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The role of goal cueing in kindergarteners' working memory

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ABSTRACT

Goal neglect has been shown to contribute to kindergarteners' poor executive control. Hence, presenting goal cues during a task improves children's performance in inhibition and switching tasks. The current study aimed at extending these findings to working memory (WM) by examining the extent to which kindergarteners' poor WM performance can result from neglecting the goal to recall memoranda at the end of the retention interval. This question was addressed by introducing goal cues, either visual (Experiments 1 and 2a) or auditory–verbal (Experiment 2b), during the retention interval in a Brown–Peterson task. Results showed no evidence of recall improvement for any cue. However, kindergarteners rehearsed more often in the presence of a visual goal cue, whereas recall was impaired with the presentation of an auditory–verbal goal cue. This suggests that introducing a goal cue in the retention interval of a WM task triggers the use of rehearsal in kindergarteners, albeit without any benefit in WM performance. This contrasts sharply with findings on other executive control tasks. Reasons why goal cues failed to improve kindergarteners' WM performance are discussed.

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Introduction

Working memory (WM) maintains and updates information while using it to complete a task (Baddeley & Hitch, 1974). As such, it is often considered as the hub of the human cognitive system (Haberlandt, 1997) and is strongly related to fluid intelligence (Unsworth, Fukuda, Awh, & Vogel, 2014). It is also a good predictor of academic achievement in children (see Gathercole, Lamont, & Alloway, 2006, for a review), and the age-related increase in WM capacity throughout childhood is considered as a major source of cognitive development (see Camos & Barrouillet, 2018, for a review; Swanson, 1996, 1999, 2017). However, despite the fact it has been largely studied in adults, many aspects of WM functioning remain obscure, especially the sources of its development during early childhood. It is well known that kindergarteners have particularly low WM performance, but among the multiple sources mentioned in the literature to account for their poorer recall such as the familiarity or knowledge of the material to memorize, the capacity to use some maintenance strategies, and the amount of available attentional resources (Camos & Barrouillet, 2018; Cowan, 2014; Cowan, Saults, & Elliott, 2002; Morra, Gobbo, Marini, & Sheese, 2008), it remains unclear what drives the age-related increase in WM capacity. Inspired by the research in executive control, the current study aimed at exploring one particular process, goal neglect, that was little examined in WM and that may be responsible for the low WM performance exhibited by kindergarteners.

The executive control literature has shown that kindergarteners have difficulty in maintaining the task goal sufficiently active (e.g., Chevalier & Blaye, 2008; Morton & Munakata, 2002) to guide task completion, a phenomenon identified as goal neglect (Duncan, Emslie, Williams, Johnson, & Freer, 1996). Goal neglect impairs their achievement in cognitive tasks. Although the role of goal maintenance has been evidenced in different executive control tasks, this was not examined in WM. However, it should particularly affect WM tasks because in the most used WM paradigms, complex span and Brown–Peterson tasks, the memorization of items is performed while doing a concurrent task. This provides a context especially prone to forgetting the primary goal of memorization because it can compete with the goal of the secondary task. Thus, as was observed in task-switching paradigms and inhibition tasks, providing goal cues should help kindergarteners to maintain the purpose of the WM task (i.e., memorizing items), leading to an improvement of their recall performance. Before describing the current study in more detail, we briefly present the development of WM mechanisms and the previous studies in executive control where the effect of goal cues was evidenced.

Development of WM maintenance

It is still unknown what are the determinants of the age-related changes observed in WM capacity. Among the variety of factors cited in the literature, those that are most often invoked are the increase in some cognitive resources, changes in long-term memory knowledge, and the use of maintenance strategies (see Camos & Barrouillet, 2018, for a review of the different factors of WM development). Since the emergence of the neo-Piagetian theories (Pascual-Leone, 1970), age-related increase in some mental resource was invoked for accounting for cognitive and WM development, a hypothesis that is commonly used in contemporary theories (e.g., Cowan, 2016; Morra, 2000, 2015). For example, Pascual-Leone (1970) suggested that cognitive development was sustained by an increase in the number of schemes that could be kept simultaneously active (called *M-space*). These schemes are used for both storage and processing of information. The growth of the M-space throughout childhood would result in the increasing ability to perform more and more complex tasks as well as to store and recall more memory items. Similarly, in Cowan's embedded processes model, the age-related increase in the size of the focus of attention would allow the maintenance of more and more memory items. Although of particular importance, the issue of a developmental increase in cognitive resources and its explanatory power in the age-related increase in WM capacity remains a rather unsolved question. It is indeed difficult to assess cognitive resources because of the vagueness of this concept (Halford, 2014; Navon, 1984) and, as a consequence, measures of recall performance are often used as a proxy to evaluate changes in cognitive resources, resulting in rather circular reasoning. Alternatively, it has also been suggested that the acquisition of new knowledge during childhood has an impact on how much can be maintained and processed in WM. For example, in Roodenrys, Hulme, and Brown (1993), young children did not show any difference in recalling lists of words and nonwords, whereas older children benefitted from knowing the words and had better recall performance for the word lists than for the nonword lists. However, contrary to this assumption, Cowan, Ricker, Clark, Hinrichs, and Glass (2015) reported a developmental increase in WM capacity even when the task relies on the recognition of unfamiliar stimuli, which excludes the role of increased long-term memory knowledge. Beyond a pure increase in resources or changes in knowledge, it has been assumed that strategies have a strong impact on the amount of information that can be maintained in the short term. Contrary to the two previously evoked factors of WM development, the age-related change in strategy use is often described as qualitative, with the appearance of new maintenance strategies being a source of development.

