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Execution and pauses in writing narratives: Processing time, cognitive effort and typing skill

Rui Alexandre Alves and Sao Luis Castro, Universidade do Porto, Porto, Portugal ; Thierry Olive, CNRS & University of Poitiers, Poitiers, France

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Address correspondence to:
Thierry Olive
Laboratoire Langage, Mémoire & Développement Cognitif
Maison des Sciences de l'Homme et de la Société
99 avenue du recteur Pineau
86000 Poitiers FRANCE

Phone: + 33 (0)5 49 36 62 99
Fax: + 33 (0)5 49 45 46 16
e-mail: thierry.olive@univ-poitiers.fr

ABSTRACT

At the behavioural level, the activity of a writer can be described as periods of typing separated by pauses. Although some studies have been concerned with the functions of pauses, few have investigated motor execution periods. Precise estimates of the distribution of writing processes, and their cognitive demands, across periods of typing and pauses are lacking. Furthermore, it is uncertain how typing skill affects these aspects of writing. We addressed these issues, selecting writers of low and high typing skill who performed dictation and composition tasks. The occurrences of writing processes were assessed through directed verbalization, and their cognitive demands were measured through interference in reaction times (IRT). Before writing a narrative, 34 undergraduates learned to categorize examples of introspective thoughts as different types of activities related to writing (planning, translating, or revising). Then, while writing, they responded to random auditory probes, and reported their ongoing activity according to the learned categories. Convergent with previous findings, translating was most often reported, and revising and planning had fewer occurrences. Translating was mostly activated during motor execution, whereas revising and planning were mainly activated during pauses. However, none of the writing processes can be characterized as being typical of pauses, since translating was activated to a similar extent as the other two processes. Regarding cognitive demands, revising is likely to be the most demanding process in narrative writing. Typing skill had an impact on IRTs of motor execution. The demands of execution were greater in the low than in the high typing skill group, but these greater demands did not affect the strategy of writing processes activation. Nevertheless, low typing skill had a detrimental impact on text quality.

INTRODUCTION

Seen from outside, writing on a keyboard is strikingly simple: bursts of typing separated by pauses. Yet this rough description fails to capture the mental effort involved in producing a text. Indeed, cognitive psychologists characterize text production as one of the most complex and demanding activities that humans engage in (Flower & Hayes, 1980; Galbraith & Torrance, 1999; Kellogg, 1994), and much research has been devoted to thinking processes in text production (cf. Hayes, 1996). However, less attention has been paid to the relationship between high-level writing processes and the writer's overt behaviour-performing motor execution, or withholding it. Here, we present a study in which this issue was addressed. We start with a cognitive analysis of typing.

TYPING IN WRITTEN COMPOSING

Typing a text is the result of several operations that have considerable motor and cognitive overlap in time (Gentner, 1988). In an influential review of transcription typing, Salthouse (1986) has proposed that four basic processing operations take place. In an initial input phase, a to-betranscribed chunk is held in working memory (WM); this chunk is parsed into discrete characters, which are translated into motor programs that specify the characteristics of the appropriate keystrokes; in a final execution phase, ballistic typing movements are performed. Thus, when typing, a writer must keep active in WM the chunk being transcribed while parsing, programming, and motor execution take place. At least for novice typists, this situation of divided attention is likely to pose problems, and interference is bound to occur. For instance, Penney and Blackwood (1989) have noticed that novice typists tend to forget items in the last serial positions of word lists. Bourdin and Fayol (1994) extended this finding to the handwriting modality and considered it within a developmental framework. They found that 8-year-olds, and adults using an untrained cursive script, performed more poorly in written serial recall than in spoken recall. Thus, the detrimental effect of unpractised motor execution is not specific to typing; it is related to the increased demands of untrained motor responses. Conversely, extended practice in typing reduces its cognitive demands. As typing becomes automatic, the translation phase in Salthouse's model is likely to be greatly shortened, and maybe even circumvented (Rieger, 2004). There is anecdotal and experimental evidence showing that expertise in typing is associated with the ability to perform concurrent activities successfully (Gentner, 1988; Pashler, 1993).

A dominant view in writing research is that skilled motor output frees WM capacity (Fayol, 1999; Kellogg, 1996; McCutchen, 1996), which can then be allocated to high-level writing processes such as planning, translating, or revising, as proposed by Hayes and Flower (1980, 1986). Planning means setting rhetorical goals, generating ideas, and organizing them into a writing plan. Translating is converting ideas into language, and transcribing them in written form (notice that Salthouse's model considers only this last transcription step). Revising includes reading, evaluating, and editing the text produced, but can also operate upon a mental plan.

