Brief Report

Developmental differences in working memory: Where do they come from?

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Abstract

Several models assume that working memory development depends on age-related increases in efficiency and speed of processing. However, age-related increases in the efficiency of the mechanisms that counteract forgetting and restore memory traces may also be important. This hypothesis was tested in three experiments by manipulating both the processing duration within a working memory task and the time available to restore memory traces. Third- and sixth-grade children performed a complex span task in which they maintained series of letters while adding numbers to series of digits. When we equated processing and restoration times between ages, the developmental difference in working memory span was reduced but remained significant. However, this residual difference was eliminated when the time available to reactivate memory traces was tailored to the processing speed of each age group. This indicates that children employ active mechanisms for maintenance and restoration of memory traces that develop with age.

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Introduction

Many theories have assumed that age-related changes in working memory (WM), as revealed by the developmental increase in WM spans, should play a crucial role in cognitive development (Case,
However, the sources of the developmental variations in WM spans are still a matter of debate. The current study addressed this question by exploring the possible role of an age-related increase in the efficiency of the mechanisms that counteract forgetting and restore memory traces.

Typically, WM span tasks involve the maintenance of memory items (e.g., digits or letters) whose presentation is interspersed with processing episodes (e.g., counting arrays of dots or reading sentences). Working memory spans, determined by the maximum number of items that can be recalled using this procedure, strongly increase with age (Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009; Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005; Gathercole, Pickering, Ambridge, & Wearing, 2004). This developmental change has often been attributed to an age-related increase in processing efficiency. Case (1985) assumed that processing and storage share a common and limited resource and suggested that recall performance increases with age because the processing part of the span task becomes less and less resource demanding as processing efficiency increases. Accordingly, Case, Kurland, and Goldberg (1982) showed that WM spans increased during childhood as a function of their speed of processing, which they took to be an index of processing efficiency. Towse and Hitch (1995; see also Towse, Hitch, & Hutton, 1998) challenged this resource-sharing assumption. They argued that it is instead sufficient to assume that attention switches between processing and storage according to the structure of the task and that short-term memory traces suffer from time-related decay during the processing phases. Thus, because older children are faster at counting arrays of dots or reading sentences, they benefit from shorter delays between encoding and retrieval at the end of the series, hence their better recall performance. Although Towse and colleagues (1998) pointed out that their conception departs from Case’s proposal, both theories rely on the same idea of an increase in processing efficiency but disregard any potential developmental change in the mechanisms underpinning short-term storage and maintenance. These mechanisms are of particular importance within the time-based resource-sharing (TBRS) model (Barrouillet, Bernardin, & Camos, 2004).

The TBRS model assumes that memory items receive activation from attentional focusing, but this activation suffers from a time-related decay as soon as attention is switched away. Because a central bottleneck forces processing and maintenance activities to take place sequentially, memory traces decay during processing episodes but can be refreshed if attention is diverted from processing and refocused on them. This results in WM functioning characterized by a permanent and rapid switching between processing and storage in which processing episodes are briefly interrupted to refresh memory traces before their complete loss (Fig. 1). Thus, recall performance in WM span tasks should be a function of the equilibrium between two durations: the time needed to perform the processing component of the span task, during which memory traces degrade, and the time left available for their restoration. In several studies, we demonstrated that WM spans are a function of the cognitive load of processing, defined as the proportion of time during which this processing occupies attention (see Barrouillet and Camos (2010), for a review).

As a consequence, two main factors should account for developmental differences in WM spans according to the TBRS. The first factor, invoked by Case (1985) and Towse and Hitch (1995), is the time needed to perform the processing component of the task, which determines the time during which

