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Enhancing visuo-spatial working memory: the role of visual support in preschoolers and adults

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ABSTRACT
Working memory is crucial in cognitive functioning, and environmental cues may enhance its performance. This study examines the role of visual support in promoting and aiding memory strategy. The aim was to determine whether visual placeholders can scaffold mnemonic processes for children and adults. Experiment 1 assessed the ability of 3.5 – to 6-year-olds to use visual support for visuo-spatial rehearsal, while Experiment 2 examined the influence of visual support in adults' working memory. Children demonstrated improved recall with visual support, which could indicate the early use of visuo-spatial rehearsal strategies. Young adults, especially those with lower working memory spans, also benefited from visual placeholders, suggesting that environmental support promotes and scaffold strategy implementation. The findings revealed that visual support plays a role in enhancing working memory performance. It facilitates rehearsal strategies, benefiting individuals across the lifespan, especially those with less efficient mnemonic strategies.

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Working memory; children; adults; visuo-spatial working memory; visual support

Introduction

Working memory is an essential structure in children's cognitive functioning, which allows to maintain and process information. Due to these central cognitive functions, the capacity of working memory is a good predictor of children's academic achievement (Camos & Barrouillet, 2018; Gathercole et al., 2006; Swanson, 1999). In the visuo-spatial and verbal domains, working memory capacity increases with age. For example, in the Corsi's block tapping test, which is a spatial task where the locations to be memorised are sequentially indicated, 4-year-olds show a span (i.e. the maximum amount of information that can be maintained in working memory) of 2.5–3, which grows to 4.5–5 in 10-year-olds (Orsini et al., 1987). The reasons for the age-related increase in working memory capacity are still debated, and several mechanisms have been evoked to account for this increase (e.g. change in the content of long-term memory, increase in processing speed, and increase in attentional capacity, see Camos & Barrouillet, 2018; Pickering, 2001, for reviews). Beyond the knowledge of the development of working memory, other studies have looked at the possibility of helping preschoolers to use their working memory more effectively. The present study aimed to enhance the weaker visuo-spatial working memory performance in preschoolers and adults by enriching the task's environmental context.

One approach that has been used for many years is to explicitly train young children in memorisation strategies, such as the articulatory rehearsal, to bolster their working memory skills. Articulatory rehearsal is a practice that involves repeatedly vocalising or mentally reciting verbal material to be memorised (Baddeley, 1986, 2012). This process enhances the retrieval of information. Most rehearsal training programmes revealed either completely ineffective one week after learning the strategy in 6.5 – and 7-year-olds (Hagen et al., 1973), or at best are effective for 65% of 7-year-old children (Gruenenfelder & Borkowski, 1975). In young adults, rehearsal training also does not lead to improved memory performance. Training young adults to perform rehearsal increases their repetition rate but does not improve their recall performance in a complex span task (Souza & Oberauer, 2020), a task typically used to measure working memory. However, other studies show that it is possible to train preschoolers to engage in rehearsal while having a positive impact on memory performance. In a

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Brown-Peterson task, after training children aged 5–9 to use rehearsal, where they were told they would be shown a great way to remember, children of all ages improved their recall (Miller et al., 2015). The effect, however, was observed immediately after the strategy demonstration. Though, a longer-term effect was achieved with kindergartners, where rehearsal training improved memory scores in a simple span task after one week (Asarnow & Meichenbaum, 1979). This evidence of improved short-term verbal memory performance in preschoolers suggests that children under 7 years of age can implement maintenance strategies if encouraged, while there is little evidence to suggest that preschoolers are capable of rehearsing. The visuo-spatial domain appears to have been less explored. Thus, we are investigating in Experiment 1 the possibility of encouraging young children in implementing a visuo-spatial working memory maintenance strategy.

Delving deeper into the mechanics of rehearsal in working memory, particularly concerning spatial information, it is posited that this involves an intentional focus of attention or gaze on the items to be remembered. The seminal work by Hale et al. (1996) demonstrated that when participants' gaze was diverted from a grid during a secondary task, their spatial memory suffered, underscoring the importance of visual rehearsal. Lawrence et al. (2001) further elucidated this phenomenon, showing that eye movements specifically disturb visuospatial, but not verbal, working memory, suggesting that rehearsal processes are domain-specific. Building on these foundations, Tremblay et al. (2006) provided empirical evidence that visual rehearsal of spatial locations during retention intervals enhances memory for sequences. Earlier, Awh et al. (1998) and Posner (1980) proposed that even without explicit eye movements, spatial locations can be rehearsed through covert shifts of attention. More recently, it has been effectively demonstrated that overt eye movements do not significantly enhance the rehearsal of visuo-spatial information in working memory compared to covert attention (Godijn & Theeuwes, 2012). This idea was previously proposed by Baddeley (1986), who suggested that the memorisation of locations might involve an implicit eye-movement programme.

An experimental design where a visual support was present, as a grid, seems to be beneficial to working memory performances. Using a Brown-Peterson paradigm, Morey et al. (2018b) featured a puppy appearing in various locations on a screen, which were to be memorised by 5–7-year-old, 8–11-year-old children and adults. At the end of the location presentation, all locations visited by the puppy were outlined in colour during the 10-second retention interval. This study did not aim to aid memorisation via a visual support but to measure the use of a gaze-bazed rehearsal mechanism. Indeed, the authors observed the use of a gaze-bazed rehearsal mechanism at any age and indicated that younger children overtly fixed more of the to-be-remembered sequences. The authors interpreted this finding as evidence of the use of a visuo-spatial rehearsal in all age groups, and particularly in children younger than 7. Hitch et al. (1988) already showed that 5-year-old children use a visual component of working memory to retain drawings. Thus, it is therefore possible to think that such placeholders could increase the working memory skills of young children even without receiving instructions about them.

The study by Lilienthal et al. (2014) provides empirical support for the hypothesis that environmental supports can enhance working memory performance. The authors presented young adults with a visuospatial simple span task where 30 circles were displayed on a screen and one of these circles was randomly displayed in red. Between each presentation of the red circle, the 30 circles remained displayed on the screen and represented an environmental support for 1000 ms or 4000 ms, or they disappeared from the screen for the same amount of time. The adults correctly recalled significantly more red circle positions in condition with environmental support rather than in condition without environmental support. For Lilienthal et al. (2014), this result suggests that the presentation of an environmental support improves performance in visuospatial memory. According to the authors, the support might offer more opportunities to engage in elaborate processing like visual rehearsal and/or it would help in retrieving locations to remember using the array as a cue. This effect appears to be robust to individual development because the same pattern of results has been found in older adults (Lilienthal et al., 2016). For the authors, this result suggests that environmental support improves performance by facilitating engagement in elaborate strategies like visuo-spatial rehearsal or cueing retrieval of the to-be-remembered locations (Lilienthal et al., 2014). Similar improvement has been replicated with simultaneous, instead of sequential, presentation of the locations in a grid during the interval of retention compared to a condition when the screen was blank (Souza et al., 2020).

Based on the facts that rehearsal training have mixed results while an environmental support could help memory performance, we proposed in the present study an experimental design, which aimed to test the influence of an environmental support on visuospatial working memory performance in children from 3.5 to 6 years old. Instead of training children explicitly, we have enriched the task environment to provide opportunities for children to implement information maintenance strategies more easily. Our study proposed a design inspired by Morey et al. (2018a), while not pursuing the same objective of identifying whether attentional resources are shared between storage and processing in children. We also chose to use a complex span task, which is the other most used working memory paradigm besides the Brown-Peterson task, and to implement a different methodology by evaluating the impact of placeholders. In the main memory task, we took up the idea of displaying an animal to memorise on a grid presented in front of a countryside landscape. In the concurrent task, children were asked to rate whether the animal displayed on the grid was presented in a normal orientation or upside down. But unlike the study by Morey et al. (2018a), during a delay following the evaluation of the orientation of the animal, the presence of the grid was manipulated in our study. The grid remained on the screen or disappeared between presentations of the animal. By leaving the visual support (i.e. the grid) available, we thought it would help the early use of a visual rehearsal strategy. The early implementation of the visual rehearsal strategy would be evidenced by an increase in recall performance in the presence of the visual support from an early age.

Compared to Morey et al. (2018b) and Morey et al. (2018a), we extended the age range, starting at 3.5 years, with age groups differing from only 6 months to each other to better track the age at which children can implement a maintenance strategy. If children, particularly the youngest, remain passive and do not implement any kind of maintenance strategy, the presence of placeholders should not impact their performance. Alternatively, if children are able to implement a visuo-spatial rehearsal strategy, the placeholders should encourage them to do so. Then, in addition to the encouragement to use a strategy, the placeholders should help them to do so more efficiently, leading to an improved recall performance, as previously reported in adults (Lilienthal et al., 2014; Souza et al., 2020). Experiment 1 tested the impact of environmental support on working memory performance in preschoolers. Without disclosing the findings of Experiment 1, we extended the hypothesis of support assistance to a population of young adults in Experiment 2.

Experiment 1

Experiment 1 involved six groups of children, aged half a year apart between 3.5 and 6 years of age performing a complex span task, in which children had to memorise the location of the houses sequentially visited by a character (a teddy bear), while judging the position (upward vs downward) of the bear in each house. During the retention interval following each evaluation of the position of the teddy bear, the presence of houses was manipulated: they either remained on the screen providing support to a visuo-spatial rehearsal or disappeared. The absence of effect on memory performance would evidence the passive maintenance of visuo-spatial information in children, while the beneficial effect would mark the fact that children were able to implement a visuo-spatial rehearsal strategy.