It is often assumed that the concurrent activation of high-level processes and low-level motor execution can only be achieved if motor output is automatic (Fayol, 1999; Kellogg, 1996, 1999). Olive and Kellogg (2002) brought direct support for this claim. They asked children and adults to compose a text, and then to copy it. Secondary reaction times (RT) were measured in three conditions: handwriting while composing, pausing while composing, and handwriting while copying. Children showed similar levels of RT interference across the three conditions. For them handwriting was equally effortful regardless of whether they were composing or copying. Presumably, children were unable to activate high-level writing processes together with motor execution, and had to suspend handwriting to think over their texts (serial strategy). Conversely, for adults, RT interference increased significantly from handwriting while copying to handwriting while composing and pausing. For adults, then, handwriting is more demanding while composing than while copying. This indicates that adults are able to activate simultaneously motor execution and high-level writing processes (parallel strategy). Olive and Kellogg also showed that adults could be forced to adopt a serial strategy if they were instructed to use an unpractised cursive script. Thus, when the demands of low-level motor execution are increased, the simultaneous activation of highlevel writing processes does not occur.

Using eye-tracking technology, Alamargot, Dansac, Chesnet, and Fayol (2007) have identified parallel events: during handwriting, the eyes move away from the pen and gather information from the text already written or from other sources. Such displacements of the eye are common in writing, and suggest concurrent activation of highlevel processes and handwriting. This study, as well as Olive and Kellogg's (2002), has shown that adults routinely engage in parallel processing during motor execution. However, as every writer has experienced, motor execution does not always proceed continuously within a writing session.

PAUSES IN WRITTEN COMPOSING

Using key-logging software, Stro¨mqvist and collaborators found that about half of the composition time is devoted to pauses lasting for more than 2 seconds (Strömqvist & Ahlsén, 1999). According to Schilperoord (2001), writers can pause for cognitive (e.g., cognitive overload), sociopsychological (e.g., writing apprehension), and physical reasons (e.g., fatigue). Of interest to this study are cognitive reasons.

Pauses can signal the pursuit of high-level writing processes that for some reason could not be carried out at the same time as typing. The function of pauses is poorly specified in writing research (see Torrance & Galbraith, 2006), but research in other domains of cognitive psychology provides plausible interpretations. One, the most influential in writing research, is that pauses are due to the competition for limited capacity (Just & Carpenter, 1992). Another is that typing and high-level processes compete for a common processing component (Pashler, 1994). A third possibility is that pauses result from cross-talk between products and processing of ongoing activities (Navon & Miller, 1987). Finally, it might be that pauses arise as consequence of memory decay, and are used to reinstate the intended message (Torrance & Galbraith, 2006).

Findings from real-time studies (Foulin, 1995; Schilperoord, 1996; Stro¨ mqvist, Holmqvist, Johansson, Karlsson, & Wengelin, 2006) have linked pauses to planning and to revising. Matsuhashi (1981) has shown that the mean pause length increased if more planning was required (by comparing argumentative, where presumably more planning is required, with narrative writing). Using a pause threshold of 3 seconds, Van Waes and Schellens (2003) have found that about half of the pauses were followed by revisions.

Chanquoy, Foulin, and Fayol (1996, p. 37) synthesize well what is known about the function of pauses in writing: ‘‘research dealing with the temporal aspects of language production has assumed that pauses occurring during the production activity are fundamental moments of conceptualization, formulation or control of the message.’’ However, even if this assumption is empirically founded, we lack precise estimates of how much of planning, translating, and revising is carried out during pauses, and during periods of motor execution.

A METHOD FOR STUDYING THE DYNAMICS OF WRITING

Two major tenets of the cognitive approach to writing are the recursivity of writing processes (Hayes & Flower, 1980), and the extremely demanding nature of writing processes (Flower & Hayes, 1980). A major contribution by Kellogg (1987a, b) was the development of a technique that allows us to evaluate these crucial aspects of writing. While writing, participants are required to detect random auditory probes and to categorize their ongoing activity according to previously learned categories. Occurrences of those categories provide estimates of processing times devoted to different writing processes. Secondary reaction times (RTs) to probes are taken as indices of the cognitive effort devoted to the ongoing activity (Kahneman, 1973). The higher the increase in RT, the more demanding was the activity going on when the probe appeared.