![Fig. 1. Time course of the activation level of a given memory item according to the TBRS model. Activation increases to an asymptote at encoding, decreases when attention is switched away during processing episodes (represented by black boxes), and increases again during free time through refreshing processes. L, letter; D, digit.](image-url)
memory traces decay. The second more novel factor is the efficiency of the maintenance mechanisms, which determines the amount of information that can be reactivated during a given period of time. Older children may be more efficient in reactivating decaying memory traces, thereby taking a greater advantage from the same free periods of time (Barrouillet et al., 2009). The three experiments described in this article aimed at verifying this prediction. Their rationale was the following: If processing time and efficiency of the maintenance mechanisms are the main determinants of WM development, neutralizing their variations across ages should strongly reduce, if not abolish, developmental differences in WM span. For this purpose, in Experiment 1, we established a baseline by assessing developmental differences in WM spans between third- and sixth-grade children who were asked to maintain letters while adding 1 to series of digits presented successively on-screen. Experiment 2 explored the effect on developmental differences of equating the digit processing times across age groups. In Experiment 3, processing times were equated across ages as in Experiment 2, but also the times available for refreshing were tailored to the processing speed of each age group (Fig. 2 and Table 2). The experimental conditions that enabled us to equate processing times and to control for processing speed were derived from the results of a pretest.  

Experiment 1

The aim of this first experiment was to provide a baseline of the developmental differences between the two age groups when performing exactly the same WM span task. For this purpose, an addition span task was designed where children needed to maintain series of letters and to add 1 to series of digits successively presented on-screen at a fixed rhythm after each letter. Because recall performance varies as a function of the cognitive load invoked by the processing component of the task, the digits were presented at three different paces defining three experimental conditions (fast, medium, and slow pace) in a within-participant design.

Method

Participants

In total, 30 third graders (mean age = 8 years 7 months, SD = 5 months, 15 girls and 15 boys) and 31 sixth graders (mean age = 11 years 8 months, SD = 6 months, 15 girls and 16 boys) from a primary school in Geneva, Switzerland, participated as volunteers after informed consent was obtained from their parents. None of them took part in the pretest.

Materials and procedure

In a complex span task paradigm, children were presented with a series of one to five consonants for further serial recall. The letter W, which is trisyllabic in French, was excluded, and repetitions acronyms and alphabetic ordered strings were avoided. Three series of letters of each length were associated with each of the three experimental conditions, resulting in a total of 45 series to be remembered. Each letter was followed by a series of three digits (from 1 to 9). The series of letters and digits were counterbalanced across conditions and participants using a Latin square procedure.

2 The pretest involved 19 third graders (mean age = 8 years 8 months, SD = 3 months, 7 girls and 12 boys) and 20 sixth graders (mean age = 11 years 7 months, SD = 3 months, 9 girls and 11 boys) from a primary school in Dijon, France, who participated as volunteers with informed consent from their parents. Children were administered three different tasks. The first was a letter discrimination task consisting of 40 pairs of letters, half same (e.g., nn, NN, Nn) and half different (e.g., FW). Children needed to judge whether the letters were the same or different by pressing one of two keys as quickly and accurately as possible. Second, they performed an addition task involving four blocks. In the first block, children were asked to add 1 to 30 digits successively presented on-screen and to give the answer aloud for coding by a voice key. In the three remaining blocks, their task was to add 2, 3, and 4 to each number, respectively. RTs and errors were recorded in both the letter discrimination and addition tasks. Third, children were asked to recite the numerical string from 1 to 10, as fast as possible, five times in a row. The entire production of each participant was audiotaped. The counting time was evaluated by averaging two independent measures from this recording. Mean times for each task are given in Table 1. Response times were significantly longer for younger children in each task (ps < .001) except for the recitation of the numerical string in which the difference did not reach significance, t(37) = 1.78, p = .08. Interestingly, third graders took approximately the same time to add 1 to each digit as sixth graders took to add 2 (1292 and 1239 ms, respectively), t(37) = 0.65, p > .50. This finding was used in Experiment 2 to equate processing times.
For each trial, a signal (an asterisk) was displayed on-screen for 1500 ms followed by the first letter. Each letter was presented for 1500 ms and was followed by three digits successively displayed on-screen at either a fast, medium, or slow pace. The faster pace was set at 1300 ms per digit, which was the time needed on average for the younger children to add 1 during the pretest. Thus, the three digits were presented for 1300 ms each in immediate succession. The medium and slow paces were obtained by adding 650- and 1300-ms interdigit intervals (IDIs), respectively, during which the screen remained blank, resulting in the presentation of a digit every 1950 and 2600 ms, respectively. At the end of each series of digits, the word “stop” appeared for 500 ms, indicating that the current series of additions was terminated and that a new letter (or the “recall” screen) would appear.

