RESEARCH ARTICLE

# Phonological similarity effect in children's working memory: Do maintenance mechanisms matter?

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Oftinger A, Camos V. Phonological similarity effect in children's working memory: Do maintenance mechanisms matter? J Child Psychol November 2017;1(1):5-11.

Previous studies using working memory (WM) span tasks have shown that phonologically similar words were less recalled than dissimilar words in adults. This phonological similarity effect (PSE) is known to affect their maintenance of verbal information. More precisely, PSE is considering as an indicator of the use of articulatory rehearsal. The small or absent PSE in young children has often been taken as evidence for the view that young children do not rehearse to maintain verbal information. The aim of the present study was to explore phonological effect in 6- to 8-year-old children and to investigate the impact of a concurrent articulation. We also chose to control for attentional refreshing, because this mechanism allows the maintenance of verbal information in WM. In two complex span tasks, children had to maintain lists of rhyming, similar or dissimilar words. The opportunity for refreshing was manipulated by varying the attentional demand of the concurrent task. Children had performed the concurrent task silently or aloud to impede the articulatory rehearsal. Our results showed that PSE appeared from 6 years of age, and at 8 this effect interacts with the presence of concurrent articulation. However, this effect relied only on the detrimental effect of the phonologically similar words, dissimilar and rhyming words leading to similar recall performance. In addition, PSE did not interact with the manipulation of attentional demand whatever the children's age. These results suggested that children could adapt the strategy used at 8, but articulatory rehearsal is available from at least the age of 6.

Key Words: WM; Rehearsal; Refreshing; Phonological similarity

## INTRODUCTION

Working memory (WM) is described as a memory system dedicated to the maintenance and active manipulation of information required to achieve complex cognitive tasks. One of the well-established findings in WM literature is the phonological similarity effect (PSE), i.e., the better recall performance for phonologically dissimilar lists of words (e.g., pit, day, cow, pen, sup) than for phonologically similar lists (e.g., man, mat, can, map, cat). This effect is assumed to show the confusion of similar items within a phonological store as described in Baddeley's model [1]. However, while the detrimental effect of phonological similarity is well established in simple span task, it is less clear in complex span tasks. Recent evidence in adults suggested that PSE in complex span tasks, which require maintaining information while performing a concurrent task, depends on the type of maintenance mechanisms [2,3]. The present study examined this issue in 6- to 8-year-old children, a particularly important developmental period for the emergence of two major maintenance mechanisms, articulatory rehearsal and attentional refreshing [4-7].

The maintenance of verbal information in WM could be achieved by two mechanisms, i.e., articulatory rehearsal and attentional refreshing [8,9]. Between the two, articulatory rehearsal is the most studied, and is described as an inner repetition of memoranda using language-based processes akin to those involved in language production. Several well-known effects related to its use have been described in the model of the phonological loop [10]. Because rehearsal relies on the same processes as language production, a concurrent overt articulation can impair rehearsal, and lead to reduced recall performance [11-13]. A second well-known effect is the word length effect evidenced by the reduction of recall when lists of long (vs. short) words are memorized, because lists of long words could be less repeated than lists of short words in a fixed duration [14-16]. Finally, storing verbal information in a phonological loop requires its encoding in a phonological format, leading to the PSE [1,17,18].

Beside the phonological loop and its maintenance mechanism, attentional refreshing has been identified as another way to maintain verbal information in WM. Refreshing allows memory traces to be reactivated through the recirculation of traces in the focus of attention [19-22]. Recently, the time-based resource-sharing (TBRS) model of WM suggests that this mechanism is involved in an executive loop in which memory items are maintained as multi-format representations through refreshing within an episodic buffer [23]. The existence of such a supplementary mechanism, beside the phonological loop, has been recently included in the multi-component model [24]. Evidence of the involvement of an attentional system in verbal maintenance relies on the decrease of memory performance when an attentional-demanding concurrent task has to be completed, distracting attention from maintenance activities [5,25].