The reliability, validity, and lack of intrusiveness of Kellog’s procedure have been carefully examined (for a review see Olive, Kellogg, & Piolat, 2002). It has been convincingly argued that: (1) directed verbalizations give reliable and valid estimates of the time devoted to different writing processes; (2) the secondary RT task provides reliable estimates of the cognitive demands of these processes; and, most importantly, (3) the overall technique does not disrupt or alter performance on the writing task, and does not affect the characteristics of written texts (Kellogg, 1987b; Penningroth & Rosenberg, 1995; Piolat, Kellogg, & Farioli, 2001).

Typically, studies with Kellogg’s technique have used labels referring to the three cognitive processes from Hayes and Flower’s model. Across several studies, a consistent picture emerges on the processing times devoted to translating, planning, and revising (Kellogg, 1987a, 1988, 2001; Levy & Ransdell, 1995; Piolat et al., 2001). Translating is the dominant activity, taking 40-50% of the writing time. Planning and revising show an asymmetric pattern: throughout a writing session; planning decreases whereas revising increases.

Regarding the demands of writing processes, the findings are contradictory. In some studies, planning was the most demanding process, but in others revising was (Olive et al., 2002). In yet another, the three processes were equally demanding (Piolat & Olive, 2000). Differences across studies in text genre, writing medium, process definition, and writer’s knowledge and interest may account for these differences. Nevertheless, translating is likely to be less demanding than both planning and revising because some translating subprocesses are shared with spoken language, and others are easily automatized, notably motor execution.

TYPING SKILL AND WRITING DYNAMICS

Recently, Alves, Castro, Sousa, and Stro¨mqvist (2007) found that undergraduate students could sustain typing for about 10 seconds before pausing for more than 2 seconds. Moreover, when participants were divided according to typing speed, a reliable difference between slow and fast typists was found in the length of motor execution periods. The slow typists had average execution periods of about 8 seconds, and produced about three words in each, whereas the fast typists had average execution periods of 12 seconds, in which they produced twice as many words as the slow typists. This finding led Alves et al. to argue that typing skill contributes to the ability to sustain typing over longer periods of time. One possible explanation for this ability is that as typing skill increases, the strategy of activating writing processes might shift from serial to parallel.

In the present study, we test the hypothesis that high typing skill allows the concurrent activation of writing processes, while low writing skill does not. Participants with low or with high typing skill performed a dictation task coupled with secondary RTs, and composed a narrative text under Kellogg's procedure. If slow typists use a serial strategy of composing, they should show similar levels of IRTs for motor execution in composition and in dictation. Fast typists, however, should show higher IRTs during composition as compared to execution. The use of Kellogg's technique, and the focus on writer activity will allow us to establish precise estimates of the occurrences, and cognitive effort, of writing processes in periods of motor execution and in pauses. We will also look for a detrimental impact of lack of typing skill on the quality of narratives.

Method

Participants

Ninety-nine undergraduate psychology students were screened using a questionnaire about writing habits. Thirty-four Portuguese native speakers were thus selected (29 females; 33 right-handed; mean age = 19.4 years, SD = 2.3). Half of the group was categorized as slow typists, and the other half as fast typists (see procedure for details about screening).

Materials

A questionnaire was used to gather participants' written informed consent, demographic data, and to assess frequency of writing activities. Frequency was measured with a 5-point Likert scale ranging from *very rarely* (1) to *very often* (5). Items asked how often participants used computers, wrote on computers, and wrote by hand. Two additional items asked for the agreeableness of the activity of writing, and preference for writing by hand or typewriting.

Two computer programs were used: ScriptLog (Stro¨mqvist & Karlsson, 2002) served as a basic word processor for typing and logging writing activity; KeySpy was developed to implement Kellogg's technique. It launched random beeps, collected RTs under single or dual task conditions, and gathered the verbalization responses.

A set of 5 definitions of writing activities and 35 sentences taken from think aloud writing protocols were devised for training the participants in the directed verbalization procedure. For each writing activity, seven exemplars were provided.

A sequence of seven coloured pictures printed on an A4 page was used to elicit written narratives. This sequence shows a boy going for a walk; he meets a balloon seller, and gets a red balloon; very pleased, he continues strolling; suddenly a blast of wind takes the balloon away; the boy bursts into tears.

Procedure

The questionnaire was administered collectively in a lecture room. Screening was done selecting the

lower and upper tails of the distribution to the question ''how often do you typewrite?'' Participants who reported ''sometimes'' (*n* = 17, M = 2.47; *SD* = 0.72) were categorized as slow typists, those who reported ''very often'' (*n* = 17, *M* = 4.82; *SD* = 0.39) as fast typists.