Participants in both age groups were asked to read each letter aloud, memorize it for further recall, and add 1 to each digit, giving the answer aloud. When the word “recall” appeared, they needed to recall aloud the series of letters in correct order. Participants were presented with increasingly long series of one to five letters until they failed to recall the letters of all nine series at a particular length. Testing was terminated at this point. Within each condition of pace, each correctly recalled series counted as one third. The total number of thirds was added up to provide a span score (Barrouillet et al., 2004). For example, the correct recall of all the series of one, two, and three letters, of two series of four letters, and of one series of five letters in the slow pace condition resulted in a slow pace span of \((3 + 3 + 3 + 2 + 1) \times \frac{1}{3} = 4\). A training phase familiarized the children with three trials in the addition task alone and then with four trials of the WM task (one series of one letter and three series of two letters for each of the three pace conditions).

Results and discussion

Concerning the addition task, an analysis of variance (ANOVA) on the rate of correct responses with pace (fast, medium, or slow) as a within-participant factor and age group (third or sixth grade) as a

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**Fig. 2.** Time course of the events occurring between two successive letters (L1 and L2) in the three experiments as a function of age group. The top panel illustrates Experiment 1, where digits (Ds) are presented on-screen for 1300 ms and followed by free time intervals of either 0, 650, or 1300 ms. The smaller black boxes in the Grade 6 line illustrate that it takes less time for older children to perform the addition task (950 vs. 1300 ms on average), thereby resulting in longer free time. The middle panel illustrates Experiment 2, where processing times (black and gray boxes) are equated by asking older children to add 2 instead of 1 to each digit. The bottom panel illustrates Experiment 3, where not only processing times are equated but also free time is tailored to processing speed. The younger children benefit here from longer free time.
between-participant factor did not reveal any significant effect of age (94% and 96% of correct responses in third and sixth graders, respectively), $F < 1$, but revealed a significant effect of pace, with faster paces inducing lower performance (97%, 95%, and 93% of correct responses for the slow, medium, and fast paces, respectively), $F(1.59, 118) = 8.49$, $p = .001$, $\eta^2_p = .13$ (degree of freedom modified with Greenhouse–Geisser’s epsilon), without any reliable interaction with age, $F < 1$. Thus, we can reasonably assume that both age groups paid comparable attention to the concurrent processing task.

An ANOVA with the same design was performed on recall performance. As expected, mean spans were higher in sixth graders than in third graders (3.05 and 1.79, respectively), $F(1, 59) = 42.48$, $p < .001$, $\eta^2_p = .42$. Faster paces resulted in poorer recall ($Ms = 2.76, 2.39$, and 2.13 in the slow, medium, and fast pace conditions, respectively), $F(2, 118) = 21.92$, $p < .001$, $\eta^2_p = .27$, with a significant interaction, $F(2, 118) = 3.18$, $p < .05$, $\eta^2_p = .05$, revealing that the pace effect was stronger in older children (Fig. 3), as already observed by Barrouillet and colleagues (2009).

Thus, this first experiment revealed a strong developmental difference between age groups, with an increase in mean span of 1.26 in 3 years. This would suggest higher WM capacities in older children. However, as the pretest revealed, older children are also faster than young children in solving additions (951 vs. 1292 ms). As a consequence, they benefited from a lower cognitive load than their younger peers, something that could account for at least part of the developmental difference observed. This confound was reduced in the second experiment.

**Experiment 2**

The aim of this second experiment was to evaluate the developmental difference in WM spans when processing times are equated across ages. Fortunately, the pretest revealed that sixth graders exhibit similar addition times as third graders when they add 2 to each digit instead of 1 (Table 1). Thus, the current experiment was a replication of Experiment 1 except that older children were asked to add 2 to each digit, whereas younger children added 1. Therefore, this procedure equated processing times across ages. We expected, in this case, a strong reduction of developmental differences.

