Sequential difficulty effects during execution of memory strategies in young and older adults

Kim Uittenhove1, Lucile Burger2, Laurence Taconnat2, and Patrick Lemaire1

1Marseille & Centre National de la Recherche Scientifique, Aix-Marseille University, Marseille, France
2Département de Psychologie, Université François-Rabelais and UMR-CNRS 7295 ‘Centre de Recherches sur la Cognition et l’Apprentissage’, Tours, France

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This study aimed at uncovering factors influencing execution of memory strategies and at furthering our understanding of ageing effects on memory performance. To achieve this end, we investigated strategy sequential difficulty (SSD) effects recently demonstrated by Uittenhove and Lemaire in the domain of problem solving. We found that both young and older participants correctly recalled more words using a sentence-construction strategy when this strategy followed an easier strategy (i.e., repetition strategy) or a harder strategy (i.e., mental-image strategy). These SSD effects were of equal magnitude in young and older adults, correlated significantly with Stroop performance in both young and older adults and correlated with N-back performance only in young adults. These findings have important implications for furthering our understanding of memory strategy execution and age-related variations in memory performance, as well for understanding mechanisms underlying SSD effects.

Keywords: Recall; Encoding; Strategy; Sequential difficulty; Executive functions.

An important question in memory, and other cognitive domains, is what factors influence performance. In all domains of cognition, performance depends on the strategies used by participants (e.g., Dunlosky & Hertzog, 1998). A strategy is “a procedure or a set of procedures to achieve a higher level goal” (Lemaire & Reder, 1999, p. 365). Previous research on memory strategies found that participants use a wide variety of strategies to encode and retrieve information in and from memory (e.g., Hertzog, Price, & Dunlosky, 2012). Moreover, the selection and execution of these strategies affects recall performance (e.g., Dunlosky & Hertzog, 2000; Hertzog et al., 2012).

For example, to memorise each word of a list, people can select one of several strategies at encoding. They can use a superficial strategy of verbally rehearsing the words or create a mental image relying on deeper encoding of the words. This deeper encoding generally leads to better memory performance (e.g., Craik & Lockhart, 1972; Dunlosky & Hertzog, 2000; Hertzog et al., 2012; Paivio & Csapo, 1969). How often they use and how well they execute the different available strategies are influenced by interactions between...
myriad factors including problem characteristics (e.g., problem difficulty, Pyc & Dunlosky, 2010), situation characteristics (e.g., time constraints, Price, Hertzog, & Dunlosky, 2010; task affordance, Bottiroli, Dunlosky, Guerini, Cavallini, & Hertzog, 2010; instruction, Dunlosky & Hertzog, 2001; Touron & Hertzog, 2009; Touron, Swaim, & Hertzog, 2007), and participants’ characteristics (e.g., age, Dunlosky & Connor, 1997; Froger, Bouazzaoui, Isingrini, & Taconnat, 2012; task experience, Touron & Hertzog, 2004; training, Bailey, Dunlosky, & Hertzog, 2010).

A crucial factor is the characteristics of the strategy itself. Indeed, in the general cognitive literature, computational models of strategy execution and selection (Adaptive Strategy Choice Model [ASCM] by Siegler & Shipley, 1995; Recycle [RCCL] by Lovett & Schunn, 1999; strategy selection learning [SSL] by Rieskamp & Otto, 2006; strategy choices and discoveries [SCADS*] by Siegler & Arraya, 2005) assume that cognitive strategies involving a larger number of procedures and/or more complex procedures are more difficult and take more time to execute. In addition to the type and number of procedures involved within each strategy, relative strategy efficacy is influenced by general cognitive resources like executive control processes (e.g., Caviola, Mammarella, Cornoldi, & Lucangeli, 2012; Hodzik & Lemaire, 2011; Imbo & Vandierendonck, 2007; Lemaire & Lecacheur, 2011; Tornisy, 2005). That is, increased difficulty arises when insufficient executive resources are available to execute the strategy.

Regarding memory-encoding strategies, the mental-image strategy is cognitively more demanding because, unlike the rehearsal strategy, it requires the creation of a link between the word and the corresponding visual representation in memory (Craik & Tulving, 1975; Froger, et al., 2012; Froger, Toczé, & Taconnat, 2014; Paivio & Csapo, 1971; Toczé, Bouazzaoui, & Taconnat, 2012; Tournier & Postal, 2011). The success of its execution will thus be tightly linked to the availability of cognitive resources.