Whereas the memorization in WM is thought to be essentially visual during early childhood (Baker-Ward, Ornstein, & Holden, 1984), a verbal mechanism, named articulatory rehearsal, appears at 6 or 7 years of age (Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009; Gathercole & Adams, 1993; Hitch & Halliday, 1983; Oftinger & Camos, 2016). This qualitative change is evidenced by the significant correlation observed between speech rate and memory span from 7 years of age onward and not before this age (Gathercole & Adams, 1993). A similar qualitative change has been evoked for another WM maintenance mechanism. Mostly based on research in adults, it has been shown that attention can be used to reactivate memory items in WM (Barrouillet, Bernardin, & Camos, 2004; Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; Cowan, 1999; Johnson, 1992). This mechanism named attentional refreshing would be constrained by the availability of attention, and as a consequence any increase in attentional demand induced by a concurrent task would reduce recall performance. This is what was observed in adults as well as in children older than 7 years (e.g., Barrouillet & Camos, 2012). However, before age 7, varying the attentional demand of the concurrent activity does not affect children's recall. This latter finding has been interpreted as reflecting the lack of refreshing use in kindergarteners (Barrouillet et al., 2009; Camos & Barrouillet, 2011), reintroducing that (at least) part of the poor WM capacity in kindergarteners compared with older children results from a lack of use of maintenance strategies. Hence, an important source of WM development stands on the emergence of maintenance strategies. These strategies would appear at around 7 years of age, and this qualitative change would account for kindergarteners' poor recall performance.

Nevertheless, recent findings questioned this qualitative shift. First, it was proposed that children younger than 7 years are able to use rehearsal (Jarrold & Citroën, 2013; see also Jarrold & Tam, 2011; Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010). Second, whereas recall should be immune to any variations in concurrent attentional demand if kindergarteners did not use any attentional refreshing, this was not observed by Bertrand and Camos (2015). Instead of a deleterious effect, they observed that kindergarteners' recall performance was improved by the introduction of a moderately attention-demanding task, such as an easy walk, compared with the absence of a concurrent task during the retention interval. This finding was puzzling but questions the fact that kindergarteners are not able to use refreshing. Inspired by the literature on goal maintenance, Bertrand and Camos (2015) proposed that a contextual element (the toy shop used in their shopping span task) provided a goal cue that helped kindergarteners to maintain their goal of memorizing the encoded items during the retention interval. This in turn would have favored the activation of maintenance strategies and led to an improvement in recall performance.

To summarize, although no theory claims that a single source accounts for WM development, and despite some recent conflicting evidence, one of the main sources to account for WM development between kindergarteners and older children is the absence of use of some maintenance strategies in younger children. Within this theoretical perspective, the current study aimed at examining one possible reason for this lack of use of maintenance strategies in younger children. As observed in other executive control tasks, young children may neglect the goal, which impairs the triggering of maintenance strategies. Indeed, it can be suggested that when the goal of the WM task is cued during the retention delay, kindergarteners would be able to use maintenance strategies, which would boost their recall performance. Hence, more than a qualitative change in strategies use, differences in goal maintenance may account for the age-related difference in WM. Previous studies examined this issue in other executive control tasks.

Goal maintenance in executive control tasks

Executive control is defined as “the ability to regulate, coordinate, and guide one’s thoughts and behaviors toward goals” (Lucenet & Blaye, 2014; see also Hughes, 2011; Zelazo, Carter, Reznick, & Frye, 1997). Hence, to correctly accomplish a task requiring executive control, management of the goals is essential and requires an identification of the goals and their active maintenance throughout the task. A lot of research has focused on the development of executive control during childhood (see Diamond, 2013, and Zelazo & Carlson, 2012, for a review), but few studies have examined goal management (see Chevalier, 2015, for a review) and goal neglect in kindergarteners. A few studies have suggested that kindergarteners are particularly prone to goal neglect (Marcovitch, Boseovski, & Knapp, 2007; Marcovitch, Boseovski, Knapp, & Kane, 2010; Towse, Lewis, & Knowles, 2007). This is not unexpected considering that goal information is maintained in the prefrontal cortex (Miller & Cohen, 2001), a region in which neural connections specifically increase during childhood (Morton & Munakata, 2002; Munakata et al., 2011).

Besides predictable age differences in goal maintenance due to neurodevelopmental constraints, tasks themselves can differ in the extent to which their context effectively supports goal maintenance. For example, in the well-known Stroop task, the level of goal support can be manipulated by varying the proportion of congruent trials (e.g., the word BLUE written in blue ink). Whereas a high rate of incongruent trials (e.g., the word RED printed in blue ink) largely removed the burden of goal maintenance (name the ink color) because these trials can serve as goal reminders, a high rate of congruent ones favors goal neglect because following the goal requirements or producing the prepotent response (i.e., reading the word) leads to correct performance (Kane & Engle, 2003; see Ambrosi, Servant, Blaye, & Burle, 2019, for similar results with a Stroop task in children). In a task-switching setting, Marcovitch et al. (2007, 2010) obtained a similar pattern in kindergartners. They used a variant of the Dimensional Change Card Sorting task (Zelazo, 2006; Zelazo, Frye, & Rapus, 1996) requiring children to sort bidimensional pictures into two target boxes following successively either a shape-matching or color-matching rule. The proportion of redundant cards in the post-switch phase (cards that would be sorted in the same box whichever the rule) was manipulated. As expected, children’s performance was better in a condition including a high proportion of conflict cards matching each target card on only one dimension. In sum, when some characteristics of the task—here, conflict cards that require wondering about the current sorting rule to be able to sort correctly—provide recurrent opportunities to reactivate the goal, kindergarteners’ performance in cognitive control tasks is enhanced. Hence, introducing task cues should improve goal maintenance and, consequently, performance in cognitive control tasks. This was the same hypothesis Bertrand and Camos (2015) proposed to account for the improvement of kindergarteners’ recall performance.

