

## Evidence of Repeated Access to Immediate Verbal Memory During Handwriting

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*Writing is a relatively slow process. A certain degree of overlapping must therefore be assumed to exist between motor activities and more «central» processes involved in the production of language. The present experiment was based on the assumption that these management processes must leave some traces at the level of execution.*

*Subjects were asked to read and memorize a sequence of three words (examples: «parachute parapluie paramètre», «taximètre décimètre paramètre»); and write them down on a graphic tablet. The results are consistent with the following ideas:*

- a) the same motor program was used for the three occurrences of repeated morphemes;*
- b) Non-repeated morphemes were recovered from verbal memory while the preceding repeated morpheme was being written.*

Whether done by hand or on a typewriter, writing is a relatively slow process. It follows that psycholinguistic processes (lexical retrieval, syntactic construction, etc) may often get ahead of execution, resulting in the need to temporarily store some verbal material in immediate memory, and subsequently retrieve this material before execution<sup>1</sup>. The aim of the present experiment is to address these final phases of the writing process (retrieval from verbal memory, motor programming and execution). The two versions of Sternberg, Monsell, Knoll and Wright's model (1978), initially proposed in the domains of oral production and typewriting will be taken as a starting point. In version 1 of this model (Motor-program Construction or Activation), the subprogram corresponding to each unit (whose nature is to be specified in each case) is-constructed (or activated) immediately before being executed. In version 2 (Subprogram Retrieval), the program is constructed right from the start for the entire sequence of units (i.e. before the first one is produced) and then each of the unit subprograms is retrieved from the «motor-program buffer» right before it is executed. Inasmuch as *oral*

production is concerned, version 2 seems to apply. Indeed, neither response latency nor execution speed decreases when certain units in the sequence are repeated. (One characteristic of the motor-program buffer is that it necessarily contains the entire set of subprograms required to produce the sequence; by contrast, immediate verbal memory is known to benefit from certain regularities in the stimulus, such as repeated elements for example). We shall argue that version 2 of Sternberg et al's model does not hold true in the case of handwriting. In order to provide evidence of *repeated access to immediate memory* during handwriting, we asked subjects to write sequences of words containing «repeated» and «new» elements in alternation. For example:

- 1) entrelacé entretenu entreposé
- 2) superposé interposé entreposé

If version 2 applies, no repetition effect should occur during writing, since the entire program is assumed to have been constructed before writing begins. If, on the other hand, the writing program for each individual unit is set up separately as the sequence is being written, then there should be some effects. In particular, we can expect the subprogram for the repeated element («entre» in example 1, «posé» in example 2) to be accessible sooner. Memory retrieval mechanisms should also leave some traces at the execution level. For example, writing might be slowed down while the next unit, whatever it may be, is being retrieved.

One question that remains is the programming unit. In most of the experiments reported by Sternberg et al., the sequences to be produced were series of monosyllabic English words (or bisyllabic words with one stressed syllable). Other units such as the syllable (Shaffer, 1975) or the morpheme (Viviani & Terzuolo, 1983) have also been considered in the literature. The units studied in the experiment reported below are words, and at the infra-lexical level, morphemes separated by a syllable boundary. One of the questions raised pertains to the lexical or infra-lexical nature of the programming unit: can a repetition effect be observed at the infra-lexical level?

## Method

Sixteen native French-speaking psychology students (average age 22 years) participated in the experiment. The experimental device was a graphic tablet (sampling every hundredth of a second) connected to a micro computer. The stimuli consisted of three bi-morphemic words. One of the morphemes, the first or the second, was identical in all three words (see examples (1) and (2) above). Eight triplets of each type were set up. Each type-1 triplet had a corresponding type-2 triplet which ended in the same word. To display a stimulus (a sequence of three words) on the computer screen, the subject had to push a control button located on the pen. As soon as he/she let go off the button, the stimulus disappeared. Mean writing speed was recorded for each morpheme in the first and last word in every sequence. The eight triplets of a given type (preceded by three practice triplets of the same type) were blocked and presented in pseudo-random order across subjects. The order of presentation of blocks was counterbalanced.

## Results and discussion

The data were analyzed according to a 2(Types of triplet)  $\times$  2(Word positions)  $\times$  2(Morphemes) within-subject design. The corresponding mean values are presented in Table 1. In the discussion below, the factors are considered two at a time.

*The Word position and Morpheme factors.* Word-initial morphemes were written more

Table 1  
Mean writing speeds (in pixels/cs)

Morpheme repeated	First word		Last word	
	Morph. 1	Morph. 2	Morph. 1	Morph. 2
Word-initial	3.90	3.92	4.03	3.79
Word-final	3.78	3.87	4.07	3.91

slowly in the first word in the sequence, and word-final morphemes were written more slowly in the last word, suggesting the existence of an «initiating» phase at the end of a sequence. This effect showed up in the analysis of variance as an interaction between Word position and Morpheme ( $F(1, 14) = 17.39, p < .001$ ).