However, unknown is whether the execution of a memory-encoding strategy on a given item also depends on strategies used on previous trials, possibly through altered availability of cognitive resources, as was found in other domains of cognition. Recently, such sequential effects on strategy execution have started receiving attention with the finding of strategy-switching effects (e.g., reduced strategy efficiency following a strategy switch, in arithmetic, Lemaire & Lecacheur, 2010 and Luwel, Schillemans, Onghena, & Verschaffel, 2009; and memory, Toczé et al., 2012). These sequential effects have been assumed to reflect the role of executive functions (EFs) in switching from one strategy to another (Taconnat & Lemaire, in press). Furthermore, Uittenhove and Lemaire (2012, 2013a, b) have shown that difficulty of strategy execution is not only influenced by the procedures involved in each strategy, and the act of switching or repeating strategies, but also by the nature of the procedures involved in the previously executed strategy. They found that a strategy was executed more slowly when it was preceded by a more complex (or more difficult) strategy than when it followed an easier previous strategy, even when the same strategy was repeated. These effects, termed “strategy sequential difficulty effects,” constituted a novel and important finding to take into account to explain cognitive performance. It was established in the domain of arithmetic problem solving. The present experiment provided the opportunity to test its generality to episodic memory.

Following Schneider and Anderson (2010), Uittenhove and Lemaire (2012) explained their findings through lesser availability of executive resources after execution of a difficult strategy. They proposed that difficult strategies temporarily consume central cognitive resources such as EFs (e.g., inhibition) and/or working memory. Consequently, the temporary depletion of executive resources results in slowing down execution of the next strategy. This hypothesis was corroborated by their findings of a correlation between working-memory capacities and the magnitude of the so-called strategy sequential difficulty (SSD) effects (Uittenhove & Lemaire, 2013a) and by larger SSD in populations (like patients with Alzheimer’s disease) known to have reduced processing resources (Uittenhove & Lemaire, 2013b).

If executive resources are the underlying mechanisms of SSD effects, these effects should account for strategy execution difficulties in any domain in which strategies require coordination of procedures and cognitive control. In the domain of memory strategies, the mental-image strategy requires the execution and linking of a visual representation to a word. Executive resources play an important role in the adequate use of this type of memory strategy (Isingrini & Taconnat, 2007), especially in “free-recall” tasks, in which participants need to recall the words without external support.
If SSD effects were found during execution of memory strategies, they could play an important role in age-related declines in memory performance. These declines have been linked to strategy implementation deficits in older adults (e.g., Dunlosky & Hertzog, 1998; Froger et al., 2012; Taconnat et al., 2009). Strategy execution has been found altered in older adults in multiple cognitive domains (Angel et al., 2010; Gandini, Lemaire, Anton, & Nazarian, 2008; Hodzik & Lemaire, 2011; Mata, von Helversen, & Rieskamp, 2010; Taconnat et al., 2006, 2009; Taconnat, Clarys, Vanneste, Bouazzaoui, & Isingrini, 2007; see Lemaire, 2010, for an overview). These changes have been most abundantly documented in memory (e.g., Isingrini & Taconnat 1997; Luo & Craik, 2008; McDaniel, Einstein, & Jacoby, 2008). For example, Taconnat et al. (2007) found that older adults recalled a smaller proportion of words at retrieval, and even fewer when retrieval was made harder by providing low cognitive support (see also Craik & McDowd, 1987), thus urging participants to employ more internal (cognitive) control.

Hence, these changes have been explicitly linked to declines in executive resources (Bouazzaoui et al., 2010; Duverne, Lemaire, & Vandierendonck, 2007; Rabinowitz, Craik, & Ackerman, 1982; Taconnat & Lemaire, in press), which are known to affect the elderly population (Saltzhouse, 1990). Reduced executive resources likely contribute to increased memory strategy switch costs in the elderly (Froger et al., 2012; Toczé et al., 2012) and even to a general reluctance to shifting strategies (Lemaire & Leclère, 2014). The executive nature of age-related deficits in execution of memory strategies thus renders them susceptible to SSD effects as well.

