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Strategy difficulty effects in young and older adults' episodic memory are modulated by inter-stimulus intervals and executive control processes☆

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ABSTRACT

Efficient execution of strategies is crucial to memory performance and to age-related differences in this performance. Relative strategy complexity influences memory performance and aging effects on memory. Here, we aimed to further our understanding of the effects of relative strategy complexity by looking at the role of cognitive control functions and the time-course of the effects of relative strategy complexity. Thus, we manipulated inter-stimulus intervals (ISI) and assessed executive functions. Results showed that (a) performance as a function of the relative strategy difficulty of the current and previous trial was modulated by ISI, (b) these effects were modulated by inhibition capacities, and (c) significant age differences were found in the way ISI modulates relative strategy difficulty. These findings have important implications for understanding the relationships between aging, executive control, and strategy execution in episodic memory.

1. Introduction

One of the most robust findings in aging research on memory is that older adults perform less well than young adults in most memory tasks (Dunlosky & Hertzog, 2001; Light, 1996; for review). To encode, store, and recall information, both young and older adults use different strategies. A strategy is defined as "*a procedure or a set of procedures to achieve a higher level goal*" (Lemaire & Reder, 1999, p. 365). Performance and age-related differences depend on the strategies used (type, number, frequency, and how they are executed). Of great importance is how age-related differences in strategy selection and execution lead to differences in memory performance. The present study contributes to this issue by investigating how strategy execution and age-related differences therein are modulated by task parameters such as inter-stimulus intervals and by individual characteristics like executive functions.

Memory performance in both young and older adults depends on which strategies participants use (e.g., Froger, Bouazzaoui, Isingrini, & Taconnat, 2012; Lemaire, 2016). Strategies differ in difficulty and efficiency. Relative strategy difficulty arises from the number and complexity of processing steps involved. Usually, harder strategies involve more and/or more complex steps, require more effort to execute, and are more demanding in processing resources. In the memory domain, complex strategies based on deep encoding usually yield better performance (e.g. Craik & Lockhart, 1972; Paivio & Csapo, 1969). An example of an efficient memory strategy is mental imagery, which involves linking the word to be memorized to a corresponding visual representation (i.e., representational processing, Paivio, 1986), but it requires a relatively long time to be correctly implemented (Paivio & Csapo, 1971; Plaie & Thomas, 2008). By contrast, rote repetition involves perceptive-lexical encoding, which requires less time and fewer cognitive resources and thus leads to shallower encoding (Tulving & Thomson, 1973; Froger et al., 2012). Studies in aging have shown that the efficiency of mental image generation declines in old age (e.g., Bruyer & Scailquin, 2000; Dror & Kosslyn, 1994; Dunlosky & Hertzog, 2001; Plaie & Isingrini, 2003). Using multiple imagery tasks (i.e., perception, generation, rotation), Briggs, Raz, and Marks (1999) showed that imagery capacity is impaired in old age, and that age-related differences could be explained by individual differences in control processes (e.g., working memory). Subsequently, further studies on mental imagery and memory found that (1) older adults use mental imagery less often than young adults (Dunlosky & Hertzog, 2001;

☆ The same analyses were run with (imagery-repetition)/repetition, with the same significant results.

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Froger et al., 2012; Froger, Toczé, & Taconnat, 2014; Tournier & Postal, 2011), and (2) when they are encouraged or instructed to use mental imagery, older adults execute it less efficiently than young adults. In sum, previous research in memory found that strategy use and efficiency of strategy execution change during aging (e.g., Froger et al., 2012; Tournier & Postal, 2011). The present study provides further evidence of the origins of the relative efficiency and difficulty of memory strategies, as well as age-related differences in the strategies used.

Relative strategy difficulty has been shown to influence performance not only on current trials but also on subsequent trials. This is evidenced by different effects such as strategy switch costs (e.g., Lemaire & Lecacheur, 2010; Ardiale & Lemaire, 2012, 2013), strategy sequence congruency effects (Lemaire & Hinault, 2014; Hinault, Dufau, & Lemaire, 2015; Hinault, Lemaire, & Phillips, 2016), and by strategy sequential difficulty effects (SSDE). The latter were originally found in arithmetic problem solving (e.g., Uittenhove & Lemaire, 2012, 2013a, 2013b; Uittenhove, Poletti, Dufau, & Lemaire, 2013) and more recently in episodic memory (Uittenhove, Burger, Taconnat, & Lemaire, 2015). In SSDE, performance on current trials is influenced by the relative difficulty of the strategies used on immediately preceding trials. In memory, Uittenhove et al. (2015) found that both young and older participants correctly recalled more words using a sentence-construction strategy when this followed an easier strategy (i.e., repetition) than after a harder strategy (i.e., mental imagery).

One of the reasons why SSDE are interesting is that they show that relative strategy performance cannot be investigated on a trial-by-trial basis, but has to be understood in the context of trial-to-trial strategy transitions. It is theoretically interesting because computational models of strategies (Lovett & Anderson's, 1996 ACT-R model; Lovett & Schunn's, 1999 RCCL model; Rieskamp & Otto's, 2006 SSL model; or Siegler & Araya's, 2005 SCADS model) assume that strategy selection and execution on each trial are independent of strategies used on preceding trials. This assumption of trial-to-trial independence in strategy execution is inconsistent with SSDE.