For the experiment proper, data were collected in individual sessions that lasted for 80 minutes. Participants started by detecting 30 beeps presented at an average interval of 10 s, ranging from 5 to 15 s. They were instructed to lay their hands on top of the keyboard, as if they were writing, and to press the F5 key, with their dominant hand, as quickly as possible. The last 25 trials were used to compute the mean baseline RT for each participant.

Next, participants read the text that would be dictated immediately afterwards. The text was dictated for 10 minutes. Dictation proceeded continuously according to the typing speed of participants. While typing, participants had to press the F5 key as quickly as possible whenever a beep was heard (on average once every 30 s, ranging from 15 to 45 s).

Then, participants were trained with the directed verbalization procedure. They started by discussing written definitions of the verbalization categories: Planning, Producing Text, Typing, Revising, and Other. Planning referred to finding and organizing ideas, Producing Text to translating ideas into words and sentences, Typing to the transcription of a segment kept in mind, and Revising to reading and editing text already written. The label Other accounted for thoughts unrelated to the task (e.g., day-dreaming). After the written definitions were understood, the participants categorized the set of sentences. The exercise lasted until they correctly categorized all examples. On average, training lasted for 15 minutes.

To ensure that participants would devote time and effort to produce their best possible narratives, they were informed that the best stories would win a prize. In order to be able to collect sufficient responses to the auditory probes, a minimum writing time was set to 20 minutes. Participants looked at the elicitation pictures for 1 minute, then started composing. While writing, they had to react as quickly as possible to beeps presented randomly at 15 to 45 s intervals and, immediately after the RT response, to choose the label that best described the interrupted activity (1 out of 5).

Treatments and analyses

The narratives were segmented into minimal terminable units (T-units), and coded in CHAT format for subsequent analysis with CLAN software (MacWhinney, 2000). T-units were defined following Hunt (1965, cited by Sturm & Rankin-Erickson, 2002) as ''one main clause plus all the subordinate clauses attached or embedded within it.'' The T-unit is usually taken as a measure of syntactic complexity (for a review see Hillocks, 1986).

CLAN was used to measure word frequency, word length, lexical density, and vocabulary diversity. Lexical density is the proportion of content words relative to total number of words (Halliday, 1985). Because content words carry more meaning than function words, it is taken as an index of semantic load. Vocabulary diversity was assessed with the D measure (McKee, Malvern, & Richards, 2000). This measure was chosen instead of the more common Type–Token Ratio (ratio of different words to total words) because it is not biased by differences in text length. Values of D range from 5, for an average text of a 5-year-old child, to 120 for a sample of academic writing (Malvern & Richards, 2002).

Indices of cognitive effort in the dictation and composition tasks were computed as Interference RTs (IRTs: RT – baseline RT) taking into account writer activity: typing or pausing. The threshold for pause behaviour was set at 1 s, a threshold appropriate for analyses of writing using a keyboard (Foulin, 1995; Schilperoord, 2001). In the composition task, IRTs from six participants, three in each group, were considered outliers (more than 3 SDs apart from the group mean) and were excluded from statistical analyses.

The occurrences of writing processes (planning, translating, and revising) during pauses or while typing were computed for each subject and then averaged across subjects. Based on Hayes and Flower (1980), the occurrences of translating grouped the producing text and typing labels. A total of 2476 directed verbalizations were collected and, of these, only eight (0.3%) referred to the label other. This was considered negligible, and thus not entered into further analyses.

Two teachers of Portuguese, blind to the objectives and method of the study, independently judged the quality of five dimensions (Formal Use of Language, Creative Use of Language, Amount of Information, Amount of Emotions, and Narrative Structure) of the narratives with a scale ranging from 1 (*very low quality*) to 5 (*very high quality*). Reliable agreement (all correlations significant at $p<.01$) was found for all scales ($r>.70$), with a high overall agreement ($r=.80$).

Results

Screening

As compared to fast typists, slow typists reported less use of computers (M = 2.82 vs 4.59); $t(33) = -5.87$, $p<.001$, $d = -2.04$, and preference for handwriting over typewriting (M = 1.76 vs 3.47); $t(33) = -4.18$, $p<.001$, $d = -1.46$. The two groups did not differ on how often they wrote by hand (*M* = 4.47 vs 4.47), or considered writing a pleasant activity (*M* = 4.35 vs 4.24).