Method

Participants

Twenty-one 3.5-year-olds (M_{age} = 3;7, min: 3;0, max: 4;2, SD = 0;4, 14 females and 7 males), twenty-eight 4-year-olds (M_{age} = 3;10, min: 3;0, max: 4;8, SD = 0;6, 18 females and 10 males), twenty-eight 4.5-year-olds (M_{age} = 4;7, min: 4;0, max: 5;1, SD = 0;4, 18 females and 10 males), thirty-five 5-year-olds (M_{age} = 5;0, min: 4;5, max: 5;8, SD = 0;4, 13 females and 12 males), twenty-eight 5.5-year-olds (M_{age} = 5;6, min: 4;11, max: 5;10, SD = 0;3, 18 females and 10 males), and twenty 6-year-olds (M_{age} = 6;1, min: 5;6, max: 7;5, SD = 0;5, 8 females and 12 males) took part in the experiment.[1] Our sample was schooled in two countries (3 educational levels in each country, Switzerland and France) that differed on the age children start preschool. Hence, children in the 3.5, 4.5, and 5.5-year groups were schooled in France, while the other groups were schooled in Switzerland. The age groups were constituted based on school years, as these have a greater impact on memory performance regardless of children's age (Davidson et al., 2023; Rogoff, 1981). Children were all French speakers. The experiment took place in a quiet room at the children's school. The experiment was approved by the Internal Review Board of our department. We gathered from the parents or legal guardians a consent form, and children gave their assent orally before beginning the experiment.

Data from additional participants were discarded due to poor instruction comprehension (two 3.5-year-old, four 4.5-year-old, three 5-year-old, two 5.5-year-old, and one 6-year-old children), a span score of 0 in at least one of the two experimental conditions (seven 3.5-year-olds, four 4-year-olds, two 4.5-year-olds, and three 5-year-olds), because their mean response time

[1]Two classes were recruited for each age group to reach similar sample size as in Morey et al. (2018b). According to ethic regulations, neither the ethnic group nor the social class of the children was recorded, because the study has no specific hypotheses about these data, only the sex (binary) of the children was collected for sample description purpose.

to the position task exceeded from 3 standard deviations (SDs) the mean time of their age group in at least one of the two conditions (one 3.5-year-old, one 4-year-old, one 4.5-year-old, and one 5-year-old child), or their performance in the position task was below the chance level (<60%; one 4-year-old). In 3.5-year-olds, nine out of twenty-one children presented a judgement score of the position below 60%. However, we decided not to exclude any 3.5-year-olds on this criterion to maintain an acceptable population size. The position task may have been difficult for the 3.5-year-olds, but this does not undermine the dual task.

Material

The task was presented on a laptop with a 13-inch screen and was built with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA, USA, 2012). The teddy bear appeared in a pseudo-random order in one of the 6 houses (i.e. 3.3 × 3.7 cm rectangles) distributed in a countryside background picture (Figure 1). In each trial, the teddy bear appeared in 1–5 houses with four trials for each length. The teddy bear could either appear in a nearby house or in a distant house over two successive locations and could not reappear in the same house within the same trial. Because the complexity of paths formed by to-be-remembered locations can impact recall performance (Parmentier & Andrés, 2006), we controlled for it and created two lists of pseudo-random order of appearance of the teddy bear in the different locations. In each list, the number of times the teddy bear continued its path two houses apart from the previous location was identical between experimental conditions. These lists were counterbalanced across conditions and participants (see at https://osf.io/42769/?view_only = 03dc504e776c490a890f64dc74988 9bd).

Procedure

Children completed a complex span task. They had to memorise the sequence locations in which a target (teddy bear) was displayed, while a concurrent task required judging the target's position (upward vs. downward) in each location. The target remained visible in a location until children responded to its position, and then disappeared for 2500 ms before reappearing in a new location. In each house, the target was displayed either the right way up or upside down. Children had to press one of two keys to indicate the target's position. A picture of each position was displayed behind each key to remind children of their meaning.

At the beginning and at the end of the 2500 ms delay, the houses remained empty for 250 ms. In the remaining

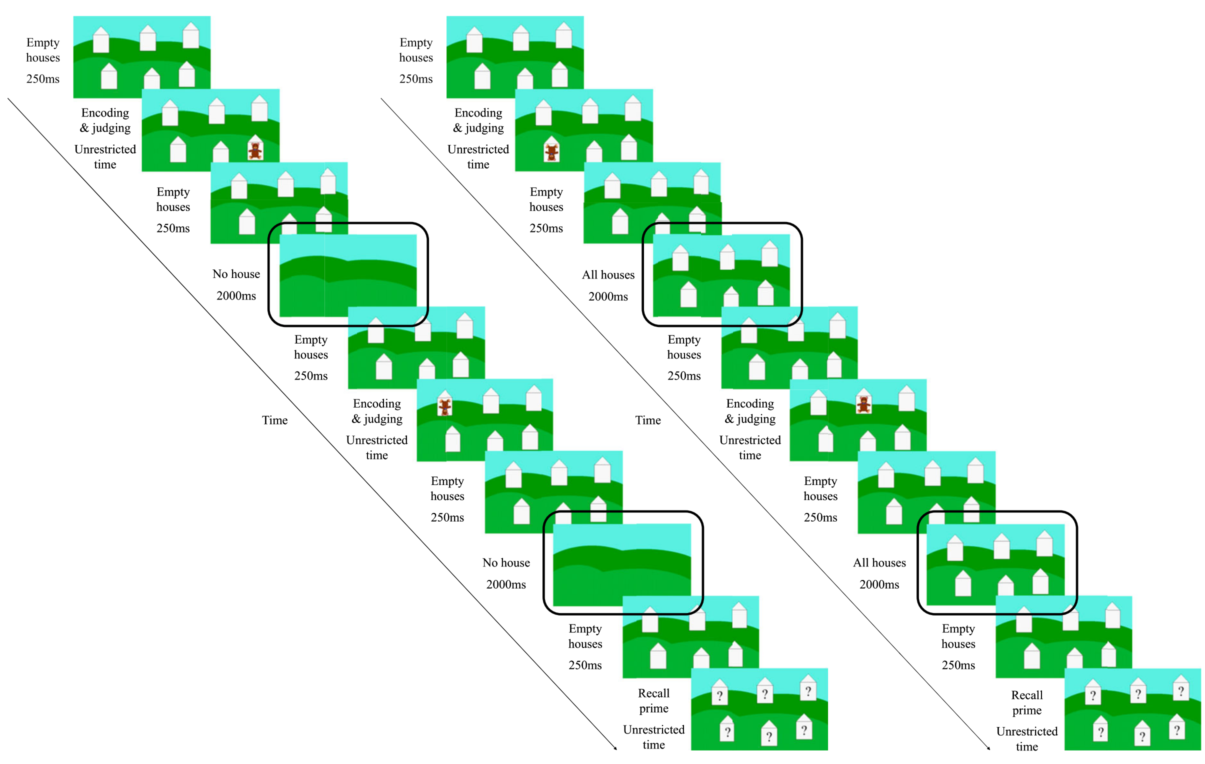

Figure 1. Illustration of the conditions presented in Experiment 1, showing a trial of length of 2. Screens that differed between conditions are circled in black.

2000 ms interval, either all 6 empty houses remained on screen providing visual support (With-support condition) or no visual support was provided and only the countryside background remained on screen (Without-support condition; Figure 1). Each child completed both conditions in a counterbalanced order and was not informed of the change of conditions between blocks. At the end of a trial, a question mark appearing in each house prompted the onset of the recall phase. The child was instructed to point successively at each house visited by the teddy bear in the order of appearance. As the screen was not a touch screen, an experimenter seated next to the child recorded their answers on a numeric keypad.

The session started with a practice phase. First, children practiced the position task. The teddy bear appeared upright or upside down in one of the 6 houses in a pseudo-random order, six times in a row. Children had to press the corresponding key on the keyboard to judge the position of the teddy bear each time it appears. During this training phase, only the key corresponding to the correct answer could work. Therefore, the child was required to answer correctly to proceed to the next trial. Otherwise, nothing happens if the child presses the wrong key. Second, children practiced memorising the teddy bear's locations. Memorisation practice contained one trial in length 1 and 2. Each trial proceeded in the same way as the experimental phase described earlier, and the experimental condition presented during the training was identical to that by which the child would begin the experiment. After practice, each child completed the two conditions in a counterbalanced order. For each condition, there were five sequences, starting from length one to length five, with four trials per sequence, making a total of twenty trials. A condition would end if all four trials of a given length were incorrect. Recall was considered correct when all locations were recalled in the order of presentation with no omissions or additions. Regardless of where the first presented condition ended, the participant continued the experiment by completing the remaining condition. Thus, all participants completed both conditions. The testing session lasted a maximum of 20 min.

Data analysis

Response time and accuracy were recorded for the concurrent position task. A span score was calculated for each child in each condition. Each correctly recalled series of a given length (i.e. in which all the locations were correctly recalled in the order of presentation) was attributed a score of .25, leading to a maximal score of 1 point per length (Barrouillet et al., 2009; Bertrand & Camos, 2015; Smyth & Scholey, 1992).

All Bayesian statistical analyses were performed using JASP 0.16.4 (2022). For each dependent variable, a Bayesian analysis of variance (ANOVA) was performed using the default settings (prior probability of 0.5). We used a uniform distribution for the priors, as this is the default setting in JASP. Bayesian t-tests analyses were also conducted using the default settings (prior probability of 0.707). For the t-tests, we used a Cauchy distribution, which is the default setting in JASP. The BF_{10} of each model (e.g. main effects only, main effects + interaction effects) was obtained by comparing it to the null model. A BF_{10} of 3 or more is considered substantial evidence for the model of interest; as a BF_{01} superior of 3 is considered substantial evidence for the null model and values between 1 and 3 indicate an anecdotal or a weak evidence either way (Dienes, 2014; Jeffreys, 1961). Then, a BF_{10} or BF_{01}, respectively testing the alternative hypothesis or testing the null hypothesis, between 10 and 30 is strong evidence, 30–100 is very strong, and over 100 is decisive according to Jeffreys. Similarly, when comparing two models, we favoured the best model when its probability to account for the data was three times greater than the second-best model; otherwise, both models were taken into consideration, and the examination of the $BF_{inclusion}$ and $BF_{exclusion}$ of the effects included in the models helped choose the model to favour. The value for each factor of the $BF_{inclusion}$ or $BF_{exclusion}$ indicates the likelihood of the data under models that included or excluded a given factor compared but were otherwise identical. For clarity, we reported the BF_{10} and $BF_{inclusion}$ for evidence in favour of the alternative hypothesis, and the BF_{01} and $BF_{exclusion}$, which is $1/BF_{10}$ and $1/BF_{inclusion}$, for evidence in favour of the null hypothesis. Finally, for repeated measures ANOVAs that included at least one between-subject factor, we have reported the 95% confidence intervals for the mean estimates derived from the within-subjects comparisons, calculated using the T distribution model.

