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## ***SUMMARIZING DIGITAL DOCUMENTS: EFFECTS OF ALTERNATE OR SIMULTANEOUS WINDOW DISPLAY***

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## **ABSTRACT**

We investigated the effect of window visibility on the computer-based summarizing of digital documents. Two experiments studied the impact of the simultaneous or alternate display of the windows containing the notepad and source documents. In Experiment 1, the participants were asked to summarize the content of the source documents. In Experiment 2, they were required to copy out sections of the source documents. The results showed that in the alternate condition, the participants performed fewer reading and writing cycles than in the simultaneous condition. Furthermore, in the alternate condition, the writing episodes were both more numerous and more effortful, while quality of the summaries produced using the copying strategy was also affected. These experiments highlight the need for writers to be able to navigate freely and easily between the windows so that they can construct an overall mental representation of their summaries.

## **SUMMARIZING DIGITAL DOCUMENTS: EFFECTS OF ALTERNATE OR SIMULTANEOUS WINDOW DISPLAY**

In many activities in the classroom or the workplace, reading and writing are closely interwoven. Readers often write texts based on the ones they are reading, while writers read before or as they write (Benson, 2001; Wright, 2000). Generally speaking, compositions and source documents can come in a range of different media. For example, a text based on information contained in a paper document can be composed using either a pencil and paper or a computer (electronic notepad or word processing software). Conversely, source information may be presented on a screen and notes written on a paper notepad. That said, the increasingly overwhelming use of the Internet to search for information, plus the digitization of a growing number of printed works, means that users are now confronted with a huge corpus of electronic documents. Alongside this, the omnipresence of computers means that we regularly use computers to take notes or compose texts based on on-line (or digital) documents. Readers/writers may thus encounter situations in which they have to read documents displayed on the very computer screen they are using to summarize or take notes on these documents. The problem is that the size and definition of the most popular screens on the market (generally 17-inch) make it difficult to display the source information at the same time as the text that is being composed. In addition to carrying out the task they have been given, users therefore have to manipulate the interface in order to consult their notes or their source documents.

The aim of the research presented here was to study the situation of computer-based writing in which the source documents are displayed on the same screen as the word processing software. When the size of the screen makes it impossible to display notes and source documents simultaneously, cognitive overload may occur, rendering the users' strategies less effective (van Oostendorp, 1996). We begin by reviewing literature showing that text composition and reading/comprehension are effortful activities, especially when they involve the use of a computer. We then present two experiments which tested the impact of the alternate or simultaneous display of windows containing the source documents or notepad on the production of a summary of multiple source documents. We chose that task for two reasons. First, reading in order to write is a common activity in both academic and occupational settings, and as part of the informational process, the reading phase frequently involves summarizing the content of the various documents that are being read (O'Hara & Sellen, 1997). This is therefore an ecologically valid task. Second, when summarizing text, the relevant documents have to be carefully read and thoroughly understood (Winograd, 1984) – activities which may therefore be affected by the medium and the format in which the information is presented.

## **WRITING FROM SOURCES AS AN EFFORTFUL ACTIVITY**

Writing from sources encompasses the activities of text production, reading and comprehension. Writing information selected in the source texts involves four main processes (Hayes & Flower, 1980). The planning process enables writers to select the information they wish to retain in the text they have read and to determine the order in which these items of information are noted. The translating process provides a means of reformulating and possibly condensing the selected information. During the revision process, the summary is reread and corrected if necessary, in order to ensure that the task's objective has been met. Lastly, the graphomotor transcription process is engaged to retranscribe the information. Experiments on working memory demands of the writing processes have shown that planning and revision are more effortful than translating (for reviews, see Olive, 2004; Olive, Kellogg & Piolat, 2002) and that the cognitive effort of each of these processes is greater than that of other cognitive activities such as taking notes, playing chess, reading a text or learning lists of words (Piolat, Olive & Kellogg, 2005). Writing a summary therefore involves a high cognitive effort, due to the heavy demands of the writing processes. Reading and understanding the source information add to the cognitive demands of this activity. The engagement of comprehension processes is indeed governed by working memory capacity, and many studies have shown that there is a relation between this capacity and the reading or comprehension of texts (Haarman, Davelaar & Usher, 2003; Just & Carpenter 1992; Lee & Tedder, 2003; Vos, Gunter & Schriefers 2001). Accordingly, writing summaries from documents should be regarded as a particularly effortful activity from a cognitive standpoint, as it engages several central cognitive operations, such as integration, inference, planning and assessment, which are extremely effortful.

## **COMPUTER-BASED WRITING FROM DIGITAL SOURCE DOCUMENTS**

There are reasons to believe that the medium has an impact on the respective cost of the processes involved in writing from documents. Firstly, composing texts on a computer from digital source documents can increase cognitive effort because it first requires the use of a keyboard to produce the text. Although typewriting is becoming more and more widespread due to the increased use of computers, few people have the degree of proficiency needed to attain the level of automatization of graphic transcription achieved by adults. Acquiring the keyboard skills needed to type a text requires intensive learning and practice (Bosman, 1993; Rieger, 2004; Salthouse, 1986). For this reason, typing frequently makes the transcription processes more demanding. On the other hand, word processors offer a great many options which may help writers (cut-and-paste functions, layout and editing options, etc.) and thus reduce the cost of composition processes (Piolat, 1991). However, studies that have looked at the effectiveness of word processing have not always been unanimous (for a review, see Goldberg, Russell & Cook, 2003). While some researchers have stressed the effectiveness of this tool in enhancing the quality of the finished text (Haas, 1996), others have failed to observe any improvement in productions (Snyder, 1993). Composing a text on a computer also appears to affect the writing strategy. Goldberg et al. (2003) found that the revision process is activated at more frequent intervals throughout the production session (see Kellogg & Mueller, 1993, for similar findings in adults writers). Lastly, when a word processor is used to compose a text, rather than pencil and paper, there is an increase in the cognitive effort of the writing processes, especially planning and revision (see also Kellogg, 2001).