In addition, the effectiveness of a goal cue to enhance goal maintenance depends on some of its characteristics. Cue transparency is known for having an impact on children’s performance in a task-switching paradigm that precisely relies on the ability to switch between two goals and use these goals to activate the relevant task set (Blaye & Chevalier, 2011; Chevalier & Blaye, 2008, 2009; Chevalier, 2015; Towse et al., 2007). In addition to cue transparency, the efficiency of goal cues may depend on their format of presentation. Chevalier and Blaye (2009) showed that auditory cues facilitated goal setting in children compared with visual cues. The stronger benefit for an auditory–verbal format could result from the lack of translation required to use the goal representation. Indeed, research in adults has suggested that task cues, critical in task-switching paradigms, are encoded and maintained in WM in a verbal format (Baddeley, Chincotta, & Adlam, 2001; Emerson & Miyake, 2003; Gruber & Goschke, 2004; Miyake, Emerson, Padilla, & Ahn, 2004). When used, a visual arbitrary cue requires transcoding into a verbal meaningful code, which captures attention that is no longer available for performing executive control (Miyake et al., 2004). Hence, presenting cues in verbal form would permit skipping a transcoding processing step, reducing the demand of goal maintenance. Translating cues into a goal and maintaining this relevant goal sufficiently active have been evidenced as a major aspect of switching development across childhood (Cepeda, Kramer, & Gonzalez de Sather, 2001; Kray, Eber, & Lindenberger, 2004; Lucenet, Blaye, Chevalier, & Kray, 2014).

To summarize, kindergarteners may have some difficulties in verbally representing and actively maintaining goals, which could result in poorer performance in executive control tasks. Either cues provided by some characteristics of the task or explicit cues help kindergarteners to improve their performance, with the nature of the cues determining how effective the cues will be. So far, this was examined in different executive control tasks requiring inhibition or switching but never in WM tasks. The aim of the current study was to explore whether goal cueing in WM tasks would provide the necessary support for maintaining the goal sufficiently active to improve kindergarteners' recall performance.

The current study

This study used a Brown–Peterson task that, like most WM span tasks, required the storage and processing of information. In our task, children needed to memorize series of verbal items while performing a concurrent task during the retention interval before recall. This concurrent task was color naming different smileys that were sequentially presented on-screen. The color-naming task aimed at impairing the maintenance of memory items because it distracts attention away from refreshing items (e.g., Camos & Barrouillet, 2011; Oftinger & Camos, 2018). It can also impair articulatory rehearsal because the aloud naming of colors hampers the articulatory processes involved in rehearsal.

In each experiment, two conditions were contrasted. In one condition, a goal cue was introduced during the concurrent task, and this condition was compared with a similar one in which the goal cue was discarded. It should be noted that the presentation of the goal cue occurred after the presentation of the to-be-remembered items as a reminder of the goal of the primary task (memory) while performing the distracting task. Through three experiments, the nature of the goal cue was varied. Following Chevalier and Blaye (2009), all cues presented in this study were transparent to explicitly trigger the goal of the WM task, that is, to memorize information or "keep things in the head" in children's words. As summarized above, transparent cues are the most effective ones, and if the poor performance in kindergarteners' WM results, even in part, from goal neglect, then transparent cues should be the most adequate way to boost their performance. Moreover, the perceptual modality of cues was varied across experiments, with cues being visual in Experiments 1 and 2a and verbal–auditory in Experiment 2b. Without precluding the results of our experiments, verbal cues should have a stronger effect than visual cues because they are directly in the format where goals are maintained and do not need any transcoding. Finally, kindergarteners were tested in each experiment, and an additional group of older children was enrolled in Experiment 1 to assess age-related differences. Indeed, if the age-related differences in WM regularly reported between kindergarteners and older children rely on a deficit in goal maintenance in the former, then cues should benefit the former and should not help the older children or should help them less.

Experiment 1

The first experiment involved two groups of children: kindergarteners and primary school pupils. If the lack of maintenance strategies in kindergarteners results from goal neglect, then presenting a visual goal cue during the task should facilitate goal maintenance and lead to improved recall performance. On the contrary, recall in older children should be less affected, or not affected, by the presentation of a goal cue because children of this age spontaneously use maintenance strategies to keep memory items active in WM.

Method

Participants

In total, 26 5- to 7-year-old kindergarteners[1] (M_{age} = 6.4 years, *SD* = 0.5, range = 5.3–7.3; 16 girls) and 26 8- to 10-year-old primary school children (M_{age} = 9.1 years, *SD* = 0.5, range = 8.3–9.9; 10 girls) participated in this experiment. In all experiments of this study, all children were native French speakers and

[1] In our educational system, children should have reached 5 years of age to enter kindergarten, and they attend 2 years of kindergarten in mixed-age classes.

we checked that none was colorblind. Most children were Caucasian and from middle- to high- socioeconomic status backgrounds, although individual demographic information was not collected. Testing took place at the children's school in a quiet area. All experiments were approved by local ethics committees. Informed consents were systematically obtained from children's caregivers, and children also gave verbal assent to participate.

Material and procedure

Children performed a Brown–Peterson task in which they needed to memorize the names of animals and objects presented as colored drawings. These memory items were selected from Snodgrass and Vanderwart (1980) database (with their coloured versions from Rossion and Pourtois, 2004) to exceed 80% of correct denomination at 4 years (Cannard et al., 2006). Each item was presented for 1500 ms and was followed by a 200-ms blank screen. Because kindergarteners are slower than older children at naming pictures, a preregistered male voice named the animal or object to minimize age-related differences in the encoding phase (Fig. 1). After the presentation of the memory items, children needed to name the color of two smileys successively presented for 1200 ms each. The aim of this concurrent task was to distract attention away from maintenance activities. The color-naming task has proved to be sufficiently attention demanding to distract attention in children (e.g., Camos & Barrouillet, 2011; Oftinger & Camos, 2018). The smileys' colors were randomly chosen among three colors: blue, green, and red. The drawings in the encoding phase and the smileys of the concurrent task were presented in an invisible 10 × 10-cm square in the center of the screen. After the 5400-ms retention interval, a serial oral recall was requested.