Results

Anonymized data are available at https://osf.io/42769/?view_only = 03dc504e776c490a890f64dc749889bd.

Detailed analysis of the accuracy and the response times on the concurrent position task was reported in detail in analytical appendices. To summarise, conditions did not impact either of these measures, while an age effect was observed for both: position mean accuracy increased with age (75% at 3.5 years, and above 96% from 4 years onward, see Table A1 for the complete

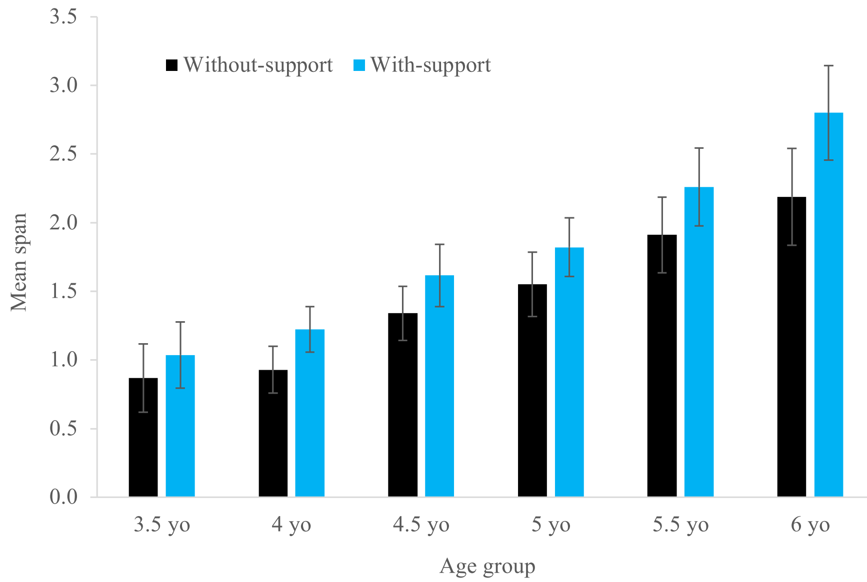

Figure 2. Mean span as a function of Age groups (in years) and visual support Conditions (Without-support vs. With-support) in Experiment 1. Vertical bars represent 95% confidence interval for the within-subjects comparison.

descriptive analysis); the mean response times decreased with age (from 4718 ms at 3.5 years to 2451 ms at 6 years).

A Bayesian ANOVA was performed on memory span scores with the condition (Without-support vs. With-support) as a within-participants factor (Figure 2), while Age groups, Condition Order, and Lists of sequences were entered as between-participants factors. The analysis revealed that the six first models did not differ from each other (Table 1).

To depart the models from each other, we examined the $BF_{inclusion}$ for each factor in the models. In line with the second-best model, which was also the most parsimonious, the $BF_{inclusion}$ for Age and Condition were 7.98×10^{15} and 1.85×10^{9}, respectively. The BF for the other factors did not support their inclusion to account for the data: $BF_{inclusion} = 1.01$ for order and 1.04 for Age x List interaction, $BF_{exclusion} = 1.45$ for List and between 1.68 and 6.48 for all the other interactions. In particular, it should be noted that the Age x Condition interaction had a $BF_{exclusion}$ of 5.05. Thus, span scores increased across Age groups, and the presence of the placeholders has a beneficial effect on span scores in all Age groups with evidence against an interaction between Age and Condition (Figure 2).

We tested how much the presence of the visual support allowed children to get ahead of the development of working memory. To assess if the support brought the performance of younger children close to the performance of the older children, we compared younger children spans in the With-support condition with the spans of older children in the Without-support condition, looking at age differences of 6 months and 1 year (e.g. 3.5 years old With-support vs. 4 years old and 4.5 years old Without-support). When contrasting with the 6-month older children, the Bayesian t-tests showed anecdotal to substantial evidence in favour of the null hypothesis ($BF_{01} = 2.73 \pm .007\%$, $2.61 \pm .009\%$, $3.60 \pm .011\%$, $3.43 \pm .011\%$, and $3.29 \pm .006\%$ when the younger group was 3.5, 4, 4.5, 5, and 5.5, respectively). The support brought the performance of the younger children close to the one of children 6 months older. Yet, when contrasted with the performance of 1-year older children, most of the Bayesian t-tests were supporting a difference in span scores, although these results could be interpreted as anecdotal evidence that does not decidedly support any hypothesis ($BF_{10} = 1.48 \pm .008\%$, $1.93 \pm .009\%$, $0.89 \pm .009\%$, and

Table 1. The six best models including main effects and interaction with their BF_{10}.

Model	Age	Condition	Order	List	Interaction	BF_{10}
1st	x	x	x			$9.72 \times 10^{24} \pm 2.01\%$
2nd	x	x				$9.17 \times 10^{24} \pm 1.03\%$
3rd	x	x		x		$7.40 \times 10^{24} \pm 14.41\%$
4th	x	x	x	x	Age x List	$6.94 \times 10^{24} \pm 5.69\%$
5th	x	x		x	Age x List	$6.41 \times 10^{24} \pm 2.00\%$
6th	x	x	x	x		$6.24 \times 10^{24} \pm 1.92\%$.

1.30 ± .008% when the younger group was 3.5, 4, 4.5, and 5, respectively).

Finally, we have conducted a new analysis of the developmental gain allowed by the support by reorganising the grouping of children according to their ages rather than their school levels as previously done. By grouping children according to their school levels, it created age overlaps between adjacent age groups, and this could question our findings of 6 month developmental advance due to the support. Alternatively, we regrouped children based on their actual ages, rather than their school levels, with a maximum of 6 months between the youngest and the oldest child in each group and without age overlap between the groups.[2] As in the previous analysis, we compared the spans of younger children in the With-support condition to the spans of older children in the Without-support condition, looking at age differences of 6 months and 1 year. When contrasting with the 6-month older children, the Bayesian t-tests showed anecdotal to substantial evidence in favour of the null hypothesis ($BF_{01} = 1.25 \pm .009\%$, $3.30 \pm .009\%$, $3.74 \pm .011\%$, $2.85 \pm .011\%$, and $2.79 \pm .002\%$ when the younger group was 3.5, 4, 4.5, 5, and 5.5, respectively). The support brought the performance of the younger children close to the one of children 6 months older. Yet, when contrasted with the performance of 1-year older children, most of the Bayesian t-tests were supporting a difference in span scores, although some results could be interpreted as anecdotal evidence that does not decidedly support any hypothesis ($BF_{10} = 4.71 \pm 9.69 \times 10^{-7}\%$, $0.86 \pm .008\%$, $1.09 \pm .010\%$, and $1.48 \pm .003\%$ when the younger group was 3.5, 4, 4.5, and 5, respectively).

Discussion

Experiment 1 examined whether visual support help children from 3.5 years onward to engage in visuo-spatial rehearsal, as previously reported in adults who use this strategy (Lilienthal et al., 2014; Souza et al., 2020). First, as expected, working memory performance improved across age groups, extending the age-related increase in working memory observed in many studies to a new task. Moreover, the visual support has a beneficial effect on visuo-spatial working memory performance. From 3.5–6 years old, children performed better in the presence of the placeholders during the delay of retention. No interaction between age and the effect of placeholders was present. Children as young as 3.5 years as well as children aged 6 years benefited similarly from the presence of placeholders during the retention interval. This finding supports the idea that even very young children can implement visuo-spatial rehearsal to support their recall. Moreover, the presence of the visual support seemed to help children approach performance levels that are closer to those aged 6 months older without visual support. However, grouping children according to their school levels resulted in age overlaps among adjacent groups, which could cast doubt on our findings of a 6-month developmental advantage due to support. To address this, we reorganised the children based on their actual ages rather than school levels, ensuring a maximum age difference of 6 months between the youngest and oldest children within each group and eliminating age overlaps between groups. This reclassification led to a similar pattern of results, which indicates that the observed effect is robust and independent of the children's groupings. Such an improvement may be indicative of the children's zone of proximal development (Vygotsky, 2012), i.e. what children would be able to do soon without any external support.

To delve further into the absence of interaction between visual support and age, it may be attributed to the children's young age. At these ages, children might not independently implement strategies for maintaining information. Indeed, some studies suggest that there is a developmental shift in the use of information maintenance strategies such as articulatory rehearsal around the age of 7 (Allik & Siegel, 1976; Barrouillet et al., 2009; Camos & Barrouillet, 2011; Flavell et al., 1966; Hitch & Halliday, 1983; Oftinger & Camos, 2015, 2017, 2018; Tam et al., 2010), others challenge the notion of a sudden shift at the age of 7 (Elliott et al., 2021; Henry et al., 2012). However, there are few instances of articulatory rehearsal before this period unless children are explicitly invited to engage in it through training (Asarnow & Meichenbaum, 1979; Miller et al., 2015). Placeholders might function as an impetus for the establishment of a visual rehearsal strategy, signifying an advancement beyond the foundational understanding that has been previously recognised in populations not yet spontaneously employing such strategies. Indeed, there are four phases in the development and use of mnemonic strategies in children (Schneider & Sodian, 1997). In the first phase, even if a strategy is taught, it does not improve performance. The second phase corresponds to the fact that children do not use strategies spontaneously but can do so if they are invited. In the third phase, children engage in strategic actions that are not yet effective in enhancing their memory recall. The final

[2]See the data file with the new categorization at https://osf.io/42769/?view_only=03dc504e776c490a890f64dc749889bd

phase is the mature use of strategies. Thus, we could hypothesise that in a population that has been employing this strategy for years, it could be applied even when the environment does not invite it. As a result, adults would then not need visual support to implement rehearsal. Hence, if the support is merely an encouragement to establish a rehearsal strategy, where this establishment is effortful before it becomes automated (for verbal rehearsal, see Naveh-Benjamin & Jonides, 1984), then we should not observe an effect of the support in adults. Indeed, the initial effort of establishing the strategy could be negligible in adults who have more attentional resources than children (e.g. Morra, 2015). Therefore, the rehearsal strategy could be implemented without environmental aid. However, Lilienthal et al.'s experiments show that adults still benefit from environmental support. In this case, the support could be an aid to the better execution of a rehearsal strategy in addition to encouraging its initial implementation, even in adults who are experts in the use of rehearsal. Thus, if the support allows, in addition to the initial implementation, to assist the execution of a rehearsal strategy, then we should observe a positive effect of the support on working memory performance in young adults as well.