Second, composing from digital sources requires the reading of source documents on a computer screen. Reading on a computer is generally slower and more effortful than reading paper documents (Dillon, 1992; Macedo-Rouet, Rouet, Epstein & Fayard, 2003). Furthermore, in the case of complex "hypertext"-type documents, navigating between the different pages induces an additional cognitive effort (see for example G erouit, Piolat, Roussey & Barbier, 2001) because non-linear information requires more in-depth processing to create a coherent mental representation of them (Rouet & Tricot, 1998; Wiley & Voss, 1999), but also because electronic displays are usually less readable (for a review, see Dillon, 1992). Thus, readers of computerized documents experience problems with surface legibility (i.e., a greater difficulty to actually perceive the information displayed), and sometimes with deep legibility as well (i.e., the text is harder to comprehend; Baccino, 2004; Rouet, 2006). People reading online can only scan a limited area of the

document set and have to build an overall representation of the contents on a collection of piecemeal fragments (Macedo-Rouet et al., 2003; O'Hara, Sellen, & Bentley, 1999; Rouet, 2003). This difficulty in constituting an overall mental representation can affect its comprehension as well as its control. For example, Piolat, Roussey and Thunin (1997) have demonstrated that a scrolling device makes reading less effective (i.e., poorer memorization and fewer mistakes identified in a correction task) than a device where the text is formatted and displayed as pages.

To overcome these display problems, several different windows can be opened and either placed side by side or superimposed (Wiley, 2001), an arrangement that is frequently observed in activities where subjects take handwritten notes from paper documents (O'Hara, Taylor, Newman & Sellen, 2002). However, if the screen is not large enough to display two windows side by side, the user has to switch between these two windows, thereby interrupting the flow of writing or reading. Foss (1989) has shown that the simultaneous opening of a large number of windows can result in information overload. Wright, Lickorish and Millroy (1994) found that a multi-window display increased the cognitive effort. Van Oostendorp (1996) studied the impact of the alternate or simultaneous display of the source document and notepad windows on the taking of notes and the memorization and comprehension of the source texts. In the first of two experiments, he compared two types of simultaneous display (screen divided either horizontally or vertically) with a conventional situation of taking handwritten notes. He failed to observe any effect of the display and note-taking modalities on either the recall of the source texts or the scores on a multiple-choice questionnaire about the content of the texts. He did, however, find that the notes were longer and denser (in terms of information density) when the participants wrote them out using a pencil and paper, and a significant advantage in this respect of the vertical layout of windows over the horizontal one. In his second experiment, van Oostendorp (1996) compared the alternate display of the notepad and source document windows with the paper and pencil condition. The results were the same as in the previous experiment. Although the note-taking modality did not affect the memorization or comprehension of the texts, it did have an impact on the quality of the notes taken by the participants. Similarly, Macedo-Rouet, Rouet, Bouin, Deshouillères and Menu (2004) observed that taking notes using a notepad displayed on the same screen as the source text, but not at the same time, made it harder to view and articulate the windows.

## **RATIONALE**

We tested the assumption that computer-based writing from digital source documents may be affected by the limited size of screen displays, which prevents writers from viewing the source documents while they are composing their texts. We hypothesized that when source and production windows overlap (a typical situation with small screens), writers are subjected to a higher cognitive effort, in contrast to a situation where windows are displayed side by side. The constraint of shifting from source to writing windows may increase the cognitive effort because the writer may attempt to encode the source information more deeply, knowing that it will no longer be available during the typing stage. This deeper form of encoding may include the planning of statements to be written during the typing stage, when the source information will no longer be visible. For instance, the lack of visibility may prevent writers from making quick "lookbacks" to check details such as technical phrases, proper nouns or figures, hence the need to memorize this sort of information (O'Hara et al., 2002). In order to test these hypotheses, we gave participants access to a computer screen displaying the source documents and notepad windows either alternately (the source texts and notepad appeared one after the other) or simultaneously (the source texts and notepad were displayed next to each other on the screen).