The relationships between rehearsal and refreshing and how they affect recall performance have been explored in adults within the TBRS model [8,9]. In particular, it has been shown that the emergence of PSE in adults depends on the mechanism used to maintain information. In two studies using complex span tasks, participants had to maintain series of phonologically similar or dissimilar words while the availability of rehearsal and refreshing was orthogonally manipulated in a fully crossed design [2,3]. PSE had a detrimental effect on recall performance when rehearsal was available, but this effect disappears when rehearsal was impeded, and refreshing was used to maintain the memory items. To sum up, the phonological characteristics of memoranda impact adults' recall performance only when rehearsal was available. This finding fits with the TBRS model, in which verbal information can be stored either in a phonological format in the phonological loop where it is rehearsed or in an executive loop in a multidimensional format where it is refreshed.

PSE in complex span tasks has been less investigated in children, and this was always to examine the development of articulatory rehearsal. More specifically, it is considered that PSE indexes the use of rehearsal, revealing that this mechanism emerges at around 7. Indeed, the phonological similarity of visually presented stimuli reduces recall performance in children above 7, whereas younger children are not affected by the phonological similarity but by the visual similarity between memory items [7,26]. In a more recent study, Tam, Jarrold, Baddeley, and Sabatos-DeVito presented lists of either phonologically similar or dissimilar words, and compared recall performance in a simple span task

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*Received: October 24, 2017, Accepted: November 06, 2017, Published: November 11, 2017*

to a delay span task, in which a delay was introduced between the presentation of memory list and recall [27]. During the delay of retention, children performed a verbal or non-verbal concurrent task, which impedes maintenance mechanisms. The verbal task induced a higher reduction of recall than the non-verbal task, because both rehearsal and refreshing were impeded while the non-verbal task only impairs refreshing. Moreover, this reduction was observed in both 6 and 8-year-olds but was stronger in 8-year-olds. These results showed that 6-year-old children can use rehearsal, hence their reduction in recall under verbal concurrent task, but to a lesser extent than the 8-year-olds, for whom the reduction was stronger. Moreover, whatever the age, recall performance was affected by PSE, but this effect disappeared when the concurrent task was verbal and impeded rehearsal. The absence of age-related difference in PSE contrasts with other studies in which PSE was larger in older children [28,29]. Currently, a debate subsists about the existence of PSE in children's WM and the implication of rehearsal on the emergence of this effect. Some authors explain the absence of PSE in young children by some scaling effect. Indeed, the size of the detrimental effect increases with the overall recall performance. Younger children having very low level of recall, this makes difficult the detection of PSE [30-32].

Our study aimed at addressing the question of the emergence of PSE in children's WM and more specifically if PSE depends on maintenance mechanisms in children, as it is in adults. Oftinger and Camos have shown that children aged from 6 to 9 already have at their disposal both rehearsal and refreshing [33]. These authors have also shown that, as in adults, these two maintenance mechanisms are independent in 6 to 9-year-old children, i.e., their effects are additive on recall performance, and one can be impaired without any effect on the implementation of the other. This reinforces the assumption that these two maintenance strategies rely on distinct processes. As a consequence, children can strategically choose to use one or the other mechanism depending on task constraints. For example, when a concurrent articulation has to be performed in a complex span task, 7-year-old children used to refresh and not rehearsal to maintain series of digits, which made their recall sensitive to variation in concurrent attentional demand [34]. To our knowledge, only one study examined the role of articulatory rehearsal and attentional refreshing on PSE in children [35]. In complex span tasks, the authors manipulated orthogonally the availability of the two maintenance mechanisms as well as the phonological characteristics of the memoranda presented to 8-year-old children. They showed that the impairment of both mechanisms reduced recall, and that the manipulation of the two mechanisms did not interact. Moreover, they also observed different profiles in recall pattern. Although all children exhibited a PSE in simple span task, two subgroups appeared in the examination of recall in complex span task. As in adults, some children exhibited PSE when rehearsal was available, but this effect disappeared when rehearsal was impaired through a concurrent articulation, confirming Tam et al.'s results [27]. However, for other children, PSE emerged only when both rehearsal and refreshing were available. When either a concurrent articulation or a concurrent attentional demand was introduced, PSE disappeared. The authors suggested that these two profiles reflect preference in the default system used to achieve complex span task. Some children could use a language-based control (like inner speech) while other could favor attentional control to perform the dual processing-and-storage task requested by the complex span paradigm [36]. However, this interpretation relies on very small sample. Moreover, this study did not investigate age-related differences, involving only 8-year-old children.