The goal of the present study was threefold. First, we wanted to generalise SSD effects to the memory domain. Second, we aimed at studying the role of EFs in potential SSD effects in this domain. Lastly, we wanted to investigate whether SSD effects could possibly contribute to age-related declines in execution of memory strategies (see also Uittenhove & Lemaire, 2013b). Answering these questions would help to gain deeper understanding of the nature of SSD effects as well as their importance across cognitive domains. Moreover, we would further our understanding of the processes contributing to memory performance and possible age-related declines in memory.

To achieve our goals, we employed a novel paradigm in memory similar to the one used in computational estimation devised by Uittenhove and Lemaire (2012). In numerical cognition, Uittenhove and Lemaire (2012) found that solution latencies with the same rounding strategy on the same type of problem (e.g., 43 + 56) were longer after using a difficult rounding strategy on the previous trial than after using an easy rounding strategy. Analogously, the novel memory paradigm used here consists of comparing the proportions of correctly recalled words using a strategy of intermediate difficulty, namely sentence-construction strategy (e.g., constructing a sentence like “The fox stole a chicken from the farmer” to memorise target word fox) at encoding, when this strategy followed an easier repetition strategy (e.g., “fox” “fox” “fox” “fox”) to encode the previous word, or when it followed a more difficult mental-image strategy (e.g., picturing a fox stealing a chicken).

The three strategies used here were selected because their execution differs in its demands for executive resources. Indeed, the mental-image strategy requires the largest amount of executive resources (Craik & Tulving, 1975; Paivio & Csapo, 1971; Plaie & Thomas, 2008), especially in older adults (Froger et al., 2012; Tourrier & Postal, 2011). This strategy requires the retrieval of information (a corresponding image) from long-term memory. Moreover, this image has to be bound to the relevant item. In contrast, the repetition strategy does not require retrieving information from memory and binding this information to the relevant item. This strategy only consists of repeating a stimulus that is perceptually present (Tourrier & Postal, 2011). Note that we used a simpler version of the task commonly used in literature (i.e., encoding word pairs). We opted for single-word encoding because of the short temporal succession of items in our study, necessary for testing SSD effects (see Toczé et al., 2012, who used a single-word list to explore strategy switching in memory). We believed that relative strategy difficulty and efficiency would be maintained. This means that, even with this simpler task version, encoding with the mental-image strategy should both be more difficult and lead to better performance than the repetition strategy.

In the present study, current accounts of SSD effects (Uittenhove & Lemaire, 2012; 2013a, b) predict that the proportions of correct recall using a sentence-construction strategy on the current item would be lower following a mental-image strategy on the previous item than following a repetition...
strategy. This would result from the mental-image strategy having consumed executive resources necessary to the sentence-construction strategy executed next. Moreover, if SSD effects do contribute to age-related declines, larger SSD is expected in older than in young adults. To maximise possible age differences, we used a free-recall test, which is more difficult because there are no helpful cues available during recall.

To directly test a link between SSD and EFs, we collected several EF measures in young and older adults. We adopted Miyake, Friedman, Emerson, Howarter, and Wager (2000) distinction between inhibition, updating and flexibility, and measured each of these components with a designated test. We measured inhibition with the Stroop test (Stroop, 1935), updating with the N-back task (Baddeley, 1996) and flexibility with the Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). Executive hypothesis of SSD effects predicts correlations between EFs and SSD effects. Due to reduced and more variable efficiency of EFs, these correlations should be larger in older than in young adults.

**METHOD**

**Participants**

Forty older adults (23 females, mean age 70.9 years, ranging from 60 to 84 years) and 41 younger adults (25 females, mean age 21 years, ranging from 18 to 28 years) participated in this experiment. Younger participants from the Universities of Aix-Marseille and Tours received course credit, whereas older participants and some younger participants were volunteers from the communities of Tours and Marseille. Older participants were screened for potential dementia with the Mini Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975). All older adults had minimum scores of 27/30, reducing the risk of including patients with beginning dementia in the sample. We collected several characteristics of both samples and conducted independent t-tests to identify relevant differences between young and older adults (Table 1). Young and older adults did not differ in measures of depression and anxiety as measured by the hospital anxiety and depression scale (HADS, Zigmond & Snaith, 1983). None of the participants included in the study obtained pathological scores on these tests. Older adults did report significantly more vivid mental imagery as measured by the visual vividness imagery questionnaire (VVIQ, Marks, 1973) than young adults. This ensured that older adults would be at least as able to execute the mental-image strategy. As expected, older adults showed significant declines in all measures of EFs. Older and younger adults did not differ with regards to verbal ability, as measured by the Mill-Hill Vocabulary Scale (MHVS, Raven, Court, & Raven, 1986). This ensured that both populations were equally able