The performance of slow and fast typists on the dictation task differed markedly. On average, the interval between two keystrokes within a word was 95 ms longer for slow (*M* = 291 ms, SD 5 95) than for fast typists (*M* = 196 ms, *SD* = 50); *t*(33) = 3.56, p<.001, *d* = 1.24. Also, the slow group typed 10 words per minute less (*M* = 21.73, *SD* = 5.46) than the fast one (*M* = 31.87, *SD* = 6.75); *t*(33)= - 4.73, *p*<.001, *d* = - 1.65. These differences in typing performance did not trade off with typing accuracy, as both groups typed texts with about 5% of typos, *t*(33)= 1.30, *p* = .20.

COGNITIVE EFFORT

Slow and fast typists were virtually identical in simple auditory RTs (*M* = 497 vs 504 ms, *SDs* = 111 vs 91, respectively). However, RTs for auditory signals while typing under dictation differed between groups: slow typists (*M* = 535, *SDs* = 118) took on average 89 ms more than the fast typists to respond (*M* = 446 ms, *SDs* 120); *t*(33) = 2.18, *p*<.05, *d* = 0.76. This indicates that the cognitive demands of motor programming are higher for slow typists.

Figure 1 shows the IRTs for the slow and fast groups while typing under dictation, typing under composition, and pausing under composition. A 2 (Typing Skill) x 3 (Condition) mixed ANOVA was conducted on those scores. A main effect of Typing Skill was found, *F*(1, 26) = 6.73, *MSE* = 381645, *p*<.01. The mean IRT of slow typists (*M* = 706 ms; *SD* = 179) was higher than that of fast typists (*M* = 571 ms, *SD* = 205). The main effect of Condition was also significant, *F*(2, 26) = 55.15, *MSE* = 529143, *p*<.001. Scheffé post hoc analyses showed that IRTs of typing or pausing in composition (*M* = 705 ms, *SD* = 197; *M* = 730 ms, *SD* = 183) were both higher than typing under dictation (*M* = 481 ms, *SD* = 123; *p*<.001). Contrary to our prediction, typing skill and IRT condition did not interact. This indicates that both groups engaged in high-level writing processes concurrently with typing.

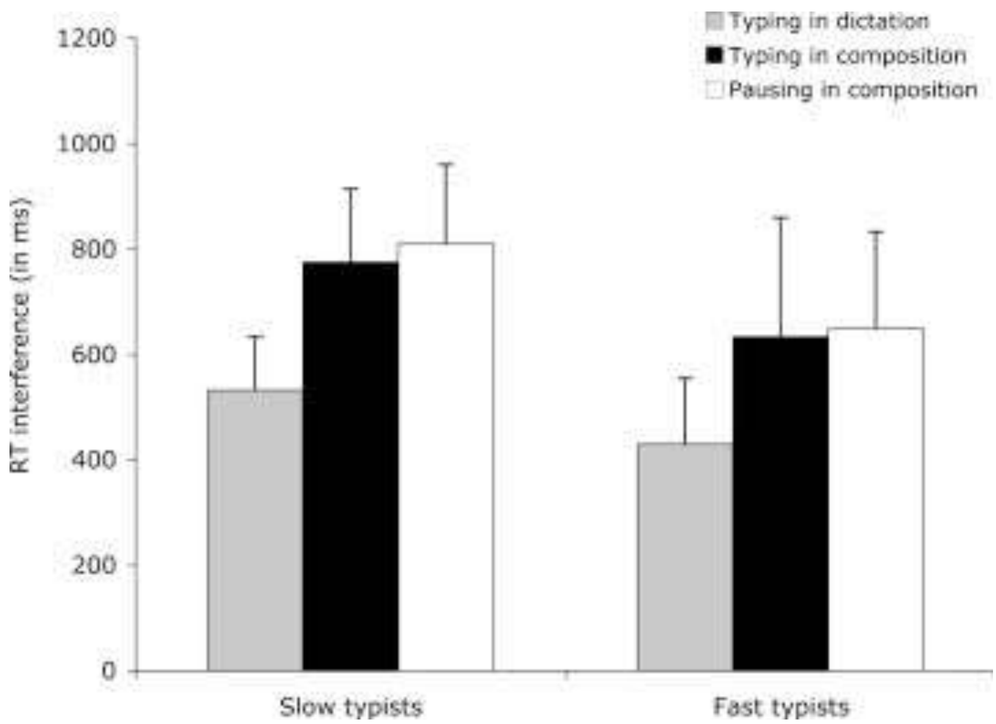

Figure 1. Interference RTs for slow and fast typists while executing during dictation, and while executing or pausing during composition (error bars indicate standard deviations).

Preliminary analyses on the demands of the writing processes and on their occurrences showed no effects of typing skill, which was thus removed from subsequent analyses.