All children were engaged in two experimental conditions: one without a goal cue (no-cue condition) and another with a meaningful visual goal cue (cue condition) presented during the retention interval. The presentation order of the conditions was counterbalanced across participants. Children performed 15 trials in each condition, with three series per length that included one to five memory items. Memory items were randomly distributed across trials with the constraints of a single occurrence per condition.

The meaningful visual goal cue represented an asexual character pointing a finger to her head in a thinking attitude (Fig. 1). The link between this cue and the goal was explicitly created in the instructions phase, with children being told the meaning of the cue: "When you see this [experimenter points to the cue], it means that you must carefully keep in mind the drawings you have seen." No instruction

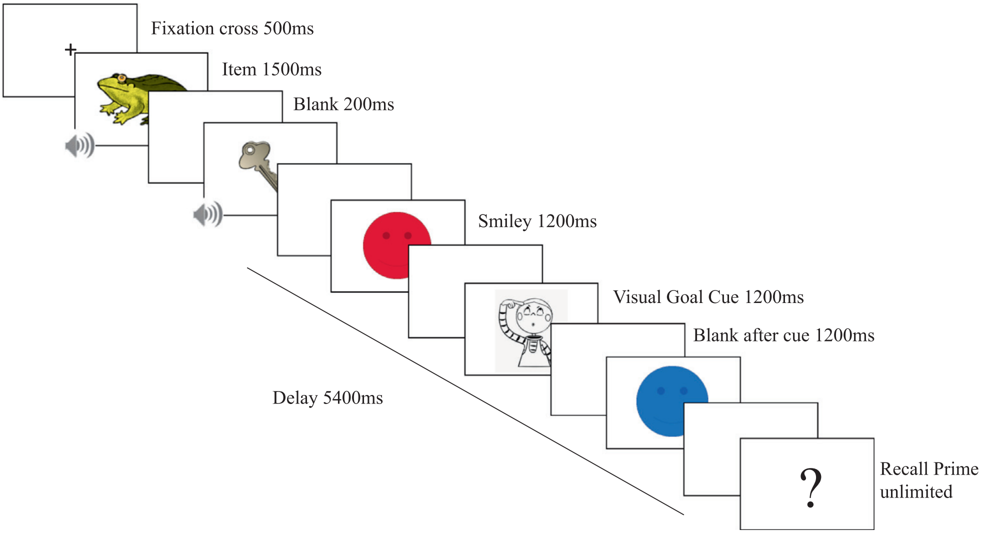

Fig. 1. Schematic illustration of the cue condition in Experiment 1. The no-cue condition was similar except that a blank screen replaced the visual goal cue.

about the use of maintenance strategies was given. The cue was presented for 1200 ms between two smileys, followed by a 1200-ms blank screen. In the no-cue condition, a 2400-ms blank screen between smileys replaced the cue presentation. At the end of the experiment, children were asked three questions to determine whether the goal of the task, the goal cue, and the recall prime (a question mark) were understood: "What was the game? What has to be done?" for the goal, "What were you supposed to do when you saw the character?" for the cue, and "What were you supposed to do when you saw the question mark?" for the recall prime. Both conditions were presented within the same 30-min session, during which each child was individually tested by one of the three different experimenters (two women and one man). Two experimenters were blind to the aim of the experiment. The experience was presented on laptop computers and was built with E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA, USA).

In the training phase, the requirement of ordered recall was explained to each child with a two-item series. Moreover, to keep track of order during recall, a piece of paper with the same number of cells and list length was presented, and children needed to point to each cell, from left to right, when they recalled the item corresponding to the position. Children were also trained to name the smileys by asking children to name, within 1 min, the maximum number of colored smileys presented on a sheet. Finally, children performed one series of one to three items as examples.

Statistical analysis

A span score was calculated for each child in each condition. Each correctly recalled series (i.e., in which all the words were correctly recalled in the order of presentation) counted as one third, and the total number of thirds was added (Barrouillet et al., 2009; Bertrand & Camos, 2015; Smyth & Scholey, 1992).

Data were submitted to Bayesian analysis of variance (ANOVA) with default prior setting using JASP software (Version 0.8.2.0). In Bayesian hypothesis testing, the strength of evidence in favor of or against an effect is quantified by comparing a model including the effect (H1) with a model omitting it (H0). The relative likelihood of the two models under comparison is the Bayes factor (BF). BF indicates the factor by which the prior odds ratio for the two models should be multiplied to obtain the posterior odds ratio. The odds ratio represents our degree of belief that the data were generated from one model (e.g., H1) relative to the other (H0). For instance, if we think that both models are equally probable before seeing the data (i.e., our prior odds ratio is 1) and BF in favor of H1 is 10, then the posterior odds ratio is 10, which means that observed data are 10 times more likely to have occurred under H1 than under H0. The BF can be used as a continuous index of the strength of evidence for one model relative to another. The BF can express the evidence in favor of H1 over H0 (BF_{10}) or the evidence of H0 over H1 (BF_{01}). Thus, by comparing the BF for the best model with the BF for the second best model (and for the third best model if necessary), we can estimate which model is more likely to explain the data. In the case of a *t* test, the unique BF was compared with the null model. BFs below 3 are usually regarded as weak evidence, those between 3 and 10 are usually regarded as substantial evidence, and those between 10 and 100 are usually regarded as strong evidence.