<table>
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<tr>
<th>Table 1: Young and older participants’ characteristics</th>
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<td><strong>Young adults</strong></td>
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<tr>
<td>N</td>
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<tr>
<td>Age</td>
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<tr>
<td>MMSE</td>
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<td>Depression</td>
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<td>Anxiety</td>
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<td>Mill-Hill</td>
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<td>VVIQ</td>
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<td>N-back</td>
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<td>Stroop</td>
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<td>WCST</td>
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Age: ranges 18–28 and 60–84.
MMSE: range 27–30, lower scores associated to age-related cognitive deficits.
Depression: ranges 0–11 and 0–15, higher scores associated to possible depression.
Anxiety: ranges 1–15 and 0–20, higher scores associated to possible anxiety.
Mill-Hill: ranges 16–29 and 14–32, higher scores associated to better vocabulary skills.
VVIQ: ranges 30–62 and 34–64, higher scores associated to more vivid mental imagery.
N-back: ranges 21–28 and 18–26, higher scores associated to better updating capacities. ns: not significant.
Stroop: ranges 0.1–0.6 and 0.3–0.7, lower scores associated to better inhibition capacities.
Wisconsin card sorting test (WCST): ranges 4–32 and 4–38, lower scores associated to better flexibility. ***p < .001.
to execute a sentence-construction strategy to memorise words.

**Stimuli**

The words to memorise were divided into two lists of 30 words each. Presenting two shorter lists instead of one longer list was expected to augment the number of words correctly recalled. The words were drawn from a list of French words taken from Bonin et al. (2003). They were as neutral as possible with regard to measures of imageability, emotional valence and frequency (values range from 0 to 5, with 2.5 representing neutrality), so as not to facilitate certain strategies. Moreover, the imaging values of words from List 1 (mean = 3.01, standard deviation [SD] = .31) and List 2 (mean = 3.09, SD = 0.42) were statistically identical, \( F(1, 58) = 1.90, p > .05 \). Words also had the same emotional valence in List 1 (mean = 2.76, SD = 0.45) and List 2 (mean = 2.19, SD = 0.72), \( F(1, 58) = 1.42, p > .05 \). Finally, the words had the same frequency in French in List 1 (mean = 2.41, SD = 0.66) and List 2 (mean = 2.63, SD = 0.55), \( F(1, 58) = 1.19, p > .05 \).

Three tests of EFs were administered. The Stroop test (Stroop, 1935) was used as a measure of inhibition. In this test, participants were required to name the colour in which a word was written as opposed to the colour it named (e.g., red printed in blue → say blue). Participants had to inhibit automatic reading processes in favour of denoting visual colours. They had to name as many colours as possible in 30 seconds. Their performance was compared to a baseline condition in which they had to name the colours of non-word stimuli. For this, an index was calculated by subtracting the number of correctly identified colour-word colours from the number of correctly identified colours, and dividing this difference by the number of correctly identified colours ([colour nbr – colour-word nbr]/colour nbr; Li & Bosman, 1996). The N-back test (Baddeley, 1996) was used as a measure of updating capacities. In this test, participants had to indicate whether a presented letter was the same as some (N) positions before. In our tests, N was equal to 2, and we measured the number of correct responses out of 27 trials. In order to measure flexibility, we used the Wisconsin Card Sorting Test (Heaton et al., 1993). In this test, participants had to order cards based on colour, form or number. After six correct classifications, the ordering category was changed, so that participants had to change their classifications. The number of trials it took for the participant to do this was taken as a measure of flexibility (Kaplan, Sengör, Gürvit, Genç, & Güzelis, 2006).