Regarding the cognitive effort associated with planning, translating, or revising during pauses or while typing, a two-way repeated ANOVA on IRTs revealed a main effect of Writing Processes, $F(2, 30) = 7.56$, $MSE = 181975$, $p<.01$. Post hoc analyses showed that revising ($M = 771$ ms, $SD = 268$) was more demanding than planning ($M = 634$ ms, $SD = 237$; Scheffé, $p<.01$) and translating ($M = 647$ ms, $SD = 214$; Scheffé, $p<.01$). Neither a main effect of writer activity, nor any interactions, were found ($Fs<1$).

OCCURRENCES OF WRITING PROCESSES

Means and standard deviations of the occurrences of planning, translating, and revising were computed according to writer activity. A twoway repeated ANOVA conducted on those scores revealed a main effect of Writing Processes, $F(2, 33) = 34.56$, $MSE = 4133$, $p<.001$. Post hoc mean comparisons confirmed that translating was the dominant process, with about half of the occurrences (51.33%), more frequent than revising (24.91%; Scheffé, $p<.001$) and planning (23.77%; Scheffé, $p<.001$). The Writing Processes x Writer Activity interaction was significant, $F(2, 33) = 66.39$, $MSE = 5090$, p,.001. As shown in Figure 2, translating was activated more during typing than during pauses (Scheffé, $p<.001$). Revising and planning showed the reverse pattern: Both were more frequent during pauses than during typing (Scheffé, $p<.001$). Revising and planning were activated concurrently with typing. Perhaps more surprisingly, translating occurred as often during pauses as did planning and revising.

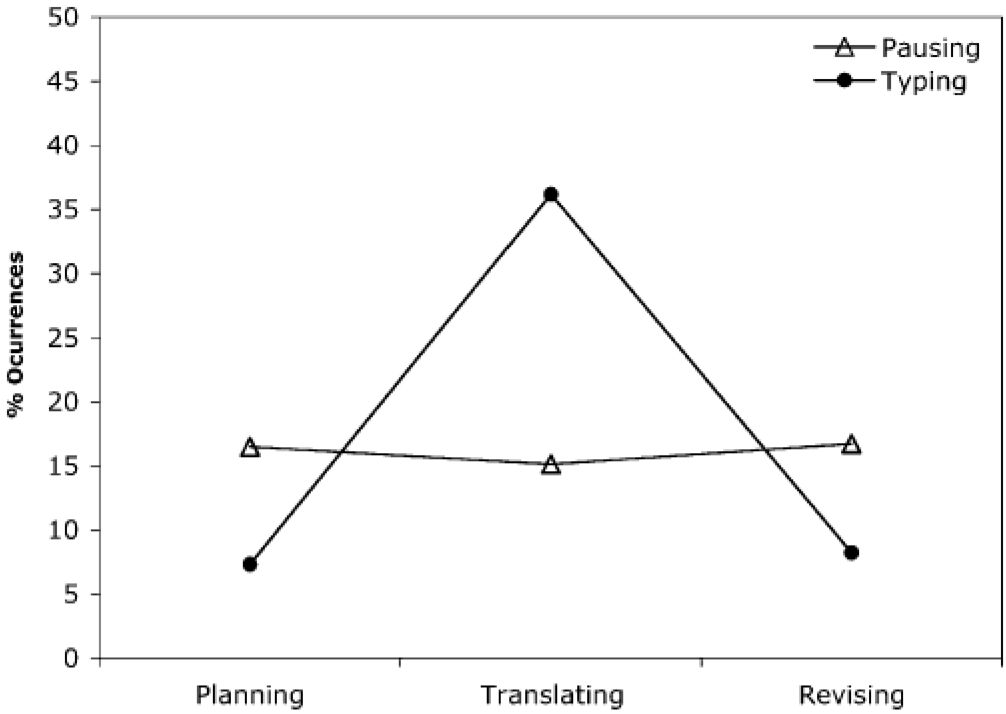

Figure 2. Occurrences of writing processes by writer activity (pausing or typing).

WRITING PERFORMANCE

Means and standard deviations are presented in Table 1. As expected, slow typists produced fewer words per minute than fast typists, on average five words less, $t(33) = -2.92$, $p<.01$, $d = -1.02$. Since both groups spent around 37 minutes composing their texts, slow typists produced shorter texts (162 words less than those of fast typists), $t(33) = 22.30$, *p*<.05, *d* = -0.80). Writing less, slow typists also produced fewer T-units, *t*(33) = -2.16, p<.05, *d* = -0.75. However, syntactic complexity did not suffer from the slow typists' reduced fluency, since T-unit size was similar across groups.