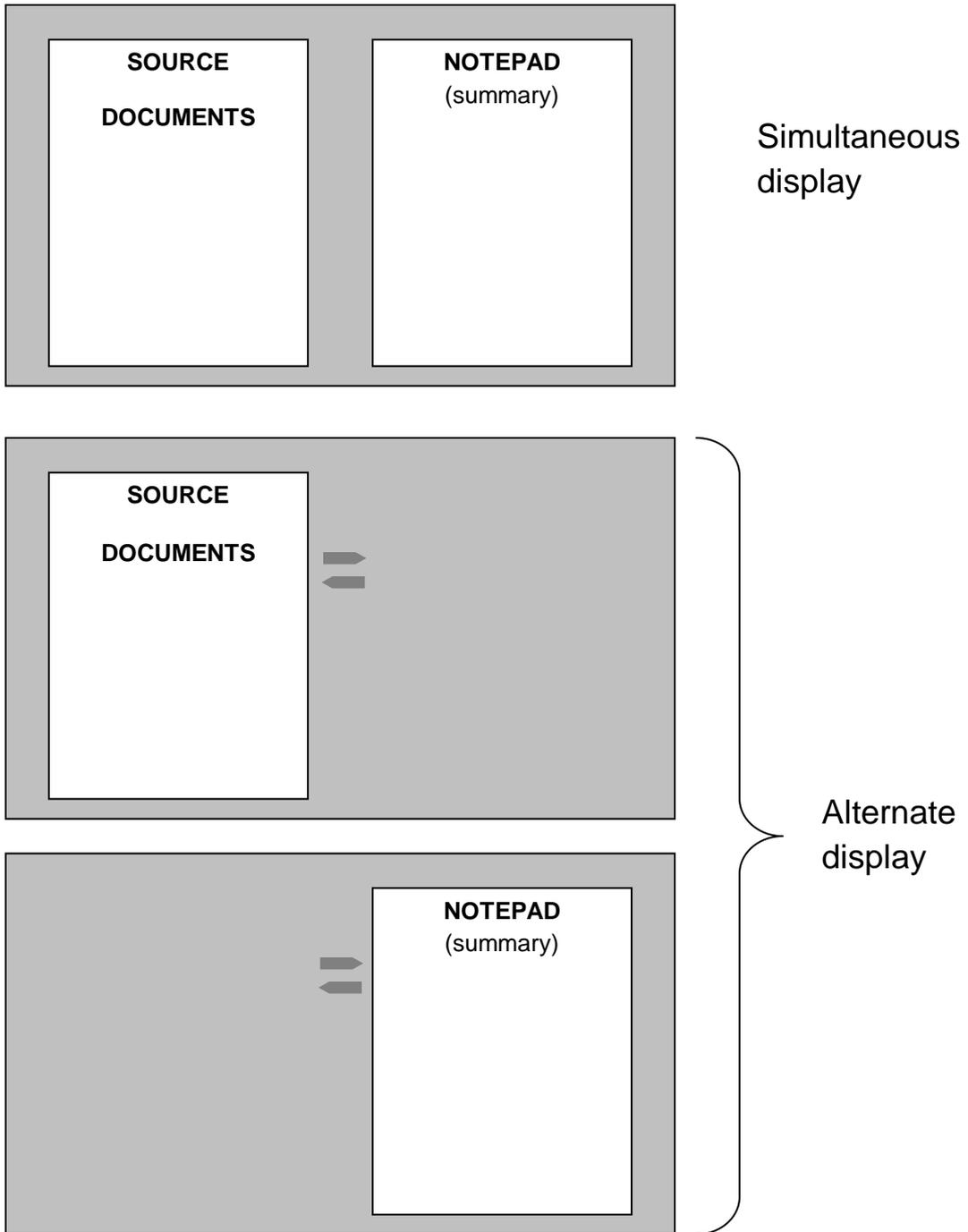


Figure 1. Schematic representation of the simultaneous (top) and alternate (middle and bottom) displays of the source document and notepad windows. In the alternate display, the two buttons in the center of the screen allowed users to switch between the source-only (middle) and notes-only (bottom) displays.

The participants were required to summarize the main ideas contained in the source documents that were constituted of three excerpts from articles of newspapers or from official reports. Generally speaking, summaries can be written using one of two strategies: either the writers compose their summaries using their own words and sentences or they copy out sections of the source texts and juxtapose them. To control the strategy used by the participants and to measure the impact of the display condition on each strategy, we therefore conducted two experiments in which we required participants to compose their summaries using only one of these strategies.. In Experiment 1, the participants had to summarize the main ideas contained in the source texts by producing original sentences (transformation task), without copying parts of the source documents. The resulting summaries therefore reflected an in-depth transformation of the source documents and the engagement of all the writing processes (planning, translating and revision). In Experiment 2, the participants had to produce a summary by copying out sections of the source texts word for word (copying task), without using the copy-paste tool provided by the computer. We assumed that the latter task made fewer demands on the writing processes, as these were restricted to planning and revision, with no transformation involved. We therefore expected to see a greater impact of the alternate display condition in Experiment 1 where the participants had to use the transformation strategy.

In order to assess participants' cognitive effort, we used the dual task method, whereby the participants had to carry out a main task (reading and writing) while reacting as quickly as possible to tones. The length of their reaction times was regarded as an indicator of the cognitive effort of the main activity. Moreover, the time spent reading and writing and the number of reading and writing cycles were analyzed in order to identify the strategies used by the participants to adapt to the two display conditions. Lastly, the summaries they produced were analyzed using a latent semantic analysis (Landauer & Dumais, 1997) in order to assess their proximity to the source texts.

## **EXPERIMENT 1**

Experiment 1 studied the impact of the display condition on the computer-based writing of a summary of documents displayed on the same computer screen. Half the participants worked with a simultaneous interface (the source document and notepad windows were visible at the same time) and the other half with an alternate interface (the windows had to be consulted one after the other). The summaries had to be composed by selecting contents from the source documents and then formulating them differently, all the while carrying out the secondary reaction time task.

## **METHOD**

### *PARTICIPANTS*

Forty psychology students (15 men and 25 women) volunteered to take part in the experiment. They had an average age of 22.5 years (18 to 34 years). All the participants were in higher education (19 undergraduates, 21 postgraduates and one postdoctoral student). More than 75% of participants had owned a computer for at least a year and more than 80% of participants used computers for composing texts and searching for information on the Internet. We complied with all the appropriate ethical criteria and when the participants were filmed they were asked whether they wished to sign an authorization to publish the images (see below).