*The Type of triplet and Morpheme factors.* The repeated morphemes were written faster (marginally significant interaction between Morpheme and Type of triplet,  $F(1, 14) = 4.14, p < .06$ ). This result is consistent with the hypothesis set forth in the introduction. The entire motor program for all three words does not appear to be assembled before execution. It is interesting to note that this effect occurred even on the first word, even though the «repeated» morpheme had not really been repeated, since nothing had been written yet. This suggests that the observed effect is not just linked to the execution stage. The concerned mechanisms must pertain to the entire sequence while it is stored in verbal memory.

*The Type of triplet and Word position factors.* There was also an interaction between Type of triplet and Word position ( $F(1, 14) = 5.13, p < .04$ ). Mean writing speed was the same for the first and last words of type-1 triplet sequences (repetition of word-initial morpheme), whereas it was slower on the first word than on the last word of type-2 triplet sequences (repetition of word-final morpheme). This pattern is compatible with the hypothesis whereby execution overlaps retrieval and programming operations during writing, as indicated in Figure 1 below.

## Conclusion

The following two hypotheses can be put forth to interpret our results.

- The repeated morpheme is «factored out» in verbal memory and the same motor program is used for all its occurrences. This would release resources for handling the units that follow.
- The next morpheme is retrieved from immediate verbal memory and programmed while the repeated morpheme is being written.

The diagram in Figure 1 showing possible ways in which the retrieval, programming, and writing of infra-lexical units could be managed is compatible with all of the above observations.

Three hypothetical instances have been diagrammed: Immediate verbal memory, containing a phonological representation of the word sequence, a motor buffer in which the motor subprograms are assembled, and finally the execution stage (writing). This final level is shifted to the right by one unit (one morpheme). Indeed, the programming unit is assumed here to be the morpheme. The following conventions also apply to Figure 1:

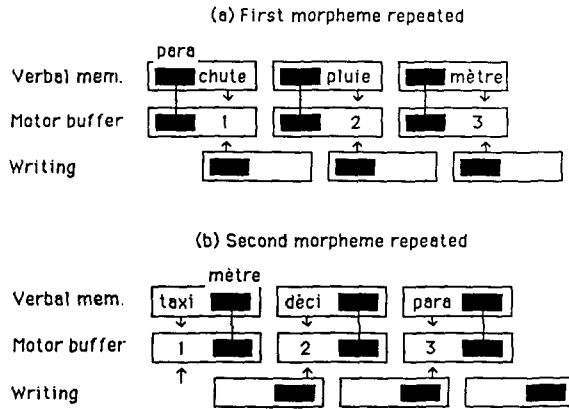


Figure 1. Overlapping of execution and retrieval for both types of triplets.

- i) The repeated morpheme is depicted by a black rectangle.
- ii) The phonological code of the repeated morpheme (at the immediate memory level) and the corresponding motor subprogram (at the motor buffer level) are connected by a line indicating that motor subprogram retrieval based on the phonological code is direct.
- iii) The downward arrows depict the programming operations carried out during the writing process. The numbers indicate the order in which the subprograms are ready to be executed.
- iv) The upward arrows indicate when the retrieval operations for the unrepeatd morpheme are assumed to occur (namely, as the repeated morpheme is being written).

In triplets where the first morpheme is repeated, the next unit processed is the second morpheme of the same word. In triplets where the second morpheme is repeated, the next unit is the first morpheme of the following word. Note that the timing of the operations is the same throughout the entire sequence when the repeated morpheme is the word-initial morpheme (Figure 1a): there is always a next unit to retrieve in this case. When it is the word-final morpheme that is repeated, however, the processing load decreases between the first and last word (Figure 1b). Indeed, there is no next unit to be retrieved following the repeated morpheme of the last word in this case.

In conclusion, it appears that a sequence of three words is too long to be handled by a single motor program, insofar as writing is concerned. This result contrasts with those found in speech production. Two main reasons might underly this difference:

- a) Writing is slower than speaking, making it unlikely that the motor program for even a short sequence of words can be maintained throughout the entire production;
- b) As suggested by Sternberg, Knoll, Wright and Monsell (1980), the link between phonological code and motor program is essentially a direct one in oral production.

Writing is possibly less automated than speech, and may involve an extra stage of processing, as suggested in this paper.

The possible consequences of these differences for idea planning and psycholinguistic

management have yet to be investigated. The methodology used in the present experiment might reveal itself useful at this level as well. For example, the slowing down of writing observed when immediate verbal memory was being accessed might provide a good index for investigating the nature of the planning units involved in writing.

## Notes

- <sup>1</sup> Obviously, a similar synchronising problem may arise between the two levels considered here and more central processes such as idea planning. We shall not address this question here.

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