Experiment 2

Based in Experiment 1 findings, which revealed that visual support aids in visuo-spatial rehearsal in children as young as 3.5 years, Experiment 2 aimed to extend this investigation to young adult. Experiment 1 established that visual placeholders enhance working memory performance across different age groups in children, suggesting that even at a very young age, individuals can employ visuo-spatial strategies to bolster recall. This effect was consistent across the age spectrum, indicating that the ability to utilise visual support does not differ with age within the tested range. Experiment 2 sought to explore whether the benefits of visual support observed in children translate to an older population that has presumably been employing mnemonic strategies independently for years. Evidence of Experiment 1 called for further investigation into whether such supports serve merely as a prompt for strategy establishment or if they play a role in the execution of the strategy itself.

In adults, who are considered able at using rehearsal strategies without external prompts, the presence of visual support should theoretically not influence working memory performance if its sole function is as an initial encouragement. Yet, previous research, including Lilienthal's work, indicates that adults still benefit from environmental support. This raises the question of whether visual support could not only be beneficial in promoting the strategy but also in its implementation. Therefore, Experiment 2 was designed to assess the impact of visual support on working memory performance in young adults. If visual support is found to enhance performance, it would suggest that its role extends beyond the mere facilitation of strategy establishment to aiding the execution of well-practiced mnemonic strategies. Such findings could have significant implications for our understanding of cognitive development and the optimisation of learning and memory processes across the lifespan.

Method

Participants

One-hundred and sixteen young adults, mainly students in psychology ($M_{age} = 21;7$, min: 18, max: 38, $SD = 2;7$, 105 females and 11 males), took part in the experiment. The experiment took place at the students' university in a testing room. The experiment was approved by the local ethic committee. We gathered from the participants a consent form before beginning the experiment. After testing, three adults were excluded due to non-compliance with the instructions. All participants received experimental hour credits or a cinema ticket.

Material and procedure

Material and procedure were similar to Experiment 1, except for the following points. Considering the larger visuo-spatial working memory capacity of adults, we conducted pre-tests on the two conditions (Without – and With-support) with young adults to determine the number of houses to memorise to avoid ceiling effect. During the first series of pre-tests in 3 additional adults, we proposed lengths ranging from 3 to 8 with 9 houses displayed on the screen, and span scores ranged from 5.75–8. We conducted a new series of pre-tests in 4 adults, two of whom had participated in the first series, and one of them had scored 8/8 the first time. In the second pre-test, the proposed sequence lengths ranged from 3 to 9 with 10 houses displayed on the screen. The scores ranged from 4.75–8.25. In both series of pre-tests, everyone succeeded in all trials of length 3. Thus, this led us to exclude lengths less than 4 and to extend the sequence lengths up to 10 houses without any stop rule. Finally, eleven houses were presented on a bigger screen (24-inch) than for children (Figure 3).

Then, the sequences of the teddy bear's appearances were no longer defined by lists, given the significant number of possible locations, but the locations where

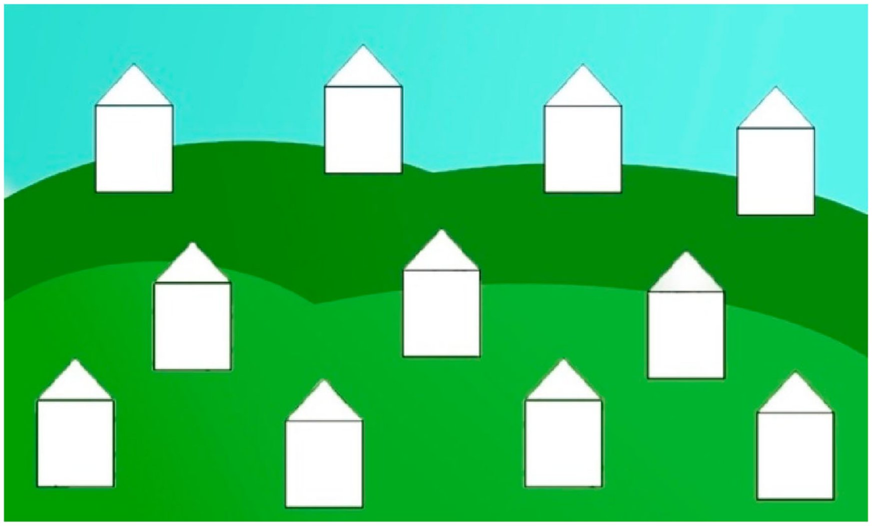

Figure 3. Tailored to the memory capacity of adults, 11 houses were distributed in the countryside in Experiment 2, instead of 6 houses in Experiment 1 for children.

the teddy bear appeared were randomised without replacement, meaning that the teddy bear could not reappear in the same location during a given trial. For the recall phase, a camera positioned behind the participants framed only the screen to record the houses pointed out by the participants. This allowed for the scoring of the responses to the memory task afterwards. Finally, the practice phase was partly similar to that of Experience 1. It involved training on the judgment of the position of 6 teddy bears, which were randomly placed in a row across six different houses. Afterward, participants received training on one trial in each length 2 and 3.

Data analysis

The set of scores was calculated in the same way as in Experiment 1. Also, the same types of Bayesian analyses were conducted.

Results

Anonymized data are available at https://osf.io/42769/?view_only = 03dc504e776c490a890f64dc749889bd.

Detailed analysis of the accuracy and the response times on the concurrent position task was reported in detail in analytical appendices. To summarise, position accuracy was around 98% in both conditions, and response times did not vary between conditions with an overall average of 1808 ms.

A Bayesian ANOVA was performed on spans with Condition (Without-support vs. With-support) as within-participants factor and Condition Order as between-participants factors. Only one model presented anecdotal evidence for the alternative hypothesis, $BF_{10} = 1.19 \pm 1.50\%$, including a main effect of Condition, a main effect of Condition Order and an interaction between those two factors. The analysis of the $BF_{exclusion}$ revealed a $BF_{exclusion}$ of 3.17 for the effect of Condition and a $BF_{exclusion}$ of 2.98 for the effect of Condition Order. However, the analysis revealed a $BF_{inclusion}$ of 11.10 for the interaction effect between Condition and Condition Order. A Bayesian Paired Samples T-Test was conducted on spans when participants started the experiment with the Without-support condition and finished with the With-support condition. Performance was substantially better in the second condition With-support (M 6.26, 95% credible interval .28) than in the first condition Without-support (M 5.90, 95% credible interval .32), $BF_{10} = 3.86 \pm 6.14 \times 10^{-7}\%$. A second Bayesian Paired Samples T-Test was conducted on spans for the reverse order of conditions. Anecdotal evidence indicated a lack of difference in the span scores between the two conditions when participants started the experiment with the condition With-support (M 5.89, 95% credible interval .28) and ended with the condition Without-support (M 6.03, 95% credible interval .25), $BF_{01} = 2.60 \pm .044\%$.

Complementary analysis – inter-individual differences

We have conducted an additional analysis considering the inter-individual differences in working memory capacities (see Ilkowska & Engle, 2010, for a review). We divided the participants into three groups, which were balanced in size and based on span scores (see e.g. Engle et al., 1992; Just & Carpenter, 1992; MacDonald et al., 1992) obtained in the Without-support condition. We chose this condition to create the groups because, as it was a post-hoc analysis, we did not have an independent measure of working memory capacity. The Without-support condition was considered as the baseline condition, one that does not provide environmental enrichment, nor assistance through visual supports, as it is mostly the case in span tasks used to assess working memory capacity. Thus, we considered that memory performance in the Without-support condition best respresented the individuals' working memory capacity. More specifically regarding the organisation of the groups, after ranking the participants based on their span scores in the Without-support condition from the lowest to the highest, we divided them into three groups. The first tier consisted of participants with the lowest spans, the second tier included those with average spans, and the third tier comprised participants with the highest spans in the Without-support condition. We aimed for an equal distribution of participants across the three groups; however, due to ties in span scores, the group sizes are not exactly equal. Thus, we formed a Low-span group of 38 participants with spans ranging from 3.5–5.25, a Medium-span group of 36 participants with spans from 5.5–6.25, and a High-span group of 39 participants with spans from 6.5–9.

Detailed analysis of the accuracy and the response times on the concurrent position task was reported in detail in analytical appendices. To summarise, position accuracy did not vary between conditions (all around 98%) and response times were slower in the Without-support condition than in the With-support condition only in the High-span group (2094 ms, 95% credible interval 357 ms, vs. 1812 ms, 95% credible interval 317 ms).

A Bayesian ANOVA was conducted on spans with the condition (Without-support vs. With-support) as a within-participants factor, while Condition Order and Span-groups (Low-, Medium-, and High-span) were entered as between-participants factors. The analysis indicated that the first three models did not differ substantially from each other (Table 2).