Therefore, the present study co-varied orthogonally the availability of the two maintenance mechanisms and examined their impact on PSE in 3 different age groups. For this purpose, we manipulated in the same complex span task the opportunity to use rehearsal and refreshing, and the phonological aspects of word lists to memorize. Contrary to Tam et al., the fully crossed design of our experiment allowed examining the interaction between the two maintenance mechanisms [27]. Children had to perform complex span tasks in which the opportunity to use rehearsal and refreshing was orthogonally manipulated. This fully crossed design has been already used in a previous study, but only in 8-year-old children, while the present study involved 6-, 7- and 8-year-old children [35]. To manipulate the use of refreshing, children had to perform two different concurrent tasks. The low-demanding task was a SRT task in which children had to press a key as soon as an animal appeared on screen. The high-demanding task was a CDtask, in which children had to judge if the presented picture was in black-and-white or in color. To manipulate the availability of rehearsal, children had to perform the concurrent task either silently by pressing keys or aloud by saying the response aloud while pressing keys to collect their responses. We expected that impairing rehearsal or refreshing should lead to a reduction in recall performance, which should be stronger in older children due to the development in use of these maintenance strategies.

Moreover, as in Mora and Camos, Tam et al., we manipulated the phonological characteristics of the memoranda. However, departing from these previous studies, we introduced different manipulations of the phonological similarity [27,35]. In adults, the phonological similarity has various effects in recall. When words of phonological similarity lists share the central phoneme (e.g., gas, bag, match), studies reported a detrimental effect of the similarity compared to dissimilar lists. When the similar words share the same final phonemes (e.g., man, ban, can), forming lists of rhyming words, a facilitation effect was observed, with better recall performance for the similar than the dissimilar word lists [16,37-40]. To account for this facilitation effect of the rhyming lists, it is often conceived that rhymes provide retrieval cues that help the reconstruction of degraded memory traces at recall based on long-term memory (LTM) knowledge. This rhyming effect had never been investigated in children with complex span task. Consequently, the present study extended the current literature by examining the impact of the maintenance mechanisms on PSE in different age groups and to different manipulations of phonological similarity.

Concerning the detrimental PSE, although it affects adults' recall performance only under the use of rehearsal, different patterns of results could be observed in children. First, children's recall could be unaffected by phonological similarity whatever the availability of maintenance mechanisms. Indeed, if children cannot use maintenance mechanisms, and more specifically articulatory rehearsal, this effect should not appear. Second, PSE could depend on children's age. Oftinger and Camos have shown that younger children always favor the use of rehearsal, whereas children above 7 shifts to refreshing under concurrent articulation [34]. Consequently, PSE should affect 6-year-olds' recall performance whatever the availability of maintenance mechanisms, while it should emerge only when rehearsal was available for children older than 7. Moreover, older children's recall should be reduced by an increased attentional demand under concurrent articulation, if they shift to refreshing. Concerning the rhyming effect in children, children could show a similar facilitation effect as adults. However, they may not benefit from rhymes as retrieval cues because they have less LTM knowledge and poorer metacognitive skills. As a consequence, rhyming word lists should lead to phonological confusion if they are stored in a phonological loop, i.e., when rehearsal is available.

## METHODS

### Participants

One hundred eighty-two children participated in the experiment: 67 kindergarteners (33 boys, mean age=5;11, SD=0;6), 63 first graders (32 boys, mean age=7;0, SD=0;5), and 52 second graders (26 boys, mean age=8;1, SD=0;6). There were all French native speakers from primary schools in Switzerland, and none of children had difficulties with perceiving colors. Permission for recruitment was gained from ethics committee and school authorities, as well as written informed consent from one of the children's caretakers. In each age group, children were randomly assigned to either the silent or aloud condition of the complex span task to have a balanced number of participants in each condition.

We tested that children assigned to these two groups did not differ in verbal storage capacity by evaluating it with the digit span task from the Wechsler Intelligence Scale for Children [41]. The digit span task has the same verbal presentation and oral recall conditions than the simple and complex span tasks used in the experiment. An analysis of variance (ANOVA) on the digit span score confirmed the absence of significant effect between the silent and aloud group, $F<1$. Although digit span score significantly increased with age, $F(2, 172) = 16.07$, $p<0.0001$, this effect did not interact with the type of responses, $F<1$.