Results

Children paid enough attention to the concurrent task, for which they reached a very high level of accuracy: 96% (*SD* = 5) in 5- to 7-year-olds and 99% (*SD* = 2) in 8- to 10-year-olds. A Bayesian ANOVA revealed that cueing (no-cue vs. cue conditions) had no impact on the color-naming performance ($BF_{10} = 0.41 \pm 1.7\%$) and did not interact with age group ($BF_{10} = 0.32 \pm 2.1\%$). Based on their answers to the three post hoc questions, 5 5- to 7-year-olds and two 8- to 10-year-olds were excluded from the analysis of recall performance because they failed to correctly answer either the goal or the cue question, whereas all children correctly answered the prime question.

A Bayesian ANOVA was computed on span scores with age group, condition order, and experimenter as between-participants factors and cueing as a within-participants factor. Condition order and experimenter were excluded from the following analysis because they had no main effect ($BF_{10} = 0.47 \pm 0.7\%$ and $BF_{10} = 0.61 \pm 0.7\%$, respectively) and were not involved in any interaction ($BFs_{10} < 1$). Results revealed that the favored model included the age group effect only (Fig. 2)

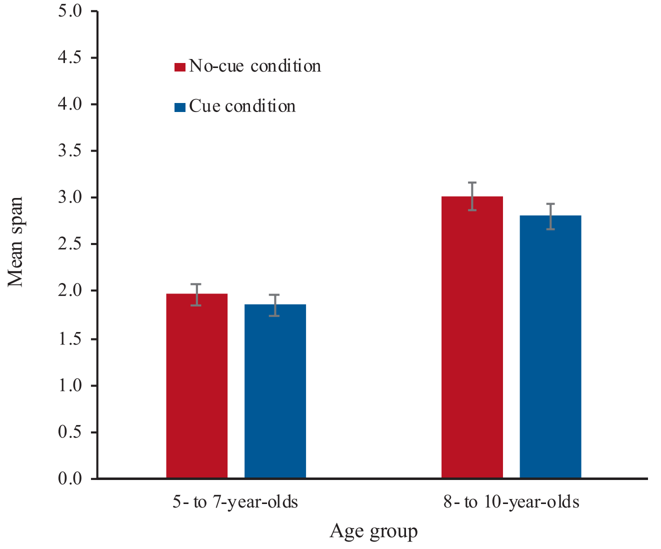

Fig. 2. Mean span according to age group and cueing in Experiment 1. Vertical lines represent standard errors.

(BF_{10} = 5958.37 ± 0.24%), cueing having no effect on span (BF_{10} = 0.77 ± 1.5%), and no interaction with age group (BF_{10} = 0.36 ± 1.9%). The preferred model was 4.3 times more likely than the model including both main effects of age and cueing with their interaction but was only 1.3 times more likely than the model including the two main effects without their interaction. The same analysis on the entire sample led to a similar pattern of results.

Discussion

Contrary to our hypothesis, the presentation of a visual goal cue did not improve WM recall performance. Whereas such an absence was expected in older children, the lack of interaction between age and cueing revealed that a visual goal cue was not helpful for kindergarteners. Yet, this absence of cueing effect on WM in 5- to 7-year-olds does not necessarily mean that any goal cueing would have no effect on WM performance. Indeed, the duration and format of the cue used in Experiment 1 might not have sufficiently scaffolded goal representation and maintenance to affect kindergarteners' WM performance. Hence, Experiments 2a and 2b examined the benefit induced by a longer display of the visual goal cue and by a verbal–auditory presentation of the goal cue, respectively.

Experiment 2a

Longer display of the visual goal cue should enhance WM performance because it increases the available duration to implement potential maintenance strategies before the onset of the next distracting stimulus. In other words, having more time would allow children to use maintenance strategies such as refreshing (Camos & Barrouillet, 2011). Indicators of strategy use were also collected because it has been shown in other domains (see Siegler, 1996, for a review) that the implementation of a new strategy might not be directly translated into improved performance. One group of kindergartners was tested to focus on the age group supposedly most prone to goal neglect and for which we failed to observe the expected benefit of goal cue.

Method

Participants

A total of 26 6- to 8-year-old children (M_{age} = 6.8 years, *SD* = 0.6, range = 6.0–7.9; 9 girls) participated in this experiment. None of them participated in Experiment 1.

Material and procedure

The design of this second experiment was similar to that of Experiment 1 with two exceptions. First, the duration of cue presentation was increased to 5400 ms (Fig. 3). Second, the experimenters collected evidence of overt and covert repetitions as an indicator of verbal rehearsal each time it was observed during the cue display. Lip movements, which are known to be a marker of verbal rehearsal (Cowan, 2012; Flavell, Beach, & Chinsky, 1966), were used as an index of covert repetitions. We avoided questioning children about their maintenance strategies for two reasons. Younger children may have more difficulties in expressing what they were doing, which could lead to an overestimation of the use of rehearsal in older children. Moreover, asking a question on rehearsal can stimulate children to use it. A percentage of trials in which signs of rehearsal, either overt or covert, were observed has been calculated, where a score of 100% represents an observation of at least one manifestation of rehearsal (overt or covert) during the cue presentation of all trials. Thus, for example, a score of 50% represents that a manifestation of rehearsal was observed in half of the trials of an experimental condition.