As in the previous Bayesian ANOVA that did not include the Span-groups factor, the analysis of the $BF_{inclusion}$ and $BF_{exclusion}$ for each factor in the models showed that the $BF_{exclusion}$ for the condition was 2.93. However, a substantial effect of the order was present, $BF_{inclusion} = 5.88$ (performance increased during the experiment: M 5.90, CI .30 for the first conditions and M 6.15, CI .27 for the second conditions) as well as a substantial effect of interaction between the condition and the order of presentation, $BF_{inclusion} = 8.49$. Obviously, the effect of the span-groups was present, $BF_{inclusion} = 2.85 \times 10^{27}$, but it did not interact with the order, $BF_{exclusion} = 3.02$. Finally, very strong evidence indicated an effect of interaction between the condition and the span-groups, $BF_{inclusion} = 50.9$, and the interaction between the three factors was neither in favour of the alternative hypothesis nor in favour of the null, $BF_{inclusion} = 1.26$.

Paired Samples T-Tests were conducted on spans in each span-group to highlight the profile of the interaction with the condition. In the Low-span group, decisive evidence showed a higher span in the condition With-support than Without-support, $BF_{10} = 173 \pm 7.461 \times 10^{-9}\%$ (Figure 4). By contrast, substantial evidence indicated a lack of difference in the span scores between the conditions With-support and Without-support in the Medium – and High-span group, respectively $BF_{01} = 3.86 \pm .04\%$ and $BF_{10} = 1.32 \pm .02\%$ (Figure 4).

Discussion

Experiment 2 was designed to explore the effect of visual support on working memory in young adults, following the insights gained from Experiment 1. The underlying hypothesis was twofold. If visual support serves merely as an encouragement for the initial establishment of a rehearsal strategy, which becomes automated over time, then its effect should be negligible in adults. This is based on the premise that adults, with their greater attentional resources, can implement rehearsal strategies without the need for environmental aids. Conversely, if visual support contributes not only to the strategy's initial implementation but also assists in its execution, then a positive effect on working memory performance in young adults would be anticipated. This hypothesis aligns with the notion that

Table 2. The three best models including main effects and interactions with their BF_{10}.

Model	Condition	Order	Span-groups	Interactions	BF_{10}
1st	x	x	x	Condition x Order Condition x Span-groups	$3.02 \times 10^{29} \pm 2.16\%$
2nd	x	x	x	Condition x Order Condition x Span-groups Order x Span-groups Condition x Order x Span-groups	$1.26 \times 10^{29} \pm 1.67\%$
3rd	x	x	x	Condition x Order Condition x Span-groups Order x Span-groups	$1.00 \times 10^{29} \pm 2.25\%$

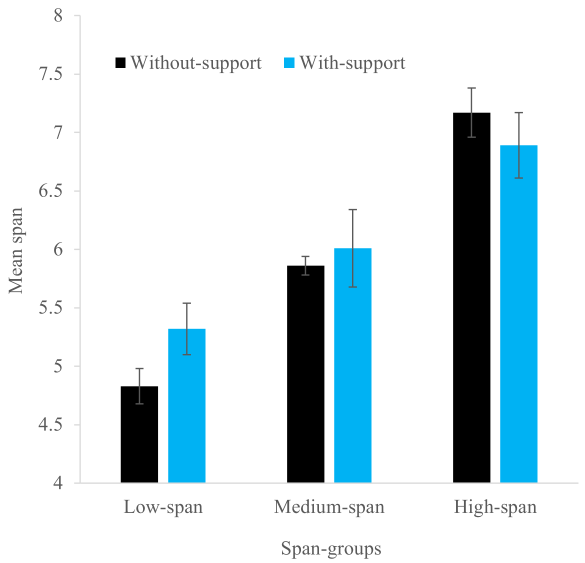

Figure 4. Mean span as a function of Span-groups (Low, Medium and High-spans) in adults and the visual support Conditions (Without-support vs. With-support) in Experiment 2. Vertical bars represent 95% confidence interval for the within-subjects comparison.

environmental support could be beneficial even for well-practiced strategies.

Our findings partially support the latter hypothesis. While no overall effect of visual support on span scores was observed across the entire population, the Low-span group showed improved performance with visual support, suggesting it aids individuals with less efficient mnemonic strategies. For the High-span group, the increase in response times (see analytical appendices) in the bear's orientation task could stem from a compensatory strategy. In the absence of support during the delay, high-span individuals could take advantage of every moment when the bear appears in a house to rehearse before judging the orientation. Indeed, the implementation of strategies requires time (Carpenter & Just, 2013; Engle et al., 1992; Friedman & Miyake, 2004).

In addition to the findings previously discussed, the analysis revealed an overall improvement in recall performance during the experiment. This improvement, however, was contingent upon the inclusion of the span-groups factor in our analytical model, which, notably, did not interact with other variables when we tested the span scores. By becoming more familiar with the task, every participant can improve their recall, regardless of the conditions and working memory abilities, which could result from the discovery of other memorisation strategies during the task. This improvement in memory performance could also be attributable to a better processing of the concurrent task, leaving more attentional resources available to be allocated to the memory task (Barrouillet et al., 2007). However, contradicting this suggestion, there was no difference in the speed of position judgments (anecdotal evidence for the null hypothesis for Condition Order, $BF_{exclusion} = 2.04$), and in the accuracy (substantial evidence for the null hypothesis for Condition Order, $BF_{exclusion} = 4.38$) across the experiment.

General discussion

The present study explored the role of environmental support in working memory performance, delving into the developmental aspects of strategy implementation. The investigation was structured into two experiments, each targeting distinct age groups, with the aim of uncovering whether visual placeholders could aid in the mnemonic process, not only for children but also for adults.

Experiment 1 examined preschoolers' ability to engage in visuo-spatial rehearsal when provided with visual support. The findings revealed that children as young as 3.5 years could benefit from placeholders, which facilitated an improvement in recall performance. This effect was consistent across the age spectrum up to 6 years, suggesting that the capacity to use visual support for memory enhancement does not differ within the tested age range. The absence of an interaction between age and the effect of placeholders underscores the potential for even very young children to implement visuo-spatial rehearsal strategies when prompted by environmental cues. The implications of these findings challenge the prevailing belief that strategic memory maintenance is unattainable for preschoolers. Instead, our results align with the second phase of Schneider and Sodian's model (1997), indicating that children can employ strategies when prompted, although they may not do so spontaneously.

One might question the ability of such young children to engage a rehearsal strategy, especially as its verbal equivalent only appears around 7 years of age for the memorisation of verbal items. Moreover, the literature on the memorisation of visuo-spatial items does not provide any evidence for such an early use of a visuo-spatial rehearsal. An alternative hypothesis for the increase in performance in the presence of the visual support is that children's attention remains focused on the house where the teddy bear last appeared. This would result in a consolidation of the memory trace for this last position, and hence an increase in working memory performance. The consolidation process has been described as taking place immediately after the presentation of the memoranda (Engle et al., 1992; Jarrold et al., 2011; Vergauwe et al., 2014), allowing transient sensory traces to be transformed into more stable memory traces (De Schrijver & Barrouillet, 2017). In agreement with this suggestion, Morey et al. (2018b) showed that young children spent a larger proportion of time than adults at fixating each spatial position at encoding, except for the first position. Moreover, giving the opportunity to consolidate immediately after the presentation of each item to be remembered leads to better recall performance in young adults (Bayliss et al., 2015). Further research is necessary, and we sought to explore the underlying mechanisms that might influence recall performance in children. Without disclosing the outcomes of our follow-up experiments, the study was designed to investigate the hypothesis of consolidation and the potential of cumulative rehearsal, where it is theorised that children may loop spatial positions similarly to a phonological loop with repeated cycling of words (Fitamen et al., submitted).

Experiment 2 extended the inquiry to young adults, hypothesising that if visual support serves merely as an encouragement for strategy establishment, its effect should be minimal in adults. However, if it also assists in the execution of strategies, then a positive impact on working memory performance in adults would be expected. The outcomes partially supported the latter hypothesis, with low-span individuals showing improved performance with visual support, indicating that environmental cues can bolster performance for those with less efficient strategies. The contrast between the Low and High-span groups in adults presented a novel pattern of results. While the High-span group did not exhibit differences in span scores at recall, they took longer to respond to the orientation of the bear in the absence of support. This could suggest a compensatory strategy, where the High-span group may have used the evaluation phase as an opportunity to consolidate the new location presented, in addition to rehearsing previous locations. Engle et al. (1992) had reported that the time spent looking at the elements of the processing task increased with the accumulation of the memory load only among High-span adults. Indeed, this additional time could be linked to the implementation of strategies, which requires time (Carpenter & Just, 2013; Engle et al., 1992; Friedman & Miyake, 2004). It is also a way to evaluate the use of strategies through self-administered paradigms in which participants are free to analyse information as long as they wish, then trigger the transition to the trial or the next information themselves (Engle et al., 1992; Friedman & Miyake, 2004; Turley-Ames & Whitfield, 2003). This partly corresponds to our concurrent task, which was self-paced, where the increased response time among High-span adults could be indicative. It would reflect their ability to employ compensatory strategies autonomously during intervals without external support.

The Low-span adults, however, displayed a pattern of results akin to that of the children, with no difference in evaluation times but improved recall performance With-support. This similarity raises intriguing questions about the developmental trajectory of working memory strategy use. It suggests that, like children, Low-span adults may be encouraged by environmental support to implement memory strategies, and the utilisation of these strategies was facilitated by the support. These results are in line with Bailey et al. (2008) and Dunlosky and Kane (2007) indicating that Low-span adults are less inclined to engage in memorisation strategies during working memory tasks. However, Low-span are the ones who benefit the most from the use of strategies (Turley-Ames & Whitfield, 2003).