Another motivation for studying SSDE is that they are assumed to result from executive control processes and hence provide a fruitful context to examine the role of these processes in trial-to-trial modulation of relative strategy performance. More precisely, Schneider and Anderson (2010) suggested that SSDE could result from the temporary depletion of relevant cognitive resources by difficult cognitive tasks or problems. Similarly, Uittenhove and Lemaire (2012) proposed that difficult strategies temporarily reduce available executive resources, or could interfere with the following strategy. Thus, SSDE could be due to fewer available resources and/or the possibility of interference by execution of a previous strategy. For example, traces could remain in working memory after a difficult strategy has been implemented on Trial 1, and these traces could interfere with the implementation of the strategy on the next trial. Consistent with these suggestions, Uittenhove and Lemaire (2013a) found a correlation between working-memory capacities and SSDE in arithmetic tasks, as participants with larger working-memory capacities showed smaller SSDE. Additionally, Uittenhove et al. (2015) found that SSDE in memory correlated with measures of inhibition processes. Their findings suggest that demands on working-memory and inhibition resources contribute to SSDE. A harder strategy could be more difficult to inhibit or require more time to be inhibited than an easier one, leading to a greater impact on strategy execution on the following items.

Given the reduced efficiency of cognitive control processes in older adults (e.g., Daniels, Toth, & Jacoby, 2006; Park & Hedden, 2001; see Diamond, 2013, for a review), if these processes are involved in SSDE, the latter should increase with age, as older adults should be relatively more impaired after executing a complex strategy. However, previous findings showed that SSDE were surprisingly comparable in young and older adults both in arithmetic (Uittenhove & Lemaire, 2013b) and in memory (Uittenhove et al., 2015). These findings question the role of executive control mechanisms in SSDE, or at least make it unclear what mechanisms underlie SSDE and why older adults are not more sensitive to them than young adults. The aim of the current study was therefore to further our understanding of SSDE and aging in episodic memory. To achieve this end, we asked participants to carry out cognitive tests known to assess control processes (West, 1996) or processing speed (Salthouse, 1990). To our knowledge, no studies have examined directly the relations among executive function, processing speed, and strategies in the memory domain. The executive functions we assessed included inhibition and up-dating of working-memory tasks (Miyake et al., 2000), which have both been found to be involved in SSDE (e.g., Uittenhove et al., 2015). Inhibition enables individuals to ignore irrelevant information that competes for attention with relevant information. This is important when words have to be learnt successively with different encoding strategies, because a previously used strategy has to be inhibited in order to implement the subsequent strategy effectively. Updating is linked to working-memory capacity, because information in working memory has to be updated by replacing older elements with new relevant elements. Executing tasks in rapid succession may require more updating capacities to replace the information and procedures for a difficult strategy than an easy strategy (Uittenhove et al., 2015). We also examined processing speed because this variable is often considered as a basic cognitive resource, which is not only crucial in most cognitive processes (Kail & Salthouse, 1994) but is also responsible for age-related decline (Salthouse, 1996).

To better understand the origins of relative strategy performance on both current and subsequent trials in episodic memory, we extended the approach adopted by Uittenhove et al. (2015) who manipulated the strategies required to learn words so that a strategy of medium difficulty (i.e., sentence construction) used for the target words was preceded by a word encoded with either an easier strategy (i.e., rote repetition) or a more difficult strategy (i.e., mental imagery). More precisely, we examined how relative strategy difficulty executed on current and subsequent trials varied with ISI. Participants were tested under either a short ISI condition (i.e., an interval of 1000 ms between word presentations) or a long ISI condition (i.e., an interval of 2000 ms). We used 1000 ms because it is the interval that is most widely used in the literature, as it is sufficient to process words at encoding, in particular when the stimulus presentation time is 3 s (e.g., Toczé et al., 2012). Furthermore, we assessed each individual's processing resources (i.e., inhibition, processing speed, and updating) in order to better understand the mechanisms underlying relative strategy difficulty effects (on current and subsequent trials) in young and older adults as modulated by ISI. The goal of the current study was twofold.

First, we tested the hypothesis that the more demanding mental imagery strategy involves more processing resources than the easier rote repetition strategy. This demand would be greater with short than long ISI, because short ISI means that the task has to be achieved rapidly, requiring more processing resources. The demand would also be greater in older adults due to their lower processing resources, in line with recent findings that memory performance depends more on executive abilities in older than in young adults (Bouazzaoui et al., 2014). We therefore compared the memory performance of young and older adults using imagery and repetition strategies under short and long ISI conditions, and performed correlational analyses to test the relations between these data and processing resources (i.e., inhibition, working-memory updating, and processing speed). We tested the following predictions. Differences in strategy performance were expected to increase with longer ISI, especially in older adults, as longer ISI would give participants more time to implement and execute the harder strategy efficiently. This would result in improved performance with imagery under the long ISI condition. This effect was expected to be larger in older adults, who, given their decreased processing speed, would benefit more from longer ISI to execute the imagery strategy efficiently. We also predicted correlations between processing re-