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When working memory updating requires updating: Analysis of serial position in a running memory task

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ABSTRACT

This study aimed to investigate updating in working memory (WM), analyzing the effects of task demand and memory resources on serial position curve (SPC), in a running memory task with slow pace presentation and a probed recognition procedure. These task conditions were supposed to produce an easier WM updating task, which may allow evidencing whether the task is performed through an active or a passive updating.

Serial position curves were compared in conditions of high or low memory load, and with or without interference of a secondary (prospective memory, PM) task. With either a high WM load, or a high PM load, results showed a SPC with both primacy and recency effects, indicating the use of an active strategy. When resources were taken up by both PM task and high WM demand the usual pattern with only recency effect was obtained.

Taken together, these findings support the ideas that 1 — people can effectively update WM, and 2 — the performance is dependent on both memory and executive resource availability.

1. Introduction

Efficient use of working memory (WM) implies selectively focusing on goal-relevant information. From this perspective, the role of working memory updating becomes crucial: this is a specific mechanism of continuous monitoring, selection of incoming information and replacement of no-longer-relevant information with new, more relevant material (Morris & Jones, 1990).

Traditionally, WM updating is investigated with a running memory task procedure (Pollack, Johnson, & Knaff, 1959), asking participants to recall the last few items of lists of uncertain lengths. This kind of task was used by Morris and Jones (1990) to study updating process within the WM model of Baddeley (1986). These authors conceptualized updating as a continuous all-or-nothing mechanism of maintenance-substitution, with the maintenance function carried out by the phonological loop and substitution by the central executive (Morris & Jones, 1990).

The running memory task has also been considered a suitable procedure for investigating executive functioning (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000), in connection with either a general intelligence factor (Friedman et al., 2006), or other complex cognitive processes (such as reading comprehension; e.g., Palladino, Cornoldi, De Beni, & Pazzaglia, 2001). It has been argued (Postle, 2003) that five discrete mental operations in short-term memory (STM) are necessary to execute this task: adding items to STM (encoding), discarding items from STM, repositioning, storing and, finally, rehearsing items in STM. However, it is considered as an updating task due to the discarding and repositioning operations only, which may themselves require executive control processes (D'Esposito & Postle, 1999, 2000).

Following the pioneering work of Morris and Jones (1990), running memory tasks are often described by use of serial position curves (SPCs). In this instance, SPCs were characterized by a marked recency effect, without primacy. This pattern in running memory tasks was validated by several other studies (Bunting, Cowan, & Saults, 2006; Fiore, Borella, Mammarella, & De Beni, 2011; Palladino & Jarrold, 2008; Ruiz, Elosùa, & Lechuga, 2005) and is therefore considered a robust result. Based on this dissociation, Bunting et al. (2006) hypothesized that two different strategies may be used to perform the task. The first consists of an active strategy of continuous updating of memory content (i.e., consistent with Postle, 2003), while the second consists of a passive "wait" until the end of the list, and a subsequent recall of the most recent items. The use of one of these two strategies was thought to depend on both task demand and memory availability, in turn, enabling use of executive resources. For example, with either low task demands and/or low memory load, participants may have had more executive

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resource available. Thus, they were likely to continuously update information and rehearse the updated sequence. Under these conditions an active strategy is used, otherwise a passive strategy is preferred.

To explore this further, Palladino and Jarrold (2008) examined the strategies employed in a running memory updating task by comparing SPCs in updating tasks with those in standard serial recall. The results showed a clear "uncertainty effect", with worse performance for updating trials compared with serial recall trials of identical length, and an overall lack of primacy in the updating curves. Taken together, this evidence suggested that participants may not be engaged in continuous active maintenance/updating. Moreover, it suggested that serial position analysis could be an effective procedure to investigate the mechanism underlying updating tasks.

A possible alternative explanation of recency effects in the serial curve is provided by the SIMPLE model (Brown, Neath, & Chater, 2007; but see also Brown, Vousden, McCormack, & Hulme, 1999), which assumes that people represent items according to their position in a multidimensional space. Among several dimensions (such as ordinal list position or phonological similarity), a central role for recall is played by the relative temporal distances, 1) between items in the list (i.e., if two items are temporally distant each other, then they are isolated in memory and likelihood of recall increases), and 2) between the items and the moment of recall (i.e., given a logarithmic transformation of the elapsed time, the further items are from the moment of recall, the more mistakable they are). According to the temporal distinctiveness (TD) model, a recency effect is clearly due to the latter point. Whilst, primacy effects could appear only when the distinctiveness of the first items due to the first issue (i.e.: inter-items distance) is strong enough to contrast the hindrance due to the second issue (i.e.: temporal distance form recall). Unlike the standard free recall task, in a running memory task, the first to-be-recalled item is typically preceded by interfering items, thus the distinctiveness of this item due to the first issue is lower than that of the first item of the list. In this situation, a primacy effect is not expected, unless other processes needed in a running memory procedure (e.g., discarding and/or repositioning) might also influence the relevance of the items. However, according to the TD approach, the SPC performance does not depend on other executive processes, but only on characteristics of the stimuli. Geiger and Lewandowsky (2008) used a running memory task procedure, and provided support for the TD account. They showed that both temporal and nontemporal information were maintained in memory until the point of cueing. In particular, Geiger and Lewandowsky's experiments described a clear recency effect when list length was higher than the number of to-be-recalled items (four), and a flat function with list length of four items. When item numerosity is below the individual span, and no discarding/repositioning operations were needed, all the items have the same likelihood of being recalled. Otherwise, when task demands are higher than individual resources, the first to-be-remembered items is confused among the other items, and other processes, specific for the running memory task, would not influence its retrieval likelihood.