Table 1
Means (and standard deviation) of writing fluency, productivity, syntactic complexity and lexical diversity for the whole group, and split by slow vs fast typists

		Groups	
	All N = 34	*Slow n = 17*	*Fast n = 17*
Total writing time (min)	36.93 (13.68)	36.56 (14.42)	37.30 (13.33)
Fluency (wpm)	12.59 (5.36)	10.17 (3.25)	15.02 (6.01)
Text length (in words)	456.15 (218.50)	375.18 (202.04)	537.12 (209.08)
Number of T-units	36.85 (22.02)	29.12 (18.89)	44.59 (22.72)
T-unit size (in words)	13.07 (2.49)	13.40 (2.61)	12.74 (2.40)
Word size (in characters)	4.56 (0.18)	4.56 (0.21)	4.56 (0.15)
Different words	223.29 (83.41)	194.41 (81.98)	252.18 (76.53)
Vocabulary diversity	98.47 (20.29)	97.56 (21.58)	99.38 (19.55)
Lexical density	.51 (.04)	.49 (.04)	.52 (.03)

The slow typists produced texts with fewer different words, *t*(33) = -2.12, *p* = .04, *d* = -0.74. However, this is not indicative of smaller vocabulary size, as there was no between-group difference on the vocabulary diversity measure; it is probably associated with less productivity. Also, the texts produced by slow typists showed less lexical density than those of fast typists, *t*(33) = -2.43, *p* = .02, *d* = -0.85; less productivity impacts more on content than on function words.

Table 2 presents means and standard deviations on text quality measures. The texts produced by slow typists were judged as having less overall quality, *t*(33) = -2.28, *p* = .03, *d* = -0.79. Amount of information reliably differed, t(33)522.26, *p* = .03, *d* = -0.79, and formal use of language and amount of emotions tended to be different, respectively, *t*(33) = -1.80, *p* = .08, *t*(33) = -1.69, *p* = .10. No differences were found in narrative structure or in creative use of language. Thus, slow typists produced texts that were less informative, had more faults regarding language correctness, and with less emotional detail.

Table 2
Average ratings (and standard deviations) of text quality in each scale for the whole group, and split by slow vs fast typists

		Groups	
Quality ratings	*All N = 34*	*Slow n = 17*	*Fast n = 17*
Overall quality (max = 25)	13.63 (3.80)	12.24 (4.07)	15.03 (3.01)
Formal use of language	2.99 (0.93)	2.71 (0.90)	3.27 (0.90)
Creative use of language	2.47 (0.89)	2.27 (0.90)	2.68 (0.85)
Amount of emotions	2.91 (.94)	2.65 (0.95)	3.17 (0.88)
Amount of information	2.97 (1.21)	2.53 (1.23)	3.41 (1.03)
Narrative structure	2.29 (.85)	2.09 (0.82)	2.50 (0.85)

DISCUSSION

This study explored the distribution and cognitive effort of writing processes (planning, translating, revising) occurring during pauses and during motor execution when producing a narrative text. Also, we looked for an impact of typing skill on the strategic activation of those writing processes. As far as we know, this is the first study to provide reliable estimates of how writing processes are distributed over pauses and motor execution periods. We confirmed that planning and revising were mostly activated during pauses (both about 17%).We also found that translating was activated to a similar extent (15%). Thus, none of these writing processes can be said to be typical of pauses. During execution, translating dominated (36%), but planning and revising were also activated, even if to a limited extent (around 7%). This study has also shown that motor execution is more demanding for slow typists than for fast typists. Yet, contrary to our prediction, both groups were able to activate high-level writing processes concurrently with motor execution. Furthermore, we did not find evidence that slow and fast typists differ on how frequently planning, translating, and revising are reported during the writing session.

The estimates of the processing time devoted to planning, translating, and revising are reliable, as they resulted from the application of a technique whose reliability and nonreactivity is well established (Olive et al., 2002). Planning and revising are more likely to be carried out during pauses than during execution. It may be that writers strategically choose to work in one segment of text at a time. Alternatively, the high reliance of these processes on executive functioning (Berninger, 2000; Kellogg, 2001; Olive, 2004) may render them difficult to manage concurrently with motor execution. However, our results also show that planning and revising sometimes co-occur with motor execution. One possibility is that some of these processes are started during motor execution and, as writers engage in them, they then interrupt execution. Alamargot et al. (2007) suggest that parallel events starting before a pause deal with conceptual processes, and those after a pause are devoted to linguistic formulation. This suggestion fits in well with our finding that, of all processes, translating is the one that is more easily performed in parallel with execution. However, it does not account for the relatively high proportion of pauses devoted to translating reported here.