### *MATERIAL*

For the purpose of these experiments, a program was specially developed in order to allow the alternate or simultaneous display of the windows containing the notepad and source texts, manage the secondary task and record the reaction times. The source document and notepad windows were displayed on a 19-inch screen and their size corresponded roughly to the size of a window displayed on a 15-inch screen. The windows were the same size in both conditions (alternate and simultaneous).

Different methods were used to record the indices relating to the summaries (number and length of reading and writing episodes, reaction times), according to the window display condition. In the alternate condition, these variables were automatically calculated by the software, which used the participants' actions to distinguish between the various

reading and writing episodes. In the simultaneous display condition, the participants were filmed and the films were then analyzed using Actogram© software to determine the number and length of the reading and writing episodes and categorize the reaction times according to the participants' activities (reading the source texts or writing). These two activities were identified according to the direction of the participants' gaze (a leftward gaze indicated a source document consultation phase, while a rightward gaze indicated a composition phase).

## TASKS

### *REACTION TIME TASK*

The participants had to respond to tones, emitted at irregular intervals, by pressing their foot on a pedal as quickly as possible. The reaction time task was carried out in a simple-task situation, followed by a dual-task situation. The simple task situation (administered at the start of the experiment) measured a baseline reaction time for each participant. Thirty tones were emitted at intervals of between 5 and 15 seconds. The first four responses, assumed to reflect adaptation to the task, were excluded from the mean baseline reaction time calculation. The dual-task situation allowed us to measure the participants' reaction times while they were composing their summaries. In this case, the tones were emitted every 15 to 35 seconds.

### *SUMMARIZING TASK*

In this task, the participants were given 20 minutes to summarize in approximately 250 words three texts that were displayed on the lefthand side of the screen. They were asked to type at their normal speed by using a notepad located on the righthand side of the screen and were not allowed to copy parts of the source documents. These documents were three excerpts from articles taken from different sources. Each excerpt was titled, paragraphed, with the name of the source presented. The shortest text was 249 words long and the longest was 447 words long. They did not contain any figure or table. In order to check for effects linked to the content or characteristics of the source documents, two different themes were used. Accordingly, in each display condition, half the participants had to produce a summary on the welfare system and the other half on smoking and lung cancer. Both sets of documents were the same length (1016 and 1019 words, respectively) and had the same degree of legibility (Flesch-Kincaid score: 77 for both topics). The task was carried out in one of the two conditions for the display of the notepad and source document windows (simultaneous or alternate, see Figure 1). In the simultaneous display condition, the windows appeared on the screen at the same time. In the second, alternate display condition, the two windows could only appear one after the other.

### *TYPING TASK*

In order to measure their individual typing speeds (number of characters typed per minute), the participants were asked to copy out a short text, typing at their normal speed, and doing their best to avoid mistakes.

## PROCEDURE

The sessions lasted approximately one hour and they were administered individually. Participants began by answering a questionnaire about the way they used their computers. The experimenter then introduced them to the experiment and informed them that part of it would be filmed. Next, the participants practiced the source document reading and summarizing task with the reaction time task for 5 minutes. After this training phase, the participants carried out the reaction time task in the simple task situation. They then composed the summary of the source documents while carrying out the reaction time task. To end the experiment, the participants carried out the typing task.

## RESULTS

The analysis of the different variables recorded during this experiment focused on the effect of the display condition on the participants' activity (reading the source documents or composing the summary). Activity (Reading, Writing) was therefore introduced into the analyses as a within-subjects factor, while Display constituted a between-subjects factor. In order to gauge the impact of the participants' keyboard skills on the cognitive effort and the summarizing strategy,

typing speed, as measured with the typing task, was included in each analysis as a covariant. All the post-hoc tests were conducted using Scheffé's test, with an alpha threshold of .05.

## REACTION TIMES

An initial analysis that compared the mean baseline reaction time of the participants in each of the experimental groups defined by the display condition failed to reveal any significant difference  $t(38) < 1$ .

A second analysis looked at interference on reaction times ( $iRT = \text{mean secondary RT} - \text{Baseline RT}$ ) in order to eliminate interindividual differences in reactions to the tones in the simple task. These  $iRT$ s solely reflected the cognitive effort attributable to the main task. As they were not distributed normally (Shapiro-Wilks,  $W = .948$ ;  $p < .01$ ), they were turned into logarithms ( $\log = \text{LN}(iRT + 1000)$ , where the constant was added so that the handful of negative  $iRT$ s could undergo logarithmic transformation).

Once we had controlled for typing speeds, the analysis of covariance suggested that the interference on reaction times was not affected either by the display condition (alternate = 173 ms; simultaneous = 139 ms) or by the nature of the participants' activity (reading = 157 ms; writing = 161 ms). The Display x Activity interaction was however significant,  $F(1, 37) = 4.82$ ;  $\text{MSE} = 27200$ ;  $p < .05$ ), as the alternate display condition led to a significant increase in the reaction times associated with writing, though not with reading (see Figure 2).