## Materials

Lists of to-be-remembered words were built from an initial set of 222 singular French nouns selected from Lexique 3 [37]. All words were three-phonemes long with a CVC structure and an age of acquisition (AoA) below 60 months.

Three sets of 18 lists with three words per list were built: One set with 18 lists of three phonologically similar words, one set with 18 lists of three rhyming words and one set with 18 lists of three phonologically dissimilar words. Each word appeared three times, one time in each set. For example, for a phonologically similar list, the word "rire" was presented in one set with "chic" and "mille", which are two phonologically similar words with only a central phoneme in common. In the second set, for a rhyme list, "rire" was presented with "dire" and "tir", which are two rhyming words, with a central and a final phoneme in common. In the third set, for a phonologically dissimilar list, "rire" was presented with two phonologically dissimilar items "serre" and "cape" without any common phoneme. Consequently, the 54 lists of three words comprised 54 words that were each presented 3 times, one time in each set. The 54 lists were split into three groups, with each group composing three blocks of six lists per block. Within a block, two lists were composed of phonologically similar words, two lists composed of rhyming words and two lists composed of phonologically dissimilar words. Each subgroup of two lists was arranged to have a similar mean frequency as the other subgroups according to Lexique 3 [42]. The lists were randomly presented within each block. We controlled that each word appeared only one time in each group. Participants were assigned to one of the three groups with a counterbalanced order. All words were recorded by a female voice and presented though headphones with a controlled duration that never exceeded 1-second per word.

For the concurrent task, 54 animal pictures were selected from an initial pool of 230 pictures from Lexique 3 [42]. The age of acquisition of the animal names was less than 74.5 months in Lexique 3 and the frequency was among the highest in LEXIQUE database [42,43]. All pictures appeared twice during the experiment, once in color and once in black-and-white.

## Procedure

The experiment was presented on a screen using Psyscope software [44]. Two test blocks of complex span task were presented in a counterbalanced order across participants. Within each block, a total of six trials were presented, with two trials for each type of lists. Each trial began with an asterisk centered on screen for 1000 ms, followed by the auditory presentation of the first memory word for 1000 ms. This word was then followed by two successively presented pictures, presented for 1800 ms each with an inter-stimulus interval of 200 ms. The second memory word appeared afterward, followed by two pictures. This word-pictures sequence was repeated for a total of three words in each trial. At the end of a trial, a question mark appeared after a 200-ms delay prompting participants to orally recall the words in the same order as they were presented. The experimenter wrote all responses down on a sheet, and systematically asked children the position of each recalled item. Each word recalled in the correct position was counted and the percentage of correct recall was computed for each experimental condition.

For the concurrent task, children had to complete either a simple reaction time (SRT) task or a color discrimination (CD) task, the order of which depended on the counterbalancing order. For the SRT task, children had to push the "b" key on the keyboard as soon as an animal appeared. An animal picture was stuck on this key as a reminder. For the CD task, the children had to determine if pictures were either in color or in black-and-white by pressing the corresponding color buttons on a Swiss keyboard. Children pushed the "c" key on the left in which three color circles (red, blue, yellow) was stuck if picture was in color, and the "n" key on the right with 2 circles (one black and one white) if picture was black-and-white. Moreover, half of the sample had to perform a concurrent articulation by responding aloud while pressing keys to induce an articulatory suppression and impair subvocal rehearsal.

Prior to the two blocks of complex span task, all children were presented with a simple span task. This task was similar to the complex span task, except there was no concurrent task, words being successively presented one after the other for 1000 ms. each.

# RESULTS

Data from 4 children (2 kindergarteners and 2 first graders) were discarded because they obtained less than 50% of correct responses in the concurrent task. The remaining 65 kindergarteners, 61 first graders and 52 second graders paid enough attention to the concurrent task and achieved a mean rate of correct responses of 91% (SD=10).

We analyzed performance in concurrent tasks, prior analysis of the recall performance in the simple and complex span tasks. For sake of clarity, we segregated recall analysis in two sections, one dedicated to the PSE and one to the rhyming effect.