Results

Whereas the mean accuracy for the group was high (91%, *SD* = 10), 1 child was excluded from the following analyses because her performance on the concurrent task (58%) was more than 2 standard deviations below the group mean (i.e., <70%). A Bayesian paired-samples *t* test showed that cueing had no impact on the accuracy in the color-naming task (BF_{10} = 0.33 ± 0.04%). A Bayesian ANOVA indicated no significant difference in the accuracy of the concurrent task between Experiments 1 and 2a in kindergarteners (BF_{10} = 1.07 ± 1.2%) and no interaction between cueing and experiments

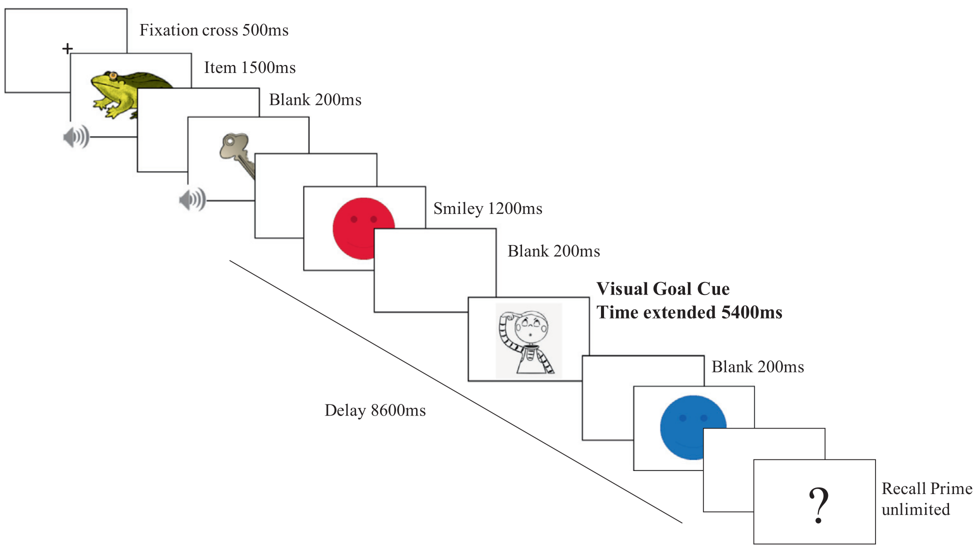

Fig. 3. Schematic illustration of the cue condition in Experiment 2a. The no-cue condition was similar except that a blank screen replaced the visual goal cue.

(BF_{10} = 0.34 ± 1.8%). Although all children succeeded at responding to the goal and prime questions, 2 children were excluded from further analysis based on their failure to answer the post hoc cue question.

A Bayesian ANOVA was performed on span scores with cueing as a within-participants factor and condition order and experimenter as between-participants factors. Condition order and experimenter were excluded from the following analysis because they had no main effect (BF_{10} = 0.48 ± 1.3% and BF_{10} = 0.49 ± 1.5%, respectively) and were not involved in any interaction (BF_{10} = 0.75 ± 2.5% for Cueing × Condition Order, BF_{10} = 0.97 ± 2.3% for Cueing × Experimenter, and BF_{10} = 0.39 ± 2.4% for Cueing × Condition Order × xperimenter). A Bayesian paired-samples *t* test did not show any effect of cueing on span measures (*M* = 2.40, *SD* = 0.63 for the no-cue condition, *M* = 2.49, *SD* = 0.70 for the cue condition; BF_{10} = 0.26 ± 0.04%).

Although goal cueing did not affect WM recall, we examined its influence on the use of a rehearsal strategy by analyzing the percentage of trials in which signs of rehearsal were observed. As for recall performance, we did not observe any main effect of condition order or experimenter (BF_{10} = 0.51 ± 0.6% or BF_{10} = 0.44 ± 0.5%, respectively) or any interaction effects on rehearsal occurrences (BF_{10} = 0.69 ± 2.6% for Cueing × Condition Order, BF_{10} = 0.31 ± 2.2% for Cueing × Experimenter, and BF_{10} = 0.38 ± 2.6% for Cueing × Condition Order × Experimenter). A Bayesian paired-samples *t* test indicated a cueing effect on the percentage of rehearsal occurrences (BF_{10} = 2.14 ± 0.001%). Although the evidence was only anecdotal, children rehearsed more often in the cue condition (*M* = 29.27%, *SD* = 27.69) than in the no-cue condition (*M* = 17.39%, *SD* = 27.02). Moreover, we gathered strong evidence for a correlation in the percentage of rehearsal between the two conditions (cue vs. non-cue) (*r* = .61, BF_{10} = 23.90). The same analyses on all children with accuracy over threshold (70%) on the concurrent task led to a similar pattern of results for both WM recall performance and the percentage of rehearsal occurrences.

Discussion

Extending the findings of Experiment 1, Experiment 2a showed that a longer visual goal cue does not translate into improved WM recall performance. However, it affects the frequency of use of rehearsal, albeit without improvement in recall. Consistently with what is observed in other domains, this suggests that this maintenance strategy may be rather new in the kindergarteners' repertoire and does not lead to enhanced performance yet (Siegler, 1996). This point is further discussed in the General Discussion.

In Experiments 1 and 2a, the visual format of goal cue required a verbal translation to be directly useful to actively maintain the task goal (Baddeley et al., 2001; Emerson & Miyake, 2003; Miyake et al., 2004). Thus, Experiment 2b tested whether making this translation unnecessary by presenting a verbal goal cue would affect WM recall performance in kindergarteners.

Experiment 2b

Although auditory–verbal cues have been shown to be the most efficient cues to remind the goal in cognitive control tasks (e.g., Chevalier & Blaye, 2009), transposing this cueing technique from the task-switching paradigm to a WM task led to two opposite predictions. First, if goal maintenance had a similar role in a WM task as in the task-switching paradigm, then a verbal–auditory cue should be particularly efficient and may lead to improved WM recall performance because no cue transcoding is required. However, if kindergarteners are using articulatory rehearsal to maintain memory items when prompted by a goal cue (as suggested by Experiment 2a) during the retention delay, then their performance should suffer from verbal interferences induced by the auditory–verbal goal cue. Nevertheless, if kindergarteners do not use articulatory rehearsal, as is often reported in the WM literature, then they should not suffer from this detrimental effect.