Several studies (i.e., Fiore et al., 2011; Palladino & Jarrold, 2008; Ruiz et al., 2005) have presented memoranda at a relatively rapid pace, and this choice may have precluded them from finding a primacy effect. Executive processes, such as discarding and repositioning an item, require time and resources to take place. Therefore, a rapid presentation of stimuli is less likely to allow WM updating occurring in a running memory task. That said, only Bunting et al. (2006) have compared slow and fast presentation pace directly. Their data suggest that a reduction in pace leads to an increase in the primacy portion of the SPC. This notwithstanding, their slow pace presentation (1000 ms) could still be considered fairly rapid and, in both slow and fast pace conditions, they failed to find a clear primacy effect. The authors themselves acknowledge that a slower presentation pace than that used is likely to allow primacy effects to occur in a running memory task (p. 1694). Support for this suggestion was reported in Postle (2003). In his first two experiments, Postle employed a running memory task with presentation pace ranging from 2.5 to 3.5 s, and a subsequent probe recognition task. The probe consisted of one letter that might (or might not) match an item in the memory set. Unfortunately, using a recognition procedure, Postle did not analyze his results in respect of serial position; for example, in Experiment 3, where he used complete recall instead of probe recognition. Although flat SPC and the absence of primacy were probably due to a ceiling effect here, these experiments provide sound evidence that updating is occurring at this slow presentation rate. The mixed methodology (i.e. recognition and serial recall procedures) used in Postle's study represents a good starting point for further investigations, capable of replicating and extending his results.

The present study represents an extension of these data on the running memory task, by means of manipulating memory demands (via memory load and task type), at a slow presentation rate, a probe recognition procedure and the analysis of the serial position curves.

Memory load demands were compared via the number of items to be maintained in WM. Participants had to remember either the last 3 or 5 items of the lists (for low and high loads, respectively): these numbers were selected in order to represent quantities sub- and supra-span (Cowan, 2001), which are known to influence performance. A sub-span quantity is not expected to produce a serial curve, but a nearly perfect recall with a flat serial position function, because sufficient memory resources are available for the task. However, supra-span quantities need resources to be optimized. The continuous update of items is expected to 'push' people into using memory strategies that would, in turn, increase the likelihood of items retrieval, but also have higher costs in terms of resource demand. With supra-span quantities, if participants are able to optimize resources and actively update items in a continuous stream, rehearsing new updated sequences, a serial curve with both primacy and recency effects would be produced. Otherwise, if the task demands do not allow implementation of such a strategy, the primacy effect would not appear.

Consistently with the TD account, the recency effect is not thought to be affected by manipulation of memory load demands, since it is based on retrieval from passive storage at the time of recall (Cowan et al., 2005). However, the primacy effect, which is related to the amount of rehearsal (Tan & Ward, 2000), or to highly focused encoding due to top-down attention (Sederberg, Howard, & Kahana, 2008) during study of early list items, is thought to appear only under conditions with low resource demands and the participants' ability to process incoming stimuli proficiently. Therefore, if the primacy effect appears in running memory task, it may be considered a marker of an effective updating (e.g., Palladino & Jarrold, 2008; Postle, 2003; Sederberg et al., 2008).

To manipulate resource availability through task demands, a secondary prospective memory (PM) task was selected to be performed simultaneously with the primary WM updating task. Prospective memory (i.e. possessing a behavioral intention, to be performed at a certain moment in the future) might compete for memory resource with a WM task, as both PM and WM are considered executive processes (Kliegel, Martin, McDaniel, & Einstein, 2002; Mäntylä, 2003; Okuda et al., 1998). In particular, two independent processes have been indicated to be resource-demanding in a PM task (Guynn, 2003; 2008): a retrieval mode and a target checking mechanism. Retrieval mode consists of a continuous monitoring process that occupies the memory central executive by maintaining representation of the PM task. Target checking is a transient process needed to check the environment continuously, detecting PM cues and discarding distracters (e.g.: Bisiacchi, Cona, Schiff, & Basso, 2011). Accordingly, the PM task is a good candidate for engaging the central executive in a resource-consuming activity, being both a continuous secondary task and disrupting on-going activity whenever a cue (or distracting cue) appears.

In this vein, Basso, Ferrari, and Palladino (2010) showed that PM demand affected performance in a verbal updating WM task, but only at high WM loads. Conversely, no effects were found with low WM loads, and overall, this effect was enhanced for higher PM demands. These data show that PM and WM compete (at least, partially) for the