## Analyses of the Concurrent Tasks

To control that SRT task was less attentional demanding than CD task, analyses were conducted on percentage of correct responses and response times of the concurrent tasks. A mixed analysis of variance (ANOVA) was performed on the percentage of correct responses with age (6, 7 and 8 years), type of responses (keyed vs. aloud) as between-subject's factors, and concurrent task (SRT vs. CD) as a within-subjects factor. Percentage of correct responses was already high at 6 with 89% (SD=11), and significantly increased with age with 92% (SD=9) at 7 and 93% (SD=8) at 9, $F(2, 172) = 4.93$, $p<0.01$, p2=0.05. All pairwise comparisons were significant (ps<0.05 with Bonferroni adjustments), except between 7 and 8 ($p=0.49$). Percentage of correct responses was higher when children had to response aloud (93%, SD=8) than when only pressing keys (89%, SD=11), $F(1, 172) = 18.66$, $p<0.0001$, p2=0.10. As expected, SRT task (93%, SD=9) induced higher percentage of correct responses than CD (89%, SD=10), $F(1, 172) = 19.57$, $p<0.0001$, p2=0.10. No interaction was significant, Fs<1.

A similar mixed ANOVA was performed on response times. This analysis revealed an age effect with 8-year-olds (872 ms, SD=148) being faster than 7-year-olds (930 ms, SD=143) and 6-year-olds (971 ms, SD=147), $F(2, 172) = 9.28$, $p<0.001$, p2=0.10; pairwise comparisons being significant (ps<0.05) except between 6 and 7 ($p=0.06$). As expected, children were significantly faster in SRT (754 ms, SD=165) than CD task (1102 ms, SD=137), $F(1, 172) = 904.33$, $p<0.0001$, p2=0.84. The type of responses did not affect the responses times (aloud: 932 ms, SD=149 vs. keyed: 925, SD=152), $F<1$, but this effect interacted with concurrent task with larger difference in responses times between the two tasks in aloud (383 ms) than in silent conditions (316 ms), $F(1,172) = 9.25$, $p<0.01$, p2=0.05. No other interaction was significant, ps>0.15.

To summarize, both analyses in percentage of correct responses and response times confirmed that SRT was less demanding than CD, leading to higher percentage of correct responses and faster responses. These effects were akin across ages and types of responses.

## The Impact of PSE in Simple and Complex Span Tasks

To assess PSE, we contrasted lists of phonologically dissimilar and similar words in two ANOVAs on percentage of correct recall, one for the simple span task and one for the complex span task. For the simple span task, the ANOVA was performed with age (6, 7 and 8 years) as between-subjects factor and type of words (dissimilar and similar) as within-subjects factor. Recall performance improved with age from 61% (SD=25) at 6 to 76% (SD=18) and 81% (SD=17) at 7 and 8 respectively, $F(2, 175) = 16.48$, p<0.0001, p2=0.16 (Figure 1). Pairwise comparisons were significant (ps<0.0001), except between 7 and 8 (p=0.16). As expected, similar word lists (66%; SD=28) resulted in poorer recall performance than dissimilar word lists (77%; SD=25), F (1, 175) =22.89, p<0.0001, p2=0.12. The age x type of words was not significant, F<1.