**Method**

In total, 29 third graders (mean age = 8 years 8 months, $SD = 6$ months, 17 girls and 12 boys) and 29 sixth graders (mean age = 11 years 11 months, $SD = 8$ months, 18 girls and 11 boys) from another primary school in Geneva participated as volunteers after informed consent was obtained from their parents. Both groups were presented with the same conditions as those used in Experiment 1 except...
Results and discussion

Data were analyzed in the same way as in Experiment 1. As in the previous experiment, the rate of correct responses in the addition task was high and did not significantly differ between ages (95% and 92% correct responses for third and sixth graders, respectively), \(F(1, 55) = 5.54, p > .10\), but decreased progressively as the pace increased (97%, 94%, and 90% for the slow, medium, and fast paces, respectively), \(F(1.67, 110) = 26.20, p < .001\), \(\eta_p^2 = .32\), with no interaction with age, \(F < 1\).

As far as recall performance was concerned, the analysis revealed a significant effect of pace as in Experiment 1 (mean spans of 1.64, 2.06, and 2.33 for the fast, medium, and slow paces, respectively) \(F(2, 112) = 25.64, p < .001\), \(\eta_p^2 = .30\). More important, although processing times were assumed to be equated, older children still significantly outperformed younger children (mean spans of 2.31 and 1.72, respectively), \(F(1, 56) = 9.37, p < .005\), \(\eta_p^2 = .14\), an effect that did not significantly interact with pace, \(F(2, 112) = 1.67, p > .10\). However, even though the effect of age was still significant in this second experiment, it was smaller than the effect observed in the first experiment. Equating processing difficulty by making the processing task more demanding for the older children resulted in a significant decrease of their mean span averaged across pace conditions (from 3.05 in Experiment 1 to 2.31 in Experiment 2), \(t(58) = 3.42, p < .001\), whereas performance in younger children remained unchanged (1.79 and 1.72), \(t(57) < 1\).

Table 1

<table>
<thead>
<tr>
<th>Task</th>
<th>Age group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 3</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Letter discrimination task</td>
<td>989 (233)</td>
</tr>
<tr>
<td>(n + 1)</td>
<td>1292 (192)</td>
</tr>
<tr>
<td>(n + 2)</td>
<td>1802 (381)</td>
</tr>
<tr>
<td>(n + 3)</td>
<td>2375 (600)</td>
</tr>
<tr>
<td>(n + 4)</td>
<td>2522 (678)</td>
</tr>
<tr>
<td>Numerical string recitation task</td>
<td>197 (35)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses. \(n + 1\), \(n + 2\), \(n + 3\), and \(n + 4\) represent the four blocks of the addition task.

that older children added 2 instead of 1 to each digit presented (Fig. 2 and Table 2). None of them took part in the previous experiments.

Fig. 4. Mean spans as a function of age group and pace of the addition task in Experiment 2. Error bars are 95% confidence intervals.
Thus, this second experiment suggests that processing efficiency, more precisely the time taken to perform the intervening task, is a factor that contributes to developmental differences in WM. When sixth graders no longer benefited from faster processing of the digits, the previously observed developmental gap in spans was reduced. Nevertheless, older children still outperformed younger children. Thus, processing efficiency and the time devoted to processing alone cannot account for all of the age-related differences in WM spans. The aim of our third (and final) experiment was to try to reduce this residual developmental difference even further by manipulating the time available to reactivate decaying memory traces.

**Experiment 3**

Beyond equating processing times across ages, this third (and final) experiment aimed to also tailor the available free time given to each age group. The rationale for tailoring reactivation times was as follows. We hypothesized that the amount of information that refreshing processes can maintain active is a function of their speed, with faster processes permitting better maintenance of a higher number of items. Thus, we compensated the potentially slower maintenance processes in young children by giving them a time available for reactivation that was commensurate with their processing speed. For this purpose, we first established the function relating processing times in third and sixth graders observed during the pretest. These Brinley plots gave us the equation from which we could evaluate the free time needed by young children to achieve the same level of refreshing as older children if one assumes that the ratio of reactivation speed in the two groups is comparable to the ratio of processing speeds. Using this equation, we calculated the free time needed by the younger children, whereas their older peers were presented with the same task as in Experiment 2. We expected that when processing times are equated, leading to comparable declines of memory traces in both age groups, and when free time is tailored to processing speed, providing younger children with the time they need to reactivate information as efficiently as older children, the residual developmental differences observed in Experiment 2 should be further reduced if not abolished.