Method

Participants

A total of 34 5- to 7-year-old children (M_{age} = 6.3 years, *SD* = 0.9, range = 5.0–7.4; 14 girls) participated in Experiment 2b. None of them participated in Experiment 1 or 2a.

Material and procedure

The procedure of Experiment 2b was similar to that of Experiment 1 except for two changes in the design. The goal cue and the recall prime were both verbal and auditory played. The visual goal cue of Experiment 1 was replaced by a white screen during which an auditory cue was uttered by a prerecorded male voice: "Remember the image(s)." For the recall prime, the question mark was replaced by the following auditory message: "What was/were the image(s)?" In the no-cue condition, the goal cue was not played but the auditory recall prime remained. All the timing parameters were the same as in Experiment 1.

Results

One child was excluded from the following analyses because her performance on the concurrent task was less than 70% of success (i.e., 65%), whereas the mean accuracy for the group was high (90%, *SD* = 9). A Bayesian paired-samples *t* test showed that cueing affected the accuracy in the color-naming task (BF_{10} = 13.56, ± 4.5 $\times 10^{-7}$%). Despite very good performance in both conditions, children had poorer accuracy in the cue condition (87%, *SD* = 12) than in the no-cue condition (94%, *SD* = 10). Based on their answers, 3 children were excluded from further analyses because they failed to answer the post hoc goal question.

A Bayesian ANOVA was performed on span score with cueing as a within-participants factor and condition order and experimenter as between-participants factors. As in Experiments 1 and 2a, condition order and experimenter were excluded from the final analysis because these factors did not have a main effect (BF_{10} = 0.45 ± 0.6% and BF_{10} = 1.06 ± 1.3%, respectively) and were not involved in any interaction (BF_{10} = 0.36 ± 1.8% for Cueing $\times$ Condition Order, BF_{10} = 0.45 ± 2.6% for Cueing $\times$ Experimenter, and BF_{10} = 0.71 ± 2.8% for Cueing $\times$ Condition Order $\times$ Experimenter). A Bayesian paired-samples *t* test revealed an effect of cueing (BF_{10} = 6.64 ± 2.48 $\times 10^{-6}$%), with lower recall span score in the cue condition (*M* = 1.70, *SD* = 0.65) than in the no-cue condition (*M* = 2.02, *SD* = 0.71). A similar pattern was obtained when considering all children with accuracy over threshold (70%) on the concurrent task.

Discussion

The detrimental main effect of cueing was observed on memory span scores and on color-naming performance. Although we did not predict this reduction of performance in color naming, it informed us on the possible nature of the cueing effect. Indeed, the addition of an auditory message harmed the naming task, which is an inherently verbal task. The fact that a similar detrimental effect is observed in recall performance, thus, is suggestive that both color naming and WM maintenance have some commonalities that would be their common reliance on some verbal processes. Hence, the fact that an auditory–verbal cue impaired recall performance would indicate the use of a verbal maintenance strategy (probably articulatory rehearsal) during the retention delay.

General discussion

The aim of this study was to test whether goal maintenance plays a role in the development of WM. Indeed, the literature on the sources of WM development suggests that one of the factors underlying the age-related changes in WM capacity between kindergarteners and primary school children is the implementation of maintenance strategies. Children younger than 7 years would not use maintenance strategies, or would have difficulty in using them, resulting in poorer recall performance compared with older children. Nevertheless, some recent studies reported that younger children may have the ability to use such maintenance strategies (Bertrand & Camos, 2015; Jarrold & Citroën, 2013; Jarrold & Tam, 2011; Tam et al., 2010). Hence, we proposed that goal neglect, which is forgetting the goal to maintain memory items in WM tasks, could be the reason why younger children have difficulty in maintaining information. Our methodology was inspired by the executive control literature, in which transparent goal cue has been used to prevent goal neglect, and resulted in improved performance in kindergarteners. In a Brown–Peterson task, we then varied both the format of the goal cue and its presentation time. The results were divergent compared what is reported in the domain of executive control. Neither visual nor auditory–verbal transparent goal cues resulted in any recall improvement in kindergarteners, in clear contrast to the improvement observed in task-switching and inhibition performance (see Chevalier, 2015, for a review). Hence, and contrary to our prediction, goal neglect does not seem to be at the root of the difficulty experienced by kindergarteners in implementing WM maintenance strategies.

The current findings that a goal cue, even one designed to scaffold the maintenance of the memory task goal (i.e., recalling the pictures), does not benefit kindergarteners' WM stands in clear contrast to previous demonstrations of the positive impact of goal cues on executive control performance in young children despite the similarities in terms of the paradigms used. Task switching is the context most often used to reveal the critical role of goal maintenance in executive control and, more specifically, the beneficial effect of transparent goal cues. Such a paradigm presents participants with bidimensional stimuli that can be processed equally based on one dimension or the other, depending on the current task at hand. Because the sequence of tasks is unpredictable, participants need to rely on goal cues to decide which task to perform. In the current study, we used a Brown–Peterson paradigm that distinguishes the encoding phase from the retention delay, during which a concurrent task is performed, and the recall phase. Effective maintenance of the memoranda during the retention delay has been shown to depend on maintenance strategies that involve rapid and self-initiated switches between the secondary task and maintenance strategies (Barrouillet et al., 2004). Hence, goal cues should have been effective in the task switching required by this WM paradigm.