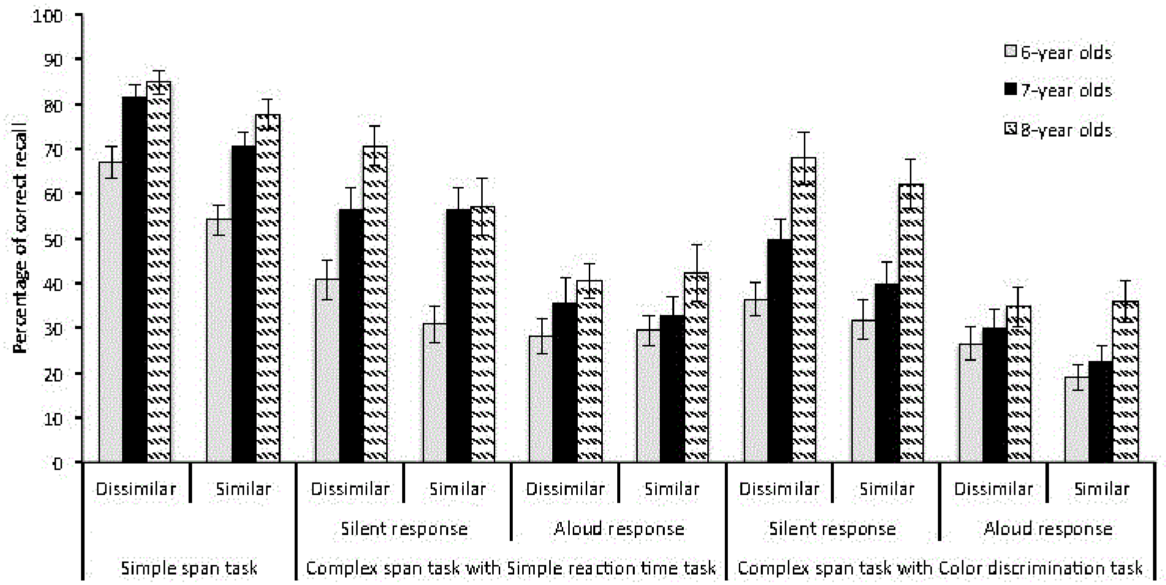


**Figure 1:** Mean percentage of correct recall in the simple and complex span tasks according to the age groups. the type of word [dissimilar and similar), the concurrent task in the complex span task (simple reaction time task and color discrimination task), and the type of response to the concurrent task. Y bars represented standard error.

For the complex span task, data from two 6-year-old children and one 7-year-old were discarded because they did not recall any word. A mixed ANOVA was performed with age (6, 7 and 8 years) and type of responses to the concurrent task (keyed and aloud) as between-subject's factors, and type of words (similar and dissimilar) and of task (SRT vs. CD) as within-subject's factors. As often reported, recall performance significantly increased with age, F (2, 169) = 20.89, p<0.0001, p2=0.85, from 31% (SD=15) at 6, 41% (SD=21) at 7 and 51% (SD=23) at 8; all pairwise comparisons being significant (ps<0.01; Figure 1). Percentage of correct recall was also affected by concurrent articulation, with worse recall in aloud (31%, SD=19) than silent condition (49%, SD=22), F (1, 169) = 49.63, p<0.0001, p2=0.23. The effect of the concurrent articulation significantly interacted with age, F (1, 169) = 3.57, p=0.03, p2=0.04. The concurrent articulation effect was stronger as children get older, F (1, 61) = 6.22, p=0.015, p2=0.09, F (1,58) = 18.79, p<0.0001, p2=0.25, and F (1, 50) = 23.73, p<0.0001, p2=0.32 in 6-, 7- and 8-year-olds, respectively. The type of task had an effect on recall performance, with poorer recall in CD (38%, SD=24) than SRT task (43%, SD=24), F (1, 169) = 11.23, p=0.001, p2=0.06. Finally, phonologically similar words (M=38%, SD=23) resulted in poorer recall than phonologically dissimilar words (43%, SD=24), F (1, 169) = 9.30, p=0.003, p2=0.05. No other interaction was significant, ps>0.11.

To summarize, PSE had a detrimental effect on recall. Moreover, all the other factors of interest had the expected effect on recall: age led to recall improvement, whereas the introduction of a concurrent articulation or the increase in attentional demand reduced performance. No factor interacted, besides the increasing impact of impairing rehearsal (with a concurrent articulation) through age, which is congruent with an increasing use of rehearsal across childhood. However, in the simple and complex span tasks, PSE did not interact with age, something that would have been expected if older children use more rehearsal and if PSE is an index of this use. This is also congruent with the fact that as well as Mora and Camos previously reported in adults and children that not all participants are sensitive to PSE [35,45].

## The Impact of the Rhyming Effect in Simple and Complex Span Tasks

To assess the rhyming effect, we contrasted lists of phonologically dissimilar and rhyming words in two ANOVAs on percentage of correct recall, one for the simple span task and one for the complex span task. For the simple span task, the date of two children (one 6-year-old and one 7-year-old) were discarded due to absence of correct recall in any trial. Recall performance improved with age from 64% (SD=27) at 6 to 77% (SD=23) and 81% (SD=22) at 7 and 8 respectively, F (2, 175) = 11.82, p<0.0001, p2=0.12 (Figure 2). Pairwise comparisons were significant (ps<0.0001), except between 7 and 8 (p=0.32). Contrary to adults, rhyming word lists (70%; SD=25) resulted in poorer recall performance than dissimilar word lists (77%; SD=25), F (1, 175) = 12.66, p<0.0001, p2=0.07. The age x type of words was not significant, F<1.