Unlike the Low-span, the Medium and High-span individuals may not have benefited from the support due to the time frame. The support remained 2000 ms on screen which can be too short to rehearse the numerous locations they are able to memorise. Therefore, we can wonder whether a longer stimulus presentation time, for example, 4000 ms as in Lilienthal's work (Lilienthal, 2018; Lilienthal et al., 2014, 2016), would yield a beneficial effect of the support in Medium and High-span adults. However, such a population with better working memory skills is also having higher processing speed (e.g. Case et al., 1982). In this case, 2000ms might be enough to rehearse numerous locations. Among Low-span adults and children, even with a slower processing speed, the 2000ms interval could be sufficient to rehearse an average of five locations for Low-span adults and children. Indeed, a beneficial effect of the grid on recall performance was already evident after just 1500 ms of presentation in Souza's study involving young adults (Souza et al., 2020). Nevertheless, we can also imagine that, given the possibly insufficient time for rehearsal, another memorisation strategy was implemented thanks to the support, such as visualising shapes formed by the movements of the teddy bear (see Gonthier, 2021).

This leads us to question the intervention of other information maintenance processes, such as visual mental imagery, which is to be dissociated from visuo-spatial rehearsal. Visual mental imagery is a cognitive process that involves both long-term memory and working memory. Visual mental imagery is more than mere retention of information, as is the case with visuo-spatial rehearsal; it is an active construction that allows for the generation of new combinations and the discovery of new properties. These representations may include visual memories, knowledge about the world, or past experiences. Once reactivated from long-term memory, representations are maintained and manipulated within working memory, enabling mental inspection and transformation (for a review, see Ganis & Schendan, 2011). Conceptually, although visuo-spatial rehearsal and visual mental imagery may share certain mechanisms and types of memory, they are distinct in their functions and applications. Visuo-spatial rehearsal is a dynamic process that involves an attentional process or eye movements to maintain spatial information that has just been presented; visual mental imagery is linked to the creation of internal perceptual experiences and the manipulation of visual knowledge and episodic memories. Despite these differences, it can be envisioned that, in children of reading age and in adults, part of the teddy bear's movements could have activated the representation of shapes (e.g. letters., squares). Thus, visual mental imagery could have allowed the creation of internal perceptual experiences; the rest of the movements could have been maintained by visuo-spatial rehearsal. In a future study, it might be relevant to question to the participants at the end of each condition on the memorisation strategies they used.

The current study also sheds light on the nuanced role of environmental support. While Lilienthal (2018) demonstrated that High-span adults benefit more from environmental support, our findings indicate that it is the Low-span individuals who reap the most benefit, marking a departure from Lilienthal's results. This divergence may be attributed to the differences in task configurations between the studies. In the works of Lilienthal et al. (2014), Lilienthal (2018), and Souza et al. (2020), the grid of locations was randomly changed on each trial and consisted of 30 new locations, which necessitated a more fine-grained location discrimination than in the current study. Here, there were only 11 locations, which were fixed throughout the study, posing a substantially smaller challenge for rehearsal. This could explain the observed differences and why only the Low-span group benefited from support in our study. The High-span individuals could maintain the smaller set of locations in their working memory, and perhaps even in long-term memory, allowing them to rehearse the locations without difficulty. Also, this difference in the results' pattern could be due to another distinction in the nature of the tasks employed. Indeed, a simple span task was used in Lilienthal (2018) and the participants could recall the locations in any order. We implemented a complex span task with order recall. Simple span and complex span are two paradigms leading to measure the same processes involved in working memory (e.g. rehearsal, maintenance, updating); however, recall performance as well as the way verbal rehearsal is used differ (Unsworth & Engle, 2007). Simple span tasks are more conducive to rehearsal processes (e.g. Cowan, 2005; Engle et al., 1992), perhaps due to the absence of a concurrent task making its use easier. Thus, by transposing this to the visuo-spatial domain, a visual support would be more welcome in a complex span task to encourage and facilitate rehearsal, especially for individuals with lower working memory capacity.

Moreover, the study contributes to the ongoing discourse on cognitive control and goal maintenance. Young children are more prone to goal neglect, which can be detrimental to their executive control (Chevalier & Blaye, 2009). Forgetting the goal in a complex span task (i.e. forgetting that locations must be maintained) means that children may not try to actively maintain the locations by implementing some maintenance strategies. This is very similar to what some authors describe as a passive maintenance in young children (Camos & Barrouillet, 2011). In Experiment 1, the presence of the houses during the retention interval, instead of supporting visuo-spatial rehearsal, may be a reminder for the children that they must remember the locations (i.e. the goal of the task), being a cue for goal maintenance. Since attentional control plays a significant role in goal management, adults, with their superior attentional capacities, are less prone to goal neglect compared to children (Engle et al., 1999). However, Low-span adults have benefited from support. There is evidence that Low-span adults neglect the goal more than High-span adults (Duncan et al., 1996; Kane & Engle, 2003). Thus, in adults as well, the support may have played the role of an aid in maintaining the goal in addition to an aid in the implementation and use of a memorisation strategy. In a complementary manner, our recent study on children aged 4–8 years tested whether support could also serve as an aid in goal maintenance (Fitamen et al., submitted).

Finally, an alternative explanation for the beneficial effect of visual support on memory performance can be drawn from the work of Spivey and Geng (2001). They manipulated the presence of visual support during retrieval and found that participants increasingly looked at the to-be-retrieved item with more visual support. Their explanation is that the absent memory item is not only stored in memory but also externalised in space, with the rich spatial context aiding in the memory search. This suggests that visual support provides a spatial framework that helps organise and retrieve information. The spatial context acts as an external cue, guiding eye movements and attention, thereby reinforcing the mental representation of the memory task. This phenomenon can be seen as an embodiment of cognition, where constructing a mental image is almost "acted out" by eye movements, integrating internal memory with external spatial cues.

Limitations and perspectives

This study presents a few limitations. One of them is due to the difficulty in defining specific behavioural measures of the use of spatial rehearsal. We acknowledge that eye tracking could have provided a potential measure of the implementation of this strategy, as evidenced in Souza et al. (2020), who demonstrated that the grid facilitates accurate rehearsal of the correct locations, which was associated with the grid benefit. Various studies indicate that spatial rehearsal mechanisms can occur without the need for overt eye movements, as attention can be shifted to target locations implicitly (Awh et al., 1998; Baddeley, 1986; Godijn & Theeuwes, 2012; Posner, 1980). To test the hypothesis of covert attention shifts, a design contrasting conditions requiring more or less attentional resources during the inter-item interval, but without requiring concurrent spatial processing, could be relevant.

Turning now to the interpretation of the effects of visual support, a question can be raised as to whether the difference between the two conditions With – and Without-support, reflect a benefit on memory performance due to the visual support, or a detrimental effect due to the lack of support. Although, we privileged the first option, considering the performance in the condition Without-support as a baseline, it could be reasonably argued that the disappearance of the houses during the inter-item interval in the condition Without-support might induce a visual interference, hampering memory performance compared to the houses that would remain continuously present on the screen throughout the trial in the With-support condition. One might wonder whether we observed follow-up. The submitted study already mentioned can provide some insight on the relevance of this last hypothesis (Fitamen et al., submitted). In this study, we only presented one house during the inter-item interval, corresponding to the last location of the teddy bear, thus making five out of six houses disappear. Without revealing too much of the results, we can indicate that the recall performance of children aged 4–8 years in this new condition was closer to the condition With-support than to the condition Without-support (i.e. the difference between the scores doubled). Although not conclusive, this would go against any hypothesis of visual interference due to the disappearance of the houses.

Conclusion

In summary, our research highlights the multifaceted role of visual support in working memory performance. It not only facilitates the establishment of rehearsal strategies but also supports their execution. This dual function appears to benefit individuals across the lifespan, from preschoolers to young adults, particularly those with less efficient mnemonic strategies. These insights contribute to a nuanced understanding of cognitive development and highlight the potential for optimising learning and memory processes through environmental interventions. In educational areas, such visual supports could be easily integrated into classroom settings, providing a method to enhance memory performance. Thus, the support could serve as an environmental aid, as training working memory has shown minimal effect (see, Melby-Lervåg & Hulme, 2013, for a meta-analysis). Especially since the support was implicit in our study, no mention of its presence or absence was made to children or adults. This would be a low-cost procedure to implement in the classroom or in the living environment of adults with weaker working memory skills.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Our experimental material and anonymized data are available at https://osf.io/42769/?view_only=03dc504e776c490a890f64dc749889bd.

References

Allik, J. P., & Siegel, A. W. (1976). The use of the cumulative rehearsal strategy: A developmental study. *Journal of Experimental Child Psychology*, *21*(2), 316–327. https://doi.org/10.1016/0022-0965(76)90045-X

Asarnow, J. R., & Meichenbaum, D. (1979). Verbal rehearsal and serial recall: The mediational training of kindergarten children. *Child Development*, *50*(4), 1173–1177. https://doi.org/10.2307/1129345

Awh, E., Jonides, J., & Reuter-Lorenz, P. A. (1998). Rehearsal in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(3), 780–790. https://doi.org/10.1037/0096-1523.24.3.780

Baddeley, A. D. (1986). *Working memory*. Clarendon Press/ Oxford University Press.

Baddeley, A. D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, *63*(1), 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Bailey, H., Dunlosky, J., & Kane, M. J. (2008). Why does working memory span predict complex cognition? Testing the strategy affordance hypothesis. *Memory and Cognition*, *36*(8), 1383–1390. https://doi.org/10.3758/MC.36.8.1383

Barrouillet, P., Bernardin, S., Portrat, S., Vergauwe, E., & Camos, V. (2007). Time and cognitive load in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(3), 570–585. https://doi.org/10.1037/0278-7393.33.3.570

Barrouillet, P., Gavens, N., Vergauwe, E., Gaillard, V., & Camos, V. (2009). Working memory span development: A time-based resource-sharing model account. *Developmental Psychology*, *45*(2), 477–490. https://doi.org/10.1037/a0014615

Bayliss, D. M., Bogdanovs, J., & Jarrold, C. (2015). Consolidating working memory: Distinguishing the effects of consolidation, rehearsal and attentional refreshing in a working memory span task. *Journal of Memory and Language*, *81*, 34–50. https://doi.org/10.1016/j.jml.2014.12.004

Bertrand, R., & Camos, V. (2015). The role of attention in preschoolers' working memory. *Cognitive Development*, *33*, 14–27. https://doi.org/10.1016/j.cogdev.2014.10.002

Camos, V., & Barrouillet, P. (2011). Developmental change in working memory strategies: From passive maintenance to active refreshing. *Developmental Psychology*, *47*(3), 898–904. https://doi.org/10.1037/a0023193

Camos, V., & Barrouillet, P. (2018). *Working memory in development*. Routledge.