However, a critical difference appears between task switching involved in the executive control tasks and task switching necessary in the Brown–Peterson paradigm. Whereas cues are needed to know how to process the same given set of stimuli in the former tasks, they are not in the latter paradigm. For example, in the Brown–Peterson task used in the current study, a subset of stimuli, the colored smileys, always required color naming and the question mark always primed verbal recall. No further indications after the instructions were needed to decide how to process the smileys or the question mark. In addition, to benefit from a goal cue that reactivates the core memory goal in this WM task, executive control needs to be engaged proactively because the cue is displayed far in advance from the stimulus that explicitly requests a response (i.e., the question mark presentation). Following Braver (2001, 2012), who offered the distinction between proactive control and reactive control, several developmental studies suggest that kindergarteners tend to engage control reactively (e.g., Blackwell & Munakata, 2014; Chatham, Frank, & Munakata, 2009; Gonthier, Zira, Colé, & Blaye, 2019; Lucenet & Blaye, 2014). Whereas proactive control supposes keeping in mind contextual information (which includes the goal), reactive control implies retrieving this contextual information "just in time" when presented with the stimulus requiring a response. The fact that the presence of a goal cue in our WM task did not allow kindergarteners to prepare themselves for the future recall is in line with the developmental studies concluding at kindergarteners' difficulty in engaging proactive control (Chevalier & Blaye, 2016; Chevalier, Dauvier, & Blaye, 2018). Hence, the lack of benefit induced by our goal cues can be due to kindergarteners' reactive processing. This highlights that an important aspect of the WM tasks is the prospective nature of the memory goal, something that is not considered in the WM literature. Findings in studies on prospective memory support such an interpretation.

Indeed, WM tasks have several commonalities with prospective memory tasks, more specifically with event-based prospective memory tasks (Einstein & McDaniel, 1990). As in an event-based prospective memory task, children in a WM task have a delayed goal that is primed by a specific event, here the recall prime (the question mark), and during the delay they need to perform an ongoing distracting task, here naming the smileys. By definition, prospective memory tasks require proactive control. When testing the benefit of cues in prospective memory tasks, Guajardo and Best (2000) showed that neither incentive nor external cues improved performance in kindergarteners, contrary to the beneficial effect that such cues have in adults. Hence, the current findings extend this absence of cue effect to WM tasks, thereby reinforcing the idea that WM and prospective memory tasks share common processes. Thus, reactive kindergarteners might not take advantage of the goal cue presentation during the concurrent task due to the absence of a direct link with the current concurrent task. It may be helpful to present a goal cue that can be used by reactive children, for example, a cue that would prompt the representation of the upcoming question mark. This type of cueing in the form of cue–action reminders proved to be effective at helping kindergarteners in a prospective memory task (Kliegel & Jäger, 2007).

Finally, despite the fact that kindergarteners used an articulatory rehearsal strategy more often when a visual goal cue was presented during the concurrent task than when no goal cue was used (Experiment 2a), this increase had no effect on recall performance. Further support of the use of this rehearsal strategy in the cue condition was obtained in Experiment 2b where the introduction of an auditory–verbal goal cue impaired kindergarteners' recall performance. The detrimental effect of the presence of a goal cue on recall performance suggests that the auditory–verbal cue used in Experiment 2b induced some interference with the maintenance of the memory items through a verbal-specific mechanism, probably articulatory rehearsal. However, manifestation of articulatory rehearsal is rarely reported in children under 7 years of age (Flavell et al., 1966; Gathercole & Adams, 1994; Gathercole, Adams, & Hitch, 1994; Jarrold, Hewes, & Baddeley, 2000; Oftinger & Camos, 2016, 2017, 2018). The observation of a detrimental effect of the auditory–verbal cue presentation in kindergarteners is in favor of an early use of rehearsal strategy, and the potential benefit of the goal cue may have been counteracted by this detrimental effect. However, as suggested by the findings in Experiment 2a, children are not able to use it effectively to maintain the information in WM given that recall performance did not improve in the cue condition. This absence of performance improvement could be a signature of a newly acquired strategy as proposed by Siegler (1996). In different domains of cognitive development, Siegler has shown that when advanced strategies emerge in their repertoire, children first exhibit longer response times with more errors. In other words, the first implementation of a new strategy has little chance to be directly translated into better performance. We proposed that goal cues triggered the use of rehearsal, but because this is a newly acquired strategy in kindergarteners, it cannot lead to improved performance. This is also congruent with another theoretical account in which kindergarteners' ability to use repetition as a maintenance strategy is dependent on the level of brain maturation and, thus, the amount of attentional resources available at a given time. Within Pascual-Leone's theory of constructive operators (TCO) framework, Morra (2000) posited that activating rehearsal would demand some attentional resources (or part of the M-space in TCO terms). Younger children who have reduced M-space would not have enough attentional capacity to successfully use a rehearsal strategy even though they can occasionally try to do so. To summarize, and as previously reported for long-term memory (e.g., Miller & Seier, 1994), kindergarteners' poor performance in WM would, at least in part, result from a maintenance strategy use deficiency.

It is worth mentioning some limitations of the current study. The current hypothesis of a benefit of goal cueing in a Brown–Peterson task was framed within an executive control framework. We probably underestimate important differences between task-switching and Brown–Peterson paradigms. To benefit from goal cueing, children must engage in advance of the stimulus to respond to, a strategy that, at the very least, they have not automatized and is attentionally costly. Research in cognitive development has emphasized both the protracted development of attentional capacities and the preference for reactive control in young children. Moreover, the role of goal cues should also be examined in other WM tasks such as complex span tasks. One can argue that the beneficial effect of goal cues should be stronger in these tasks because they require the alternation of encoding memory items and processing distractors. The constant switch between maintenance and processing could constitute a particularly difficult challenge for goal maintenance.

Conclusion

This study suggests that goal neglect does not cause the absence of (or difficulty in) setting up WM maintenance strategies in kindergarteners. Our results suggest, on the contrary, that other factors should be considered to understand the poor performance usually observed in kindergarteners' WM. The reactive style of kindergarteners and strategy use deficiency can jointly explain what we observed in this series of three experiments. Finally, modifying the environment to scaffold the implementation of maintenance strategies would be a promising avenue for reducing the attentional demand and reveal benefits for WM performance in kindergarteners.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2019.104666.

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