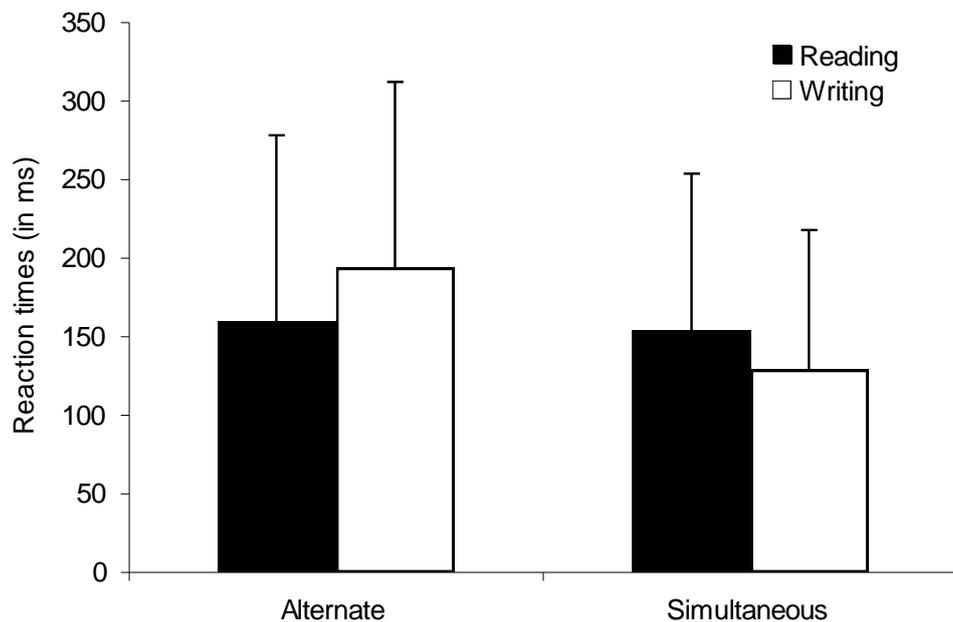


Figure 2. Interference in reaction times (in ms) during the reading and writing episodes according to the display condition (alternate vs. simultaneous) of the source document and notepad windows in the transforming task (Experiment 1)

## TOTAL TIME SPENT READING AND WRITING

The analysis of covariance revealed that once we had controlled for typing speeds, the participants spent no longer on the task with a simultaneous display (599 s) than on the one with an alternate one (562 s),  $F(1, 37) = 3.619$ ;  $MSE = 8013$ ;  $p = .065$ . In both display conditions, the amount of time spent consulting the source texts was significantly shorter (468 s) than the amount of time spent composing the summary (693 s),  $F(1, 37) = 5.129$ ;  $MSE = 20933$ ;  $p < .05$ . However, this effect is modulated by a significant interaction between the Display and Activity factors,  $F(1, 37) = 5.477$ ;  $MSE = 20933$ ;  $p < .05$ . Post-hoc comparisons indicated that, although the total amount of time spent writing was significantly longer than that spent reading the source documents in both experimental conditions, the difference between these times was greater in the alternate condition. In other words, when the windows were displayed alternately, participants spent far longer writing than reading (see Table 1).

Table 1

*Total time (in seconds) spent reading in both display conditions of the source documents and notepad windows (standard deviations in brackets).*

	Display			
	Alternate		Simultaneous	
	Reading	Writing	Reading	Writing
<i>Experiment 1: Total time</i>	411 (129)	712 (144)	524 (107)	675 (89)
<i>Experiment 2: Total time</i>	430 (143)	752 (179)	621 (103)	568 (100)

## NUMBER OF READING AND WRITING CYCLES

The analysis of the number of reading and writing cycles revealed a main effect of Display,  $F(1, 37) = 57.58$ ;  $MSE = 248.9$ ;  $p < .001$ . The number of reading and writing cycles performed by the participants was significantly higher in the simultaneous display condition ( $M = 45$ ) than in the alternate one ( $M = 7$ ).

## WRITING FLUENCY AND LENGTH OF SUMMARIES

There was no significant difference ( $F(1, 37) < 1$ ) between the simultaneous and alternate display conditions when it came to the writing fluency (number of words per minute) and the total number of words in the summaries (see Table 2).

Table 2

Length of summaries (number of words), fluency (in words per minute) and score of proximity between the summary and the sources (percentage of sentences with an LSA cosine above .70) according to the organization of the source document and notepad windows (standard deviations in brackets).

	Display	
	Alternate	Simultaneous
<i>Experiment 1</i>		
Number of words	182.1 (45.7)	177.8 (50.3)
Fluency	9.2 (2.5)	8.7 (2.6)
Summary/sources proximity	8.9 (10.8)	8.6 (9.5)
<i>Experiment 2</i>		
Number of words	158 (57.5)	199.3 (35) <sup>a</sup>
Fluency	8.1 (2)	9.9 (2.8) <sup>b</sup>
Summary/sources proximity	42.1 (20.4)	57 (19.8) <sup>b</sup>

<sup>a</sup>:  $p < .05$ ; <sup>b</sup>:  $p < .01$

## PROXIMITY OF THE SUMMARIES TO THE SOURCE DOCUMENTS

The proximity of the summaries to the source documents was assessed by means of a Latent Semantic Analysis (Deerwester et al., 1990; Foltz, 1996). For each participant, we calculated the cosine of each sentence in the summary with each sentence in the three source texts for both themes. We then empirically determined a threshold cosine value (0.7) that enabled us to compare the level of similarity of students' texts with source materials across presentation conditions. This value corresponds to one standard deviation above the maximum cosine that was obtained. Such a threshold thus indicates that a sentence with a cosine above that value presents a good degree of proximity with at least one sentence in the source texts. We calculated the percentage of sentences where comparison with the source texts revealed a cosine equal to or greater than 0.7 and analyzed the effect of Display on this proximity (see Table 2). The analysis of covariance did not reveal any significant effect of the display condition of the source documents or notepad,  $F(1, 37) < 1$ .