Carpenter, P. A., & Just, M. A. (2013). The role of working memory in language comprehension. In D. Klahr, & K. Kotovsky (Eds.), *Complex information processing* (pp. 51–88). Psychology Press.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology*, *33*(3), 386–404. https://doi.org/10.1016/0022-0965(82)90054-6

Chevalier, N., & Blaye, A. (2009). Setting goals to switch between tasks: Effect of cue transparency on children's cognitive flexibility. *Developmental Psychology*, *45*(3), 782–797. https://doi.org/10.1037/a0015409

Cowan, N. (2005). *Working memory capacity*. Psychology Press. https://doi.org/10.4324/9780203342398

Davidson, C., Shing, Y. L., McKay, C., Rafetseder, E., & Wijeakumar, S. (2023). The first year in formal schooling improves working memory and academic abilities. *Developmental Cognitive Neuroscience*, *60*, 101205. https://doi.org/10.1016/j.dcn.2023.101205

De Schrijver, S., & Barrouillet, P. (2017). Consolidation and restoration of memory traces in working memory. *Psychonomic Bulletin and Review*, *24*(5), 1651–1657. https://doi.org/10.3758/s13423-017-1226-7

Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in Psychology*, *5*, Article 781. https://doi.org/10.3389/fpsyg.2014.00781

Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: The organization of goal-directed behavior. *Cognitive Psychology*, *30*(3), 257–303. https://doi.org/10.1006/cogp.1996.0008

Dunlosky, J., & Kane, M. J. (2007). The contributions of strategy use to working memory span: A comparison of strategy assessment methods. *Quarterly Journal of Experimental Psychology*, *60*(9), 1227–1245. https://doi.org/10.1080/17470210600926075

Elliott, E. M., Morey, C. C., AuBuchon, A. M., Cowan, N., Jarrold, C., Adams, E. J., Attwood, M., Bayram, B., Beeler-Duden, S., Blakstvedt, T. Y., Büttner, G., Castelain, T., Cave, S., Crepaldi, D., Fredriksen, E., Glass, B. A., Graves, A. J., Guitard, D., Hoehl, S., … Voracek, M. (2021). Multilab direct replication of Flavell, Beach, and Chinsky (1966): Spontaneous verbal rehearsal in a memory task as a function of age. *Advances in Methods and Practices in Psychological Science*, *4*(2), 1–20. https://doi.org/10.1177/25152459211018187

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*(5), 972–992. https://doi.org/10.1037/0278-7393.18.5.972

Engle, R. W., Laughlin, J. E., Tuholski, S. W., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, *128*(3), 309–331. https://doi.org/10.1037/0096-3445.128.3.309

Fitamen, C., Blaye, A., Chevalier, N., & Camos, V. (submitted). New evidence for a visuo-spatial cumulative rehearsal strategy in children's working memory.

Flavell, J. H., Beach, D. H., & Chinsky, J. M. (1966). Sponteneous verbal rehersal in a memory task as a function of age. *Child Development*, *37*(2), 283–299. https://doi.org/10.2307/1126804

Friedman, N. P., & Miyake, A. (2004). The Reading span test and its predictive power for reading comprehension ability. *Journal of Memory and Language*, *51*(1), 136–158. https://doi.org/10.1016/j.jml.2004.03.008

Ganis, G., & Schendan, H. E. (2011). Visual imagery. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(3), 239–252. https://doi.org/10.1002/wcs.103

Gathercole, S. E., Lamont, E., & Alloway, T. P. (2006). Working memory in the classroom. *Working Memory and Education*, *21*(5), 219–240. https://doi.org/10.1016/B978-012554465-8/50010-7

Godijn, R., & Theeuwes, J. (2012). Overt is no better than covert when rehearsing visuo-spatial information in working memory. *Memory and Cognition*, *40*(1), 52–61. https://doi.org/10.3758/s13421-011-0132-x

Gonthier, C. (2021). Charting the diversity of strategic processes in visuospatial short-term memory. *Perspectives on Psychological Science*, *16*(2), 294–318. https://doi.org/10.1177/1745691620950697

Gruenenfelder, T. M., & Borkowski, J. G. (1975). Transfer of cumulative-rehearsal strategies in children's short-term memory. *Child Development*, *46*(4), 1019–1024. https://doi.org/10.2307/1128417

Hagen, J. W., Hargrave, S., & Ross, W. (1973). Prompting and rehearsal in short-term memory. *Child Development*, *44*(1), 201–204. https://doi.org/10.2307/1127704

Hale, S., Myerson, J., Rhee, S. H., Weiss, C. S., & Abrams, R. A. (1996). Selective interference with the maintenance of location information in working memory. *Neuropsychology*, *10*(2), 228–240. https://doi.org/10.1037/0894-4105.10.2.228

Henry, L. A., Messer, D., Luger-Klein, S., & Crane, L. (2012). Phonological, visual, and semantic coding strategies and children's short-term picture memory span. *The Quarterly Journal of Experimental Psychology*, *65*(10), 2033–2053. https://doi.org/10.1080/17470218.2012.672997

Hitch, G. J., & Halliday, M. S. (1983). Working memory in children. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *302*(1110), 325–340. http://www.jstor.org/stable/2395997

Hitch, G. J., Halliday, S., Schaafstal, A. M., & Schraagen, J. M. C. (1988). Visual working memory in young children. *Memory & Cognition*, *16*(2), 120–132. https://doi.org/10.3758/BF03213479

Ilkowska, M., & Engle, R. W. (2010). Trait and state differences in working memory capacity. In A. Gruszka, G. Matthews, & B. Szymura (Eds.), *Handbook of individual differences in cognition: Attention, memory, and executive control* (pp. 295–320). Springer. https://doi.org/10.1007/978-1-4419-1210-7_18

Jarrold, C., Tam, H., Baddeley, A. D., & Harvey, C. E. (2011). How does processing affect storage in working memory tasks? Evidence for both domain-general and domain-specific effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*(3), 688–705. https://doi.org/10.1037/a0022527

JASP, T. (2022). *JASP (Version 0.16.4) [Computer software]*. https://jasp-stats.org/.

Jeffreys, H. (1961). *Theory of Probability* (3rd ed.). Oxford, England: Clarendon Press.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*(1), 122–149. https://doi.org/10.1037/0033-295X.99.1.122

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to stroop interference. *Journal of Experimental Psychology: General*, *132*(1), 47–70. https://doi.org/10.1037/0096-3445.132.1.47

Lawrence, B. M., Myerson, J., Oonk, H. M., & Abrams, R. A. (2001). The effects of eye and limb movements on working memory. *Memory (Hove, England)*, *9*(4–6), 433–444. https://doi.org/10.1080/09658210143000047

Lilienthal, L. (2018). Individual differences in visuospatial working memory: Benefits from environmental support for rehearsal. *Journal of Cognitive Psychology*, *30*(8), 863–871. https://doi.org/10.1080/20445911.2018.1534855

Lilienthal, L., Hale, S., & Myerson, J. (2014). The effects of environmental support and secondary tasks on visuospatial working memory. *Memory and Cognition*, *42*(7), 1118–1129. https://doi.org/10.3758/s13421-014-0421-2

Lilienthal, L., Hale, S., & Myerson, J. (2016). Effects of age and environmental support for rehearsal on visuospatial working memory. *Psychology and Aging*, *31*(3), 249–254. https://doi.org/10.1037/pag0000077

MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, *24*(1), 56–98. https://doi.org/10.1016/0010-0285(92)90003-K

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, *49*(2), 270–291. https://doi.org/10.1037/a0028228

Miller, S., McCulloch, S., & Jarrold, C. (2015). The development of memory maintenance strategies: Training cumulative rehearsal and interactive imagery in children aged between 5 and 9. *Frontiers in Psychology*, *6*, Article 524. https://doi. org/10.3389/fpsyg.2015.00524

Morey, C. C., Hadley, L. V., Buttelmann, F., Könen, T., Meaney, J.-A., Auyeung, B., Karbach, J., & Chevalier, N. (2018a). The effects of verbal and spatial memory load on children's processing speed. *Annals of the New York Academy of Sciences*, *1424*(1), 161–174. https://doi.org/10.1111/nyas.13653

Morey, C. C., Mareva, S., Lelonkiewicz, J. R., & Chevalier, N. (2018b). Gaze-based rehearsal in children under 7: A developmental investigation of eye movements during a serial spatial memory task. *Developmental Science*, *21*(3), 1–8. https://doi.org/10.1111/desc.12559

Morra, S. (2015). How do subvocal rehearsal and general attentional resources contribute to verbal short-term memory span? *Frontiers in Psychology*, *6*, Article 145. https://doi.org/10.3389/fpsyg.2015.00145

Naveh-Benjamin, M., & Jonides, J. (1984). Maintenance rehearsal: A two-component analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*(3), 369–385. https://doi.org/10.1037/0278-7393.10.3.369

Oftinger, A.-L., & Camos, V. (2015). Maintenance mechanisms in children's verbal working memory. *Journal of Educational and Developmental Psychology*, *6*(1), 16–28. https://doi.org/10.5539/jedp.v6n1p16

Oftinger, A.-L., & Camos, V. (2017). Phonological similarity effect in children's working memory: Do maintenance mechanisms matter? *Journal of Child Psychology*, *1*(1), 5–11.