**Procedure**

After being comfortably seated in a dimmed room during an individual testing session, participants were asked to fill out an informed consent. Then, they were explained that they would have to memorise two lists of 30 words each. It was explained that preceding each item, a word would indicate which strategy to use for encoding. The repetition, sentence-construction and mental-image strategies were described to participants. Overall, 30 words were cued with the sentence-construction strategy (e.g., participants had to form a sensible and brief sentence containing the word). In half the trials, the previous word was cued with the easier repetition strategy (e.g., participants had to repeat the word four times). In the remaining trials, the previous word was cued with the more difficult mental-image strategy (e.g., participants had to create a mental image of each word). Note that the experiment thus contained 15 repetition trials (8 in the List 1, 7 in the List 2), 15 mental-image trials (7 in the List 1, 8 in the List 2) and 30 sentence-construction trials.

Then, the memorisation task started. All the words of a list were presented sequentially. Every word was preceded by a cued strategy for the duration of 1 second. Sentence-construction, repetition and mental-image strategies were cued with the words “repetition” (repetition), “phrase” (sentence) and “image” (image), respectively. The experimenter monitored correct strategy execution by the verbal output of the participants in the case of sentence-construction and repetition strategy. For the mental-image strategy, the experimenter asked participants at the end of the experiment for three examples of mental images used during the experiment (i.e., free recall). Following the strategy cue, the word was presented for 3 seconds before the next trial appeared. After each list of 30 words, recency effects in subsequent recall were eliminated by having participants execute a letter comparison test (Salthouse, 1990) for the duration of 30
seconds. After each interfering test, participants were asked to freely recall the words of the preceding list. Following the memory task, the other tests were administered to the participants in a fixed order (VVIQ, N-back, Stroop, MMSE, HADS, Mill-Hill and WCST).

RESULTS

Three sets of analyses were conducted. First, to test ageing and strategy effects on memory performance, we analysed mean number of correctly recalled words by young and older adults for mental-image and repetition strategies. Second, to test SSD effects in memory and age-related differences in SSD effects, we analysed young and older adults’ performance when using the sentence-construction strategy as a function of the previous strategy. Last, to test possible associations between SSD effects and EFs in young and older adults, we calculated correlations between measures of EFs and SSD effects in both populations.

Performance differences between mental-image and repetition strategies

A repeated-measures analysis of variance (ANOVA) on mean number of correctly recalled words while using the sentence-construction strategy, with previous strategy (mental image or repetition) as a within-participants factor and age group as a between-participants factor revealed main effects of strategy and of previous strategy (see Table 2). Participants recalled fewer items with the sentence-construction strategy when this strategy followed the mental-image strategy than when it followed the repetition strategy (3.7 vs. 4.7 words), $F(1, 157) = 8.96, p < .01, \eta^2_p = .05, MSE = 4.4$. Moreover, older adults correctly recalled fewer items than young adults (3.4 vs. 5 words), $F(1, 157) = 8.61, p < .01, \eta^2_p = .05, MSE = 4.4$. The interaction between age and previous strategy was not significant, $F < 1$.

Because age significantly reduced correct recall, we further analysed age differences in SSD effects expressed as percentages of correctly recalled words after the repetition strategy (i.e., [recall after repetition – recall after mental image]/recall after repetition × 100). A t-test comparing young and older adults’ percentages of SSD percentages revealed no significant differences between young and older adults, $t(81) < 1$ (see Table 2).

| TABLE 2 |
| Mean number of correctly recalled words (and standard deviations) for successive words as a function of mental-image or repetition strategies, and SSD effects, in young and older adults |

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<thead>
<tr>
<th></th>
<th>Young</th>
<th>Older</th>
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<tbody>
<tr>
<td>Item 1</td>
<td>Item 2 (sentence construction)</td>
<td>Item 1</td>
</tr>
<tr>
<td>Repetition</td>
<td>3 (1.8)</td>
<td>5.6 (2.1)</td>
</tr>
<tr>
<td>Mental image</td>
<td>4 (1.9)</td>
<td>4.4 (2)</td>
</tr>
<tr>
<td>SSD</td>
<td>1.2 (2.7)</td>
<td>0.8 (2.5)</td>
</tr>
<tr>
<td>SSD%</td>
<td>4.7 (6.6)</td>
<td>1.2 (6.6)</td>
</tr>
</tbody>
</table>

SSD was calculated as the difference between correctly recalled words after the repetition strategy and after the mental-image strategy. SSD% divided this difference by number of words correctly recalled after repetition strategy for each participant, and multiplied it by 100.
Associations between SSD effects and EFs

Before the correlation analysis, participants with significantly abnormal EF scores were removed from the sample, to avoid extreme EF scores artefactually inflating the correlation results. This included participants with Stroop inhibition scores larger than .60, N-back updating scores lower than 20 and WCST flexibility errors larger than 30. Using these criteria, we removed three participants from the sample of young adults and six participants from the sample of older adults. The correlation analyses were thus performed for 39 younger and 34 older adults (see Table 3).