## DISCUSSION

This experiment highlighted an effect of the display condition on the organization of a writing activity based on digital documents. The alternate display of the source documents and notepad increased the cognitive effort of the writing activity, though not of the reading activity. This increase may have stemmed from a difference in the way the interface was used in the alternate condition: the amount of time spent writing increased and the number of reading-writing cycles fell. Much of the participants' activity therefore consisted of writing, with just the notepad displayed on the screen and the source documents hidden from view most of the time. In this condition, as they had only reduced access to the source documents, the participants were unable to make frequent comparisons between the content of the source documents and that of their summaries. They therefore had to base their writing processes on information they

had memorized, thus saturating their working memory during the writing phase. In the simultaneous condition, on the other hand, the constant presence of the source document window served as a backup memory and the writers could regularly – and with no extra effort – check that their summaries matched the source documents.

Given that it only took a mouse click to bring the source texts back to the screen, it seems curious that the participants should have consulted them less often in the alternate display condition. However, studies have shown that this simple action is actually associated with a substantial cognitive effort which can put participants off (Black, Wright, Black & Norman, 1992; Wright, Lickorish & Milroy, 1994). By contrast, in the simultaneous condition, the participants had simply to glance at the source window to find the information they needed. Apart from the fact that visual location was easier, in that the shape of the text remained in the participants' peripheral vision during the writing activity, eye movements were therefore less effortful than the combination of eye movements and pointing and clicking gestures.

Accordingly, the alternate display of the source document and notepad windows mainly impacted on the composition activity. When only one window could be displayed at a time, either for writing or consulting sources, participants spent more time writing than reading, engaging in fewer but longer and more effortful writing episodes. In the simultaneous condition, the frequent toing and froing between source text and summary enabled the participants to maintain closer control over the information they selected. Lastly, the proximity of the summaries to the source documents was unaffected by the display condition.

## **EXPERIMENT 2**

In Experiment 1, participants were instructed to produce a summary of the source texts by transforming their contents. After selecting the important information, they had to organize and reformulate it, in order to draft a consistent summary. In other words, the writing processes of planning, translation and revision were all fully engaged. We therefore sought to identify the effect that the display of the source document and notepad windows would have when the writers had to summarize the source documents not by composing their own text but by copying out sections of the source documents.

We used the same methodology as in Experiment 1. The only difference between the two experiments lay in the summarizing strategy: participants were required not to compose a text but to copy out elements of the source texts and organize them in the form of a summary. As they were not allowed to use a cut-and-paste function, they first had to read the texts, then select those items of information they regarded as most relevant, memorize them and type them in the notepad. The main difference between the two tasks was that a greater demand was placed on short-term memory in the copying task than in the content transformation task. Moreover, the participants did not have to implement the translating process, just planning and revision. As in Experiment 1, they encountered two interfaces: one displaying the source document and notepad windows simultaneously and one which could only display them one after the other.

## **METHOD**

### *PARTICIPANTS*

The participants in this second experiment were the same as in the first one. They had all agreed to carry out both experiments during their initial meeting with the experimenter. To avoid any effect arising from the repeated use of the same interface, the participants used a different interface from the one they had encountered in Experiment 1. The theme of the summary was also different.

### TASKS, MATERIAL AND PROCEDURE

With the exception of the summarizing strategy, this experiment was conducted in exactly the same way as the previous one. The participants also carried out the secondary reaction time task during the summarizing task and finished by performing the typing task.

## RESULTS

The variables measured in this experiment were analyzed in exactly the same way as in the previous experiment.

### REACTION TIMES

The analysis of the reaction times focused on the interference on reaction times. As these iRTs did not have a normal distribution (Shapiro-Wilks,  $W = .948$ ;  $p < .01$ ), they were turned into logarithms ( $\log = \text{LN}(iRT + 1000)$ ; see Experiment 1, Results section). Once we had controlled for typing speeds, the analysis of covariance failed to reveal any effect of Display (Alternate = 197 ms; Simultaneous = 143 ms) or Activity (Reading = 165 ms; Writing = 176 ms) on the reaction time,  $F(1, 37) < 1$ . However, the Display x Activity interaction did tend to be significant,  $F(1, 37) = 3,287$ ;  $\text{MSE} = 12170$ ;  $p = .078$  (cf. Figure 3). Post-hoc tests revealed that the reaction time associated with writing was significantly longer in the alternate display condition (211 ms) than in the simultaneous one (140 ms), while the reaction time associated with reading was not significantly different in either condition (Alternate = 183 ms; Simultaneous = 147 ms). Moreover, the cognitive effort of the reading and writing activities was the same in both display conditions.