Oftinger, A.-L., & Camos, V. (2018). Developmental improvement in strategies to maintain verbal information in working memory. *International Journal of Behavioral Development*, *42*(2), 182–191. https://doi.org/10.1177/0165025416679741

Orsini, A., Grossi, D., Capitani, E., Laiacona, M., Papagno, C., & Vallar, G. (1987). Verbal and spatial immediate memory span: Normative data from 1355 adults and 1112 children. *The Italian Journal of Neurological Sciences*, *8*(6), 537–548. https://doi.org/10.1007/BF02333660

Parmentier, F. B. R., & Andrés, P. (2006). The impact of path crossing on visuo-spatial serial memory: Encoding or rehearsal effect? *Quarterly Journal of Experimental Psychology*, *59*(11), 1867–1874. https://doi.org/10.1080/17470210600872154

Pickering, S. J. (2001). The development of visuo-spatial working memory. *Memory (Hove, England)*, *9*(4–6), 423–432. https://doi.org/10.1080/09658210143000182

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Psychology Software Tools, Inc. [E-Prime 2.0]. (2012). https://www.pstnet.com.

Rogoff, B. (1981). Schooling's influence on memory test performance. *Child Development*, *52*(1), 260–267. https://doi.org/10.2307/1129239

Schneider, W., & Sodian, B. (1997). Memory strategy development: Lessons from longitudinal research. *Developmental Review*, *17*(4), 442–461. https://psycnet.apa.org/doi/10.1006drev.1997.0441.

Smyth, M. M., & Scholey, K. A. (1992). Determining spatial span: The role of movement time and articulation rate. *The Quarterly Journal of Experimental Psychology Section A*, *45*(3), 479–501. https://psycnet.apa.org/doi/10.108002724989208250624.

Souza, A. S., Czoschke, S., & Lange, E. B. (2020). Gaze-based and attention-based rehearsal in spatial working memory. *Journal of Experimental Psychology: Learning Memory and Cognition*, *46*(5), 980–1003. https://doi.org/10.1037/xlm0000771

Souza, A. S., & Oberauer, K. (2020). No evidence that articulatory rehearsal improves complex span performance. *Journal of Cognition*, *3*(1), 1–25. https://doi.org/10.5334/joc.103

Spivey, M., & Geng, J. (2001). Oculomotor mechanisms activated by imagery and memory: Eye movements to absent objects. *Psychological Research Psychologische Forschung*, *65*(4), 235–241. https://doi.org/10.1007/s004260100059

Swanson, H. L. (1999). What develops in working memory? A life span perspective. *Developmental Psychology*, *35*(4), 986–1000. https://doi.org/10.1037/0012-1649.35.4.986

Tam, H., Jarrold, C., Baddeley, A. D., & Sabatos-DeVito, M. (2010). The development of memory maintenance: Children's use of phonological rehearsal and attentional refreshment in working memory tasks. *Journal of Experimental Child Psychology*, *107*(3), 306–324. https://doi.org/10.1016/j.jecp.2010.05.006

Tremblay, S., Saint-Aubin, J., & Jalbert, A. (2006). Rehearsal in serial memory for visual-spatial information: Evidence from eye movements. *Psychonomic Bulletin and Review*, *13*(3), 452–457. https://doi.org/10.3758/BF03193869

Turley-Ames, K. J., & Whitfield, M. M. (2003). Strategy training and working memory task performance. *Journal of Memory and Language*, *49*(4), 446–468. https://doi.org/10.1016/S0749-596X(03)00095-0

Unsworth, N., & Engle, R. W. (2007). On the division of short-term and working memory: An examination of simple and complex span and their relation to higher order abilities. *Psychological Bulletin*, *133*(6), 1038–1066. https://doi.org/10.1037/0033-2909.133.6.1038

Vergauwe, E., Camos, V., & Barrouillet, P. (2014). The impact of storage on processing: How is information maintained in working memory? *Journal of Experimental Psychology: Learning Memory and Cognition*, *40*(4), 1072–1095. https://doi.org/10.1037/a0035779

Vygotsky, L. S. (2012). *Thought and language*. MIT press.

Analytical Appendices

We reported here the analysis of the concurrent position task for each experiment.

Experiment 1

Table A1. Descriptive analysis of the scores for the concurrent task, with mean and 95% credible interval for each Condition (Without – and With-support) across each Age group, in Experiment 1.

	M [95% CI] by Age					
Variable	3.5-yo	4-yo	4.5-yo	5-yo	5.5-yo	6-yo
Accuracy in %						
Without	76.4 [10.3]	96.5 [2.4]	96.7 [1.7]	98.3 [1.0]	98.5 [1.1]	98.4 [1.2]
With	74.4 [11.0]	95.6 [2.9]	97.9 [1.5]	97.5 [1.3]	97.7 [1.2]	97.0 [2.9]
Response times in ms						
Without	4594 [866]	4419 [698]	3270 [372]	3267 [366]	2854 [347]	2534 [295]
With	4843 [1088]	4452 [585]	3124 [270]	3274 [352]	2821 [308]	2368 [216]

A first Bayesian ANOVA was performed on the accuracy of position judgments to ensure that the accuracy did not vary between the conditions. Condition (Without-support vs. With-support) was entered as a within-participants factor, while Age groups, Condition Order, and lists of sequences were entered as between-participants factors. The first model included the main effects of Age groups, Condition Order, lists, and interactions between Age groups and Condition Order, and between Age groups and lists, $BF_{10} = 2.14 \times 10^{18} \pm 5.14\%$. The second-best model additionally included the interaction between Condition Order and the lists, $BF_{10} = 9.27 \times 10^{17} \pm 17.89\%$. The first two models only anecdotally differed from each other.

We then examined the $BF_{inclusion}$ for each factor in the models. Confirming the models, the $BF_{inclusion}$ for the Age effect was 5.94×10^{13}. The $BF_{exclusion}$ of 1.57 for Condition Order, and of 3.02 for List suggested that these factors should be excluded from the model. However, the $BF_{inclusion}$ for the Age x Order interaction was 27.59, and the $BF_{inclusion}$ of the Age x List interaction was 3.51×10^4. The $BF_{exclusion}$ for the other interactions ranged between 1.30 and 18.35. To summarise, position accuracy increased with age, with an already very high accuracy from 4 years of age (>96%), but did not vary between conditions.

A second Bayesian ANOVA was performed on response times to ensure that the mean test times did not vary between conditions. The same factors as in the previous ANOVA were entered in the analysis, which revealed that the best model included only a main effect of Age groups, $BF_{10} = 2.78 \times 10^8 \pm 1.77\%$. The second-best model had a 3.9 smaller probability to account for the data than the best model. Response time for the position assessment decisively decreased with age, but did not differ between conditions, $BF_{exclusion} = 7.99$.

Experiment 2

A first Bayesian ANOVA was performed on the accuracy of position judgments with Condition (Without-support vs. With-support) as within-participants factor and Condition Order as between-participants factors. The analysis revealed only the presence of an interaction effect between support Condition and Condition Order, $BF_{inclusion} = 7.32$. All other models indicated a $BF_{01} > 4.44$. Nevertheless, the accuracy of position judgments was all close to 100% of success what was the expected situation. When participants started with the condition Without-support, they had a mean accuracy of 98.84% (95% credible interval .34%) in this first condition and obtained an accuracy of 98.42% (95% credible interval .40%) in the second condition With-support. When participants started with the condition With-support, they had an accuracy of 98.77% (95% credible interval .33%) in this first condition and obtained an accuracy of 98.40% (95% credible interval .38%) in the second condition Without-support.

A second Bayesian ANOVA was performed on the response times of position judgments with the same factors as in the previous ANOVA. The analysis revealed no main effects and no interaction, all $BF_{01} > 1.46$. With a $BF_{exclusion} = 1.46$ for no effect of the order of presentation on the response times, $BF_{exclusion} = 2.09$ for no effect of the type of support condition on response times, and no interaction $BF_{exclusion} = 3.23$. Response time of position judgments did not differ between the experimental conditions where adults responded to the teddy bear orientation in 1853 ms (95% credible interval 168 ms) Without-support, and in 1762ms (95% credible interval 174 ms) With-support.

Complementary analysis – inter-individual differences

A first Bayesian ANOVA was performed on the accuracy of position judgments, with Condition (Without-support vs. With-support) entered as a within-participants factor, while Span-groups (Low-, Medium-, and High-span) and Condition Order were entered as between-participants factors. In the same way as the previous analysis which did not involve the Span-groups factor, the present analysis revealed only the presence of an interaction effect between support Condition and Condition Order, $BF_{inclusion} = 7.73$. All other models indicated a $BF_{01} > 4.17$. However, the Span-groups factor did not have an impact on accuracy ($BF_{exclusion} = 10.6$, M from 98.55% to 98.64%) and did not interact with other factors ($BFs_{01} > 5.03$).

A second Bayesian ANOVA was performed on the response times of position judgments with the same factors as in the previous ANOVA. The analysis revealed that there was only an anecdotal effect of interaction between the conditions and the span-groups, $BF_{inclusion} = 2.04$. All other models indicated a BF_{01} between 1.23 and 4.24. Paired Samples T-Tests were conducted on response times in each group to highlight the profile of the interaction. In the High-span group, decisive evidence for the alternative hypothesis showed that the response time was slower in the condition Without-support (M 2094ms, 95% credible interval 357 ms) than With-support (M 1812 ms, 95% credible interval 317 ms), $BF_{10} = 452 \pm 4.757 \times 10^{-5}\%$. No difference was present in the Medium-span group (Without-support M 1723ms, 95% credible interval 237 ms, With-support M 1652 ms, 95% credible interval 305 ms, $BF_{01} = 4.23 \pm .04\%$) and in the Low-span group (Without-support M 1728ms, 95% credible interval 266 ms, With-support M 1826 ms, 95% credible interval 308 ms, $BF_{01} = 4.49 \pm .05\%$).