_AOI3 control	NfixReg_AOI3 interruption	Tfix_AOI3 control	Tfix_AOI3 interruption	Error rate inter-control	Error rate inter-interruption
Digit span	—									
Reading span	.55***	—								
Nfix_AOI3_control	.26	.02	—							
Nfix_AOI3_interruption	-.11	-.09	.58***	—						
NfixReg_AOI3_control	.39*	.08	.86***	.53**	—					
NfixReg_AOI3_interruption	.04	.02	.54***	.91***	.63***	—				
Tfix_AOI3_control	.10	-.19	.92***	.62***	.76***	.52**	—			
Tfix_AOI3_interruption	-.23	-.24	.51**	.97***	.45**	.86***	.62***	—	.02	
Error rate inter-control	-.08	-.07	.03	.03	.08	-.07	.14	.02	—	.20
Error rate inter-interrupted	-.01	.05	-.28	-.12	-.20	-.13	-.12	-.11		—

Note. * p < .05, ** p < .01, *** p < .001

Nfix = number of fixation

NfixReg = number of regressive fixation

Tfix = duration of fixation

Correlation Matrix between the error rate between the intra and inter paragraph condition as function of the condition of interruption

Correlation Matrix between the error rate between the intra and inter paragraph condition as function of the condition of interruption

	Error rate inter-control	Error rate inter-interrupted	Error rate intra-control	Error rate intra-interruption
Error rate inter-control	—	.20		
Error rate inter-interrupted	.20	—		
Error intra-control	-.09	.32	—	
Error intra-interruption	.12	.40*	.31	—

Note. * p < .05, ** p < .01, *** p < .001

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2021.101565.

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