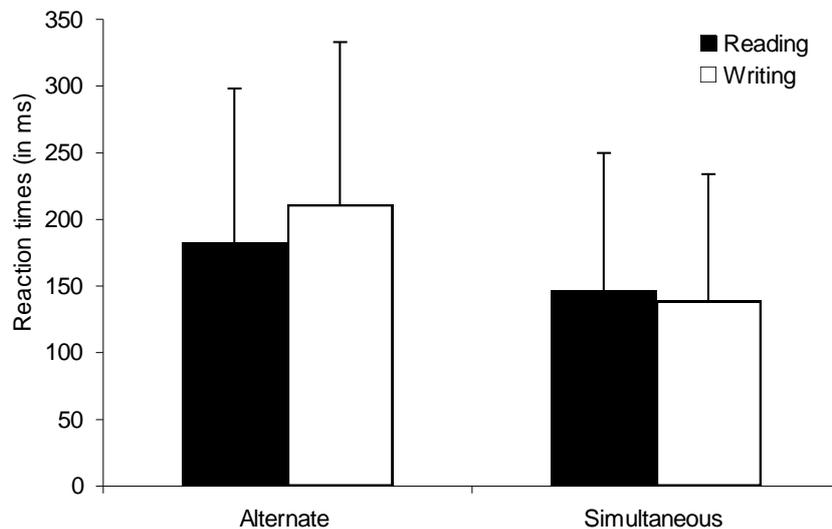


Figure 3. Interference in reaction times (in ms) during the reading and writing episodes according to the displaycondition (alternate vs. simultaneous) of the source document and notepad windows in the copying task.

## TIME SPENT READING AND WRITING

The analysis of covariance for the time spent reading and writing failed to reveal any main effect of Display (Alternate = 591 s; Simultaneous = 595 s;  $F < 1$ ), although there was a main effect of Activity,  $F(1, 37) = 3.259$ ;  $MSE = 30655$ ;  $p = .079$ . The amount of time spent reading the source texts (526 s) was shorter than that spent writing the summaries (660 s). The Display x Activity interaction was significant,  $F(1, 37) = 23.127$ ;  $MSE = 30655$ ;  $p < .001$ . As the post-hoc tests show, whereas there was no difference between reading and writing times in the alternate and simultaneous conditions, the writing time increased in the simultaneous condition, to the detriment of the reading time (cf. Table 1). This means that the participants spent less time reading and more time writing in the alternate display condition.

## NUMBER OF READING AND WRITING CYCLES

The analysis of covariance for the number of reading and writing cycles revealed a main effect of Display,  $F(1,37) = 203.133$ ;  $MSE = 466.8$ ;  $p < .001$ . The number of reading and writing cycles completed by the participants was significantly higher in the simultaneous display condition ( $M = 112$ ) than in the alternate one ( $M = 14.9$ ).

## WRITING FLUENCY AND LENGTH OF SUMMARIES

The analysis of covariance revealed that writing fluency (in words per minute) was significantly slower with the alternate display than with the simultaneous one,  $F(1, 37) = 8.821$ ;  $MSE = 4.224$ ;  $p < .01$  (cf. Table 2) and that participants produced shorter summaries in the alternate display condition than in the simultaneous one,  $F(1, 37) = 9.821$ ;  $MSE = 1844.7$ ;  $p < .01$  (cf. Table 2).

## PROXIMITY OF THE SUMMARIES TO THE SOURCE TEXTS

As in Experiment 1, for each participant we calculated the proximity of their summaries to the source documents. The analysis of covariance indicated that the summaries produced in the simultaneous condition were closer to the source texts than those produced in the alternate one,  $F(1, 37) = 5.399$ ;  $MSE = 401.1$ ;  $p < .05$  (cf. Table 2).

## DISCUSSION

Experiment 2 highlighted the impact of the display condition of the source text and notepad windows on the composition of a summary using a copying strategy. In terms of cognitive effort, the display condition had no overall effect on the users' cognitive effort. Whether they encountered an alternate or a simultaneous display, the cognitive effort of the overall task remained the same. Similarly, the cognitive effort of the source document reading phases was no different from that of the summary composition phases. Moreover, the windowing mode affected the cognitive effort of writing, which was greater in the alternate condition than in the simultaneous one, whereas the cognitive effort of reading remained unaffected. As in the previous experiment, this increase in the cognitive effort of the writing must have resulted partly from a difference in the way the interface was used. In the alternate condition, the writers spent more time writing to the detriment of reading. They also did less toing and froing between the source document and notepad windows than in the simultaneous condition and consequently, the reading phases were shorter and the writing ones were longer in this display condition. As in the previous experiment, the main consequence of alternate display was therefore a less fluent articulation between reading and writing and accordingly an increase in the writing activity's cognitive effort (Benson, 2001; O'Hara, Taylor, Newman, & Sellen, 2002).

Moreover, contrary to the findings of the first experiment, the writing fluency was slower in this display condition. As the time taken to complete the task remained unaffected by the display condition, the summaries produced were shorter in the alternate condition. As to why the participants wrote (copied) more slowly in the alternate display condition, this can be explained by the increased amount of effort required to check that the content of their

summaries corresponded to that of the source texts. The participants probably spent more time rereading their summaries (in the absence of the source documents), as suggested by the greater amount of time spent in front of the notepad window. The validity of this explanation could be verified by carrying out an experiment to assess more accurately the respective lengths of the summary transcription and rereading episodes. An analysis of the time course of the experiment would provide further evidence for or against this explanation. For if the participants spent more time rereading their summaries than those in the simultaneous condition, we would expect to observe longer production pauses.

Lastly, in this experiment, the summaries produced using the alternate interface were not as close to the source texts as those produced using the simultaneous one. In order to cope with the heavy demands for memorization imposed by the combination of the copying task and the alternate interface, participants may have memorized shorter sections of the source texts than their counterparts in the simultaneous condition. As the method used to calculate the proximity score consisted in dividing the summaries into sentences (see Experiment 1, Results section), a lower proximity score may indicate that participants in the alternate condition preferred to memorize extremely short sections of the source documents rather than whole sentences. It may also indicate that in order to manage the heavy demands for memorization imposed by both the copying task and the alternate interface, participants in the alternate condition transformed the source contents to a greater degree than the participants in the simultaneous condition, thereby reducing the demands imposed by the task. Analyses of the time course of the task would confirm or invalidate these explanations.