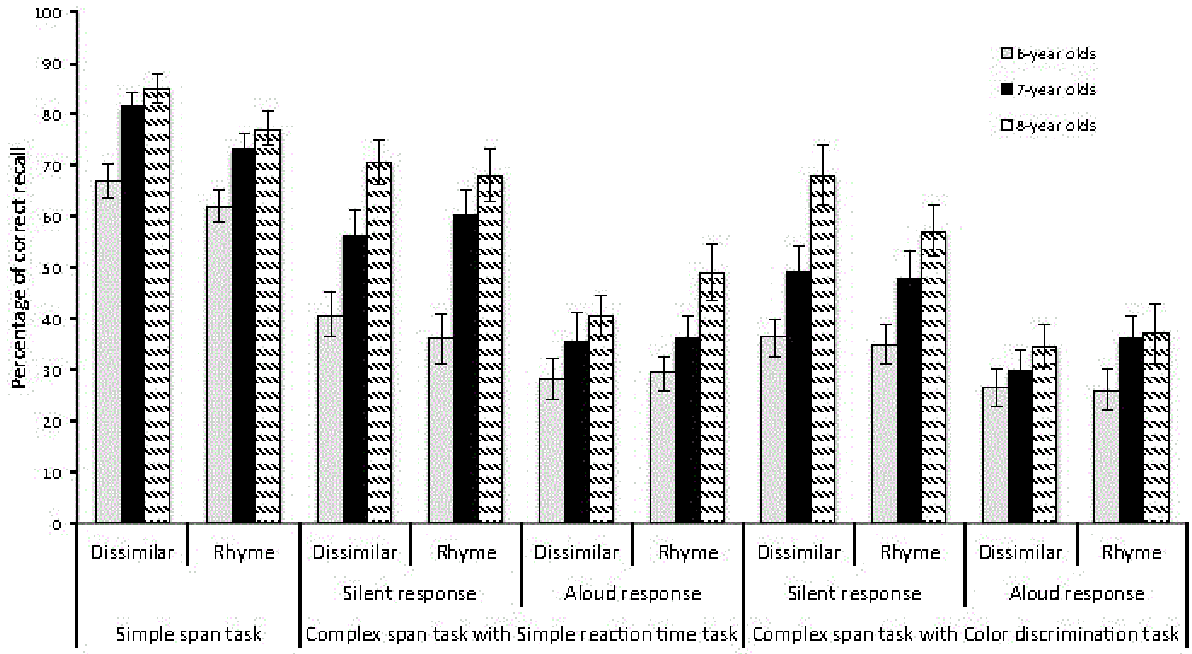


**Figure 2:** Mean percentage of correct recall in the simple and complex span tasks according to the age groups. the type of word (dissimilar and similar), the concurrent task in the complex span task (simple reaction time task and color discrimination task), and the type of response to the concurrent task. Y bars represented standard error.

For the complex span task, data from one 6-year-old child were discarded due to absence of recall. A mixed ANOVA was performed with age (6, 7 and 8 years) and type of responses to the concurrent task (keyed and aloud) as between-subject's factors, and type of words (rhyming and dissimilar) and task (SRT vs. CD) as within-subject's factors. As reported in the previous analyses, recall performance significantly increased with age, $F(2, 171) = 22.11$, $p<0.0001$, $p2=0.21$, from 32% (SD=23) at 6, 44% (SD=28) at 7 and 53% (SD=29) at 8. All differences between age groups were significant ($ps<0.01$; Figure 2). Recall was worst in aloud (34%, SD=24) than silent condition (52%, SD=26), $F(1, 171) = 47.61$, $p<0.0001$, $p2=0.22$. This effect significantly interacted with age, $F(1, 171) = 3.27$, $p=0.04$, $p2=0.04$, being stronger as children get older: $F(1, 62) = 6.52$, $p=0.013$, $p2=0.10$, $F(1,59) = 15.42$, $p<0.0001$, $p2=0.21$, and $F(1, 50) = 25.39$, $p<0.0001$, $p2=0.34$ in 6-, 7- and 8-year-olds, respectively. Recall was poorer under CD (40%, SD=27) than SRT task (45%, SD=29), $F(1, 171) = 11.68$, $p=0.001$, $p2=0.06$. Finally, and contrary to simple span task, recall of rhyming words (42%, SD=28) and dissimilar words (42%, SD=28) did not significantly differ, $F<1$. No interaction was significant, $ps>0.07$.