We found that Stroop performance significantly correlated with magnitude of SSD effects in young adults, $r = .32, p = .05$, and in older adults, $r = .50, p < .01$. The difference between these correlations was not statistically significant, $Z = .88; p = .39$. N-back significantly correlated with magnitude of SSD effects in younger adults, $r = -.33, p = .05$, but not in the older population, $p = .88$. Finally, WCST correlated with SSD effects neither in young ($p = .39$) nor in older adults ($p = .82$).

**DISCUSSION**

In order to better understand condition- and age-related differences in episodic memory, the present research adopted a strategy approach. More specifically, we asked whether execution of encoding strategies on a given item is influenced by which strategy was used on the previous item, and whether this influence changed with participants’ age. Using a strategy-instruction paradigm, we were able to test strategy sequential difficult effects in young and older adults while they memorised lists of words for subsequent free-recall tasks. Our results showed that, even though the mental-image strategy led to better recall than the repetition strategy, it had detrimental effects on the recall of subsequent words. Young and older participants showed performance declines when encoding words following the harder mental-image strategy compared to following the easier repetition strategy. This confirms that SSD effects are not restricted to the domain of numerical cognition, in which they were initially discovered (Uittenhove & Lemaire, 2012, 2013a, b; Uittenhove, Poletti, Dufau, & Lemaire, 2013).

Strategy sequential difficulty effects thus seem to involve mechanisms common to many domains. A possible candidate proposed by Uittenhove & Lemaire (2012, 2013a,b) and Uittenhove et al. (2013) is executive control. The latter is important in the application of strategies with more complex procedures in both numerical cognition and memory (Duverne et al., 2007; Imbo, Duverne, & Lemaire, 2007; Isingrini & Taconnat, 2007; Velanova, Lustig, Jacoby, & Buckner, 2007). Strategies that are more complex could be liable to affect the availability of executive resources for the next strategy, provided that this strategy requires these resources.

In line with this account of SSD effects, our study showed that the size of the effects was likely related to the efficiency of EFs in both young and older adults. In young and older adults alike, participants with less efficient inhibitory processes, as measured by Stroop performance, seemed to present larger SSD effects. In young adults, there was an additional link with updating. Participants with poorer performance on the N-back test showed larger SSD effects. Interestingly, Uittenhove et al. (2013) previously found that participants with lower working-memory capacities also presented larger SSD effects. The fact that correlational results suggest that both EFs and WM capacities are associated to the size of SSD effects can perhaps be understood by taking into account the strong association between EFs and WM capacity (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Miller & Cohen, 2001). Indeed, WM capacity relies on inhibition of irrelevant information that competes for attention with relevant information (Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012). Thus, following a difficult encoding strategy, active elements could be more present in WM, thus increasing the need for inhibition capacities. Similarly, updating is also linked to WM capacity because information present in WM has to be updated through replacing

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**TABLE 3**

<table>
<thead>
<tr>
<th>Young</th>
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<tr>
<td>SSD</td>
<td>SSD%</td>
</tr>
<tr>
<td>SSD%</td>
<td>0.89***</td>
</tr>
<tr>
<td>N-back</td>
<td>-0.35*</td>
</tr>
<tr>
<td>Stroop</td>
<td>0.18</td>
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<tr>
<td>WCST</td>
<td>-0.21</td>
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</table>

* $p < .05$; ** $p < .01$; *** $p < .001$. 

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In line with this account of SSD effects, our study showed that the size of the effects was likely related to the efficiency of EFs in both young and older adults. In young and older adults alike, participants with less efficient inhibitory processes, as measured by Stroop performance, seemed to present larger SSD effects. In young adults, there was an additional link with updating. Participants with poorer performance on the N-back test showed larger SSD effects. Interestingly, Uittenhove et al. (2013) previously found that participants with lower working-memory capacities also presented larger SSD effects. The fact that correlational results suggest that both EFs and WM capacities are associated to the size of SSD effects can perhaps be understood by taking into account the strong association between EFs and WM capacity (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Miller & Cohen, 2001). Indeed, WM capacity relies on inhibition of irrelevant information that competes for attention with relevant information (Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012). Thus, following a difficult encoding strategy, active elements could be more present in WM, thus increasing the need for inhibition capacities. Similarly, updating is also linked to WM capacity because information present in WM has to be updated through replacing
older elements with the new elements. When strategies are executed in short succession, it could require more updating capacities to replace the information and procedures regarding a difficult strategy than an easy strategy.