The relatively high occurrence of translating during pauses may be due to instances of keyboard search for infrequent keys. It is unlikely, however, that this is the main reason, because for both groups the mean intervals between two keystrokes were well below the 1 s pause threshold. More likely, and in line with McCutchen's (1988) proposal, our results may be explained by the fact that translating is not fully automatized; in order to achieve expertise in writing, language generation must be penetrable to metacognitive control and to interaction with other writing processes. In other words, expertise in writing is associated with the ability to use high-level goals (e.g., produce the best possible text, maintain coherence, consider audience) to exert control over language generation. This may explain why, in several moments of composition, the writers in this study spent more than one second dealing with issues such as word selection or sentence framing.

Olive and Kellogg (2002) have shown that nonproficiency in handwriting leads to the activation of writing processes serially, not in parallel, and here we hypothesized that slow typists might behave like nonproficient handwriters. However, our results indicate that this is not the case. Although motor execution is more demanding for slow typists, this higher demand neither prevented them from activating high-level processes concurrently with typing, nor changed the distribution of occurrences of the writing processes. Instead, the higher demands of execution for slow typists appeared to add to the demands of high-level processes in written composition, in that slow typists exerted more cognitive effort than fast typists in the composition task. The failure to find evidence of serial activation of writing processes in slow typists can be explained by two lines of reasoning.

First, achieving parallel processing in typing might be substantially different from achieving it in handwriting. Foulin (1995) noted that the slowness of handwriting as compared to speaking makes handwriting more prone to parallel processing than speaking. By the same token, since for nonexpert typists typing is generally slower than handwriting, parallelism in typing might be more easily achieved than in handwriting. Second, our naturally occurring levels of typing skill might not have been as extreme as the manipulation created by Olive and Kellogg. This point can be illustrated by comparing the fluency between our slow typists and the adults who used the untrained script; respectively, 10.2wpm and 4.1wpm. A manipulation that might allow a more direct comparison between the demands of untrained typing and untrained handwriting is the use of modified keyboard layout. Also, a comparison between children learning to type and children of the same age with prior practice of typing might provide a naturally occurring context in which to explore further if typing skill has an impact on the activation of writing processes. Thus, the issue of replicating Olive and Kellogg's (2002) findings in the typing modality remains open to further inquiry.

Even if slow typists managed to activate highlevel writing processes concurrently with typing, they did so by spending more effort and being less fluent on the composition task than fast typists. Both of these characteristics were already present in the dictation task (the ratio between fluency in dictation and fluency in composition is virtually identical in the two groups). It is therefore safe to conclude that both groups were equally affected by the demands of written composition. This favours the idea that the reduced fluency of slow typists in composition is not due to difficulties in high-level processes of writing, it is instead related to difficulties in low-level transcription (cf. Alves et al., 2007). As transcription builds on the close integration between motor programming and spelling (Berninger, Mizokawa, & Bragg, 1991; Christensen, 2004), the difference between slow and fast typists may lie in one, or both, of these transcription components. Further inquiry should try to disentangle motor programming from spelling.

This study indicates that, of the several measures of writing processes that were examined, the ones related to fluency are more relevant for the distinction between slow and fast typists. The reduced fluency of the slow group is accounted for by the higher demands of low-level transcription. However, reduced fluency did have an impact on the written products: the texts written by slow typists were judged to be of lower quality than those written by fast typists. This result is in line with several others that have found that text quality can suffer from difficulties in low-level transcription, as well as from the experimental manipulation of the demands of motor execution (Bourdin & Fayol, 2002; Connelly, Dockrell, & Barnett, 2005; Graham, 1990; Olive & Kellogg, 2002). Note, however, that this negative impact was restricted to the lexical level, as no differences were found in syntactic complexity, narrative structure, or creativity.

Similarly to Kellogg (2001), we found that in the writing of a narrative, revising is the most demanding process, and translating is as demanding as planning. The comparatively low demands of planning are accounted for by the high availability of narrative schemata in adults (Bruner, 1990).

To conclude, even though differences in typing skill have an impact on the demands of execution, on fluency, and on text quality, these differences neither affected the strategic activation of planning, translating, and revising, nor the processing time devoted to these writing processes. All in all, the analysis of the distribution of writing processes over pauses or motor execution showed a general pattern in which language formulation is more likely to co-occur with motor execution, while conceptual planning and text revising tend to suspend motor execution.

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