**Method**

**Participants**

In total, 31 third graders (mean age = 9 years 0 months, SD = 4 months, 17 girls and 14 boys) and 30 sixth graders (mean age = 12 years 3 months, SD = 8 months, 16 girls and 14 boys) from a primary school in Geneva participated as volunteers. None of them took part in the previous experiments.

**Materials and procedure**

The design of this task was the same as in Experiment 2, with the younger children being asked to add 1 to each digit presented and the older children being asked to add 2, except that we also tailored the duration of the IDI to the mean processing speed of each age group. For this purpose, we plotted the mean reaction times (RTs) collected during the pretest in third graders against the mean RTs in sixth graders in a regression analysis, revealing a linear trend ($R^2$ value of .99) with the following equation (Fig. 5):

$$RT_{younger} = RT_{older} \times 1.6272 - 175.42.$$  

(1)

The IDIs used in the previous experiments (i.e., 0, 650, and 1300 ms for the fast, medium, and slow pace conditions, respectively) were used in the current experiment for the older group and entered into Eq. (1) to estimate the corresponding intervals in the younger group. The corresponding values were 0, 880, and 1940 ms for the fast, medium, and slow pace conditions, respectively (Table 2). Note that the negative intercept$^4$ ($-175.42$ ms) would have led to a negative IDI in the fast pace condition, hence hampering younger children even more. Therefore, we chose to keep a 0-ms interval in that condition.

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$^4$ It is usual in Brinley plot analysis to observe negative intercept when RTs from the slowest group are regressed on RTs from the fastest group (Barrouillet, Lépine, & Camos, 2008).
Results and discussion

The rate of correct responses in the addition task was lower than in the previous experiment, but participants still responded correctly to more than 85% of the operations (89% and 87% of correct responses for third and sixth graders, respectively). As observed previously, pace significantly influenced the proportion of correct responses, \( F(1.57, 118) = 34.08, p < .001, \eta^2_p = .37 \). Most important, correlational analyses indicated no trade-off between operation solving and recall performance. Strikingly, the analysis of recall performance revealed that only the effect of pace remained significant, \( F(2, 118) = 62.93, p < .001, \eta^2_p = .52 \) (Fig. 6). Mean spans decreased with faster pace (2.86, 2.33, and 1.85 for the slow, medium, and fast paces, respectively), but age no longer significantly influenced performance (mean spans of 2.28 and 2.42 for third and sixth graders, respectively), \( F < 1 \). The pace by age interaction also failed to reach significance, \( F(2, 118) = 2.02, p > .10 \).

Two main results arose from this third experiment. First, tailoring reactivation times in the younger group resulted in an increase in recall performance from Experiment 2 to Experiment 3 (mean spans of 1.72 and 2.28, respectively), \( t(58) = -3.54, p < .01 \). Second, third graders recalled as many letters as sixth graders. Giving young children the amount of time they actually need to reactivate memory traces, which of course is longer than the time that older children need, makes them perform at the same level as their older peers. This suggests that WM development, at least between the two ages studied here, depends more strongly on quantitative changes, such as the speed and efficiency of reactivation of memory traces, than on qualitative changes, such as the propensity to use reactivation mechanisms (Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010).

Table 2
Summary of experimental details of the three experiments at Grades 3 and 6.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Addition task</th>
<th>IDI at fast pace (ms)</th>
<th>IDI at medium pace (ms)</th>
<th>IDI at slow pace (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>n + 1</td>
<td>0</td>
<td>650</td>
<td>1300</td>
</tr>
<tr>
<td>2</td>
<td>n + 1</td>
<td>0</td>
<td>650</td>
<td>1300</td>
</tr>
<tr>
<td>3</td>
<td>n + 1</td>
<td>0</td>
<td>880</td>
<td>1940</td>
</tr>
<tr>
<td>Grade 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>n + 1</td>
<td>0</td>
<td>650</td>
<td>1300</td>
</tr>
<tr>
<td>2</td>
<td>n + 2</td>
<td>0</td>
<td>650</td>
<td>1300</td>
</tr>
<tr>
<td>3</td>
<td>n + 2</td>
<td>0</td>
<td>650</td>
<td>1300</td>
</tr>
</tbody>
</table>