In spite of the potential association between EFs and magnitude of SSD effects, our study did not find larger SSD effects in older than in young adults, above and beyond better overall performance in young adults. This is in contrast to our prediction given well-known general age-related declines in EFs. Moreover, although inhibition was linked to SSD effects in young and older adults, updating was correlated only with young adults’ SSD effects. This suggests that if EFs are indeed involved in SSD effects as suggested by the correlations, the mechanism is not the same in young and older adults. A possibility is that younger adults engaged more in strategy execution than older adults, changing the underlying mechanisms, and perhaps increasing the need for different EFs compared to older adults. This could have resulted in reduced SSD effects in older adults. Note that this lack of Age × SSD replicates the findings of Uittenhove and Lemaire (2013b) findings. Indeed, Uittenhove and Lemaire found comparable SSD effects in young and older adults. They found massively increased SSD effects in patients with Alzheimer’s disease, in whom decreased EFs is amplified compared to controls (Grady et al., 1988). It is possible that with normal ageing, executive resources were not sufficiently decreased to result in increased SSD effects. As in the numerical cognition domain, studying SSD effects in patients with Alzheimer’s disease’ memory may reveal much larger effects.

Another possibility is that older adults were somehow able to compensate for the effects of reduced EFs on SSD amplitude. Some crystallised abilities in older adults could facilitate strategy execution. For example, better vocabulary skills could facilitate the use of the sentence-construction strategy, so that this strategy requires less executive resources, and SSD effects are less visible. However, we failed to find significant correlations between vocabulary skills measured by the MHVS, and execution of the sentence-construction strategy measured by recall (r = .07, p > .05) and SSD effects (r = -.27, p > .05). Note that it is possible that other crystallised abilities, not assessed in the present study, could have played a compensatory role.

However, it is more likely that SSD effects in older adults were absorbed through more general performance declines. Recall rates showed that older adults’ performance suffered after both the repetition and the mental-image strategies. These declines could, for example, be due to higher switch costs following both strategies towards the sentence-construction strategy. In the domain of arithmetic, Ardiale, Hodzik, and Lemaire (2012) found that older adults presented larger switch costs than young adults when switching between three strategies, like in the current study. However, corresponding studies with memory strategies have not yet been conducted, so it is unclear whether larger switch costs could have absorbed older adults’ SSD effects in the current study. Moreover, if older adults’ larger switching effects affected execution of the sentence-construction strategy, this could also account for the lack of a link between vocabulary skills and recall with this strategy. Another possibility is that older adults suffered from the high task speed in this experiment (i.e., 3 seconds to encode every word). This could reduce SSD effects if older adults are not sufficiently engaged in strategy execution when the next trial is announced, a pattern supported by the finding of reduced recall with the repetition and mental-image strategies in older adults. Future studies will have to vary inter-trial intervals in young and older adults in order to answer this question.

Our findings have several important implications. First, future studies investigating memory performance will have to take into account the SSD factor if they want to adequately assess individuals’ performance. Even though the mental-image strategy allows for deeper encoding of the words, and therefore efficient recall in the current study, application of this strategy may negatively affect subsequent encoding. Interestingly, Uittenhove and Lemaire (2012, 2013a, b) and Uittenhove et al. (2013) found performance declines even in the case of repetition of the same difficult strategy, thus going against typical task or strategy switch effects (Lemaire & Lecacheur, 2010; Luwel et al., 2009). It should be investigated whether executing the mental-image strategy consecutively is associated with the same detrimental effects compared to executing this strategy intermixed with less demanding strategies.

In conclusion, our findings demonstrate the omnipresence of SSD effects across domains. Moreover, they suggest a link between SSD effects and executive efficiency. In any domain relying on executive control (e.g., reasoning, decision making and problem solving), we would thus need to take
into account that executing difficult strategies in quick succession can negatively affect performance, thus influencing individual’s performance.

REFERENCES