## **GENERAL DISCUSSION**

Composing a document on a computer from digital sources is an increasingly common activity. Because of the small size of the most widely-used screens, the display of the reading and writing windows is always a problem. We set out to discover the exact nature of this problem, based on current cognitive theories of reading and text composition processes.

As shown by the results of the two experiments described here, the mode of display of the source document and notepad windows affects how writers intertwine the reading and summary production phases. With a simultaneous display, the participants frequently go back and forth between the source document and notepad windows. With an alternate display, these toings and froings are far less frequent (nearly 10 times less frequent). For O'Hara and Sellen (1997), the possibility of navigating freely between source documents and notes is constitutive of writing from source and a frequent navigation between source documents and notes can improve the way the contents of the finished texts are organized. The simultaneous presence of source documents and notes means that users can check at frequent and regular intervals that they have not forgotten to select any important items of information and that they have included all these selected items in their text. For this reason, a simultaneous interface allows for better control over the summary writing task. Moreover, the window display condition mainly affected the composition activity. With an alternate display, the participants spent far more time writing than reading. This result can be compared with the finding for cognitive effort of writing which was greater in the alternate condition. Accordingly, whichever summarizing strategy was used, the display condition chiefly affected the writing activity, in terms of both the length of this activity and its cognitive effort. This can probably be attributed to the high cognitive effort of writing which makes this activity more sensitive to changes in the display condition (Piolat, Olive & Kellogg, 2005).

One unexpected result was the absence of any major difference between the tasks studied in the two experiments. We had assumed that the alternate condition would have a greater impact when the summary had to be produced by transforming the way the source documents were formulated rather than when sections of these documents simply

had to be copied out. Added to the high cost of text production in Experiment 1, the heavy demands on short-term memory in the alternate condition should have resulted in cognitive overload, strongly affecting the participants' activity. We had based this hypothesis on the fact that the transformation strategy engages all the writing processes, thereby making a composition task far more effortful than a copying task (Olive & Kellogg, 2002).

Contrary to our expectations, the display conditions had the same impact on the manner in which the participants carried out the task, whichever summarizing strategy was used, although there was a difference in the resulting summaries. When the participants were instructed to produce a summary by copying out sections of the sources, the alternate interface reduced the pace of writing (the participants therefore produced shorter summaries) and the summaries were not as close to the source texts. We can infer from this result that the impact of the alternate display of the source documents and notepad was greater when the information in the sources had to be memorized verbatim than when it served as a basis for linguistic and semantic elaboration, as in the transformation strategy. Nevertheless, an alternate mode of windowing might sometimes appear better, especially with tasks requiring deep understanding of the source material. In that case, knowing that the material will disappear might incite participants to encode the source material deeper than with a simultaneous mode of display. Experiments with tasks that require different levels of encoding of the source material should address that issue.

A comparison of the processes engaged in the copying and transformation tasks indicates that the cognitive effort of the copying strategy differed in origin from that of the transformation strategy. With the transformation strategy, because the shift from consultation window to notepad did not require the word-for-word storage of selected items but rather integration of contents of the source texts, cognitive effort of that strategy probably stemmed from the processing demands of the writing processes. Thus, space was saved in short-term memory. With the copying strategy, on the other hand, the participants had to memorize the selected information word for word. The cognitive effort of the copying strategy therefore arose chiefly from the high demand in short-term storage. This distinction between the origins of the cognitive efforts of these two strategies mirrors the distinction that is traditionally made between the processing and storage functions of working memory (Baddeley, 2001; Cowan, 2005). In other words, the effort imposed on working memory by the transformation strategy arose essentially from the processes engaged in this strategy, whereas the effort imposed by the copying strategy essentially concerned short-term storage, more specifically, the phonological loop of working memory. Furthermore, it should be noted that with the copying strategy, failure to recall an item of information could result in the repetition of work that had already been done (rereading the document in order to find the precise way in which the information was formulated). With the transformation strategy, as the information did not have to be memorized word for word, failure to recall it had less major consequences for participants, as their work depended on a semantic representation of the information to be included in the summary.

To conclude, the two experiments we presented in this article highlight the negative impact of an alternate display when writing with computer from digital sources. As it is writing that suffers the greatest impact, especially when items of information have to be memorized so that they can be copied out, one partial, if not total solution, would be to offer users tools that facilitate selection of information. For instance, annotation tools and highlighting options can support the process of information selection (Brown & Brown, 2003; Wolfe, 2002) and several annotations programs and solutions are now available (for a review, see Glover, Xu & Hardaker, 2006). Another solution would consist in enhancing gathering of information, with for example copy-and-paste operations which are very common operations when reading for writing or notetaking (Igo, Bruning, & McCurdden, 2005). As for annotations tools, several programs implement copy-and-paste options (see Apperley, Fletcher & Rogers, 2002 for an example). It appears that multiple copy-and-paste operations are poorly supported in current writing interfaces despite their potential effectiveness for note taking. More important, few of them are independent of the applications that are used to display the source documents. Thus, regardless of the tools available, simultaneous displays should be used wherever possible in order to make it easier to move freely between the source documents and the text being composed. As O'Hara et al. (2002) indicate, these interfaces must create conditions in which "the change of attentional focus can be rapid, frequent and non-disruptive to ongoing activities, particularly for the flow of writing".

## AUTHORS' NOTES

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