Note. Each digit was displayed on-screen for 1300 ms. IDI refers to the interdigit interval, that is, the duration of the blank screen between two successive digits.
Our results indicate that the large developmental difference observed between third- and sixth-grade children performing the same complex span task is reduced when processing efficiency is equated across ages and disappears when the time available to reactivate memory traces is tailored to processing speed, with younger children benefiting from longer reactivation times (Fig. 7). In his influential theory, Case (1985; see also Case et al., 1982) suggested that the age-related increase in processing efficiency is one of the main factors of WM development. Assuming that a fixed and limited total processing space is shared between operations and short-term storage, any reduction of the space allocated to operations results in the correlative increase of the space available for storage. Because more efficient processes need fewer resources, the age-related increase in processing efficiency should result in an increased short-term storage space and higher WM spans (see also Kail and Ferrer (2007), for an akin conception). Accordingly, Case and colleagues (1982) observed that when adults and first graders are equated in processing efficiency, they achieve the same WM span performance. However, the current study (Experiment 2) demonstrates that even when processing efficiency is kept constant across ages, there are still developmental differences in WM span. Thus, contrary to Case’s assumption, WM spans do not depend solely on processing efficiency.

Fig. 6. Mean spans as a function of age group and pace of the addition task in Experiment 3. Error bars are 95% confidence intervals.

Fig. 7. Summary of the evolution of the mean spans (data averaged across pace conditions) in both age groups from Experiment 1 to Experiment 3.
Instead, and as we hypothesized, WM spans also depend on the efficiency of the processes of reactivation that take place during periods of free time. Even when free time is kept constant, as in Experiment 2, older children take greater advantage of these free periods and achieve more efficient reactivation of memory traces. This echoes Cowan, Morey, AuBuchon, Zwilling, and Gilchrist (2010), who concluded that age differences exist not only in processing but also in storage functions. Accordingly, when investigating the sources of WM development, Bayliss and colleagues (2005) found evidence for a general speed of processing factor that could underlie processing efficiency but also for a storage-related factor corresponding to “the rate at which to-be-remembered items can be refreshed by some type of general reactivation mechanism” (p. 592).

The fact that tailoring reactivation times to processing speed led young children to reach a comparable level of recall performance as their older peers suggests that storage is an active process by which the memoranda are probably continuously reactivated through a time-constrained mechanism, the efficiency of which depends on its speed. The superiority of older children in Experiment 2 disappears when young children are given the time they presumably need to do a similar amount of work as older children during the reactivation periods. This strongly suggests that older children are faster than younger children in reactivating memory traces. In other words, it seems that there is a strong connection between processing speed and WM capacity that goes further than the relationship envisioned by Towse and Hitch (1995), who thought that older children outperformed younger children because they are faster in performing the concurrent task and benefit from shorter delays of maintenance. In the same way, our results also go further than the simultaneity mechanism postulated by Salthouse (1996), according to which the products of early processing may be lost by the time later processing is completed because the availability of information decreases over time as a function of either decay or displacement. Of course, a higher processing speed permits shorter periods during which memory traces suffer forgetting, but it also allows a more effective reactivation of these memory traces when attention is again available after processing episodes. The potential link between processing and reactivation efficiency suggested by the current study is consistent with one of the main tenets of the TBRS model, which assumes that processing and storage involve executive functions within some central executive (Barrouillet & Camos, 2010). Thus, the capacity of the central executive might determine the efficiency of both functions of processing and storage. Because the main constraints of the cognitive system are the sequentiality of the central executive and the ephemeral nature of WM representations, processing speed is one of the main psychological variables that mediates the relation between cognitive resources and WM span.

To conclude, age-related differences in processing efficiency, but also in the efficiency of the maintenance mechanism, account for developmental differences in WM span. It is worth noting that the speed-related mechanisms investigated in this study are probably not the only constraints on WM development. Other important factors could be age-related increases in the absolute size of the focus of attention (Cowan et al., 2010) and the efficiency of strategies to cope with the requirements of complex span tasks (McNamara & Scott, 2001). However, the speed-related mechanisms described here appear to have a role above and beyond these other factors because increases in speed allow older children to avoid the dramatic loss of the items they are able to store both by reducing the time devoted to intervening activities during which forgetting occurs and by improving the efficiency of the mechanisms devoted to reactivating memory traces.

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