To summarize, these analyses replicated our previous findings, that increasing attentional demand and the introduction of concurrent articulation reduced recall performance in children from 6 onwards. However, contrary to adults, rhyming words did not benefit recall. They were neither less recalled as the assumption that rhyming word lists could suffer from more interferences. In fact, rhyming words were treated as the dissimilar words, and this did not change with age.

## DISCUSSION

This experiment aimed at examining the impact of phonological characteristics of memoranda while the availability of maintenance mechanisms was manipulated. Only two studies have previously investigated this in children impeded either both refreshing and rehearsal with a verbal concurrent task or only refreshing with a non-verbal concurrent task, whereas Mora and Camos used a fully crossed design [27,35]. However, Mora and Camos centered their exploration on 8-year-old children without considering the potential developmental changes of these mechanisms [35]. The present study investigated the phonological similarity effect and rhyming effect using a fully crossed design to vary the availability of both mechanisms in children aged 6 to 8.

## The Detrimental Effect of the Word Phonological Similarity

Concerning the classic PSE, the present study brought further evidence on its existence in children. As explained in the introduction, Mora and Camos, Tam et al. already reported a better recall of lists of dissimilar compared to similar words in children [27,35]. What is new in this study is the exploration of this effect depending on the availability of maintenance mechanisms within different age groups.

Our results show that phonological similarity impedes 8-year-olds' recall, only when rehearsal was available. This suggests that older children could adapt the use of mechanism to maintain verbal information. However, at 6 and 7, lists of phonologically similar words impeded recall whatever the availability of the mechanisms, suggesting that younger children favor rehearsal, even under articulatory suppression condition. This pattern strengthens Oftinger and Camos findings, and is also in line with previous experiments showing the use of rehearsal before 7 [27,28,30,34,46].

Moreover, if no interaction appeared between refreshing and rehearsal in children, a PSE was still observed in younger children recall when both mechanisms were impeded, as Mora and Camos reported in 8-year-olds [35]. But, contrary to this previous study, PSE in the present study was present at 8, only when rehearsal was available. This could be explained by the fact that is the concurrent task was here performed either silently or aloud, whereas in Mora and Camos, children had to perform a supplementary articulation in addition to the concurrent task [35]. This stronger attentional demand in this previous experiment can explain the observed pattern in 8-years-olds while we observed a different pattern in children younger than 7. As, previous studies [34,35] explained, younger children could also favor rehearsal. Indeed, 6- and 7-year-olds were impeded by PSE even in articulatory suppression condition. Whereas older children can be flexible and using refreshing under articulatory suppression condition, younger children seem to be not flexible. They could favor rehearsal because it requires less attention and they cannot be flexible in using both mechanisms.

## Rhyming Effect in Children

Whereas the findings were in line with previous experiments with PSE having a detrimental effect on recall, rhyming effects were at odds with previous findings [27,35]. Indeed, while previous studies supported the idea of a facilitating rhyme effect, this study failed to show an effect [37,39]. However, these studies were performed in adults, and to our knowledge no previous work examined the impact of rhymes in children performing complex span tasks.

This absence of effect could be due to the difficulty of young children to use cues given by rhymes. Actually, studies using simple span task showed a detrimental effect of rhymes that could be explained by this difficulty and induced a similar detrimental effect as lists of similar words [47,48]. In the present study, we also observed a detrimental effect of rhyming words in the simple span task. During complex span tasks, children could have more time to use cues, but this may be not enough to improve recall as it is in adults. It might be interesting to explore this effect in older children who could be more likely to use rhyming cues as adults. However, this suggests that rhyming effect relies on more strategic aspects, probably metacognitive, compared to the classic PSE that reflects the functioning of a verbal subsystem.

To conclude, this study provides some examination in children of the phonological similarity effect, disentangling the classic PSE from the rhyming effects. Our findings reinforced the idea that rehearsal is available before 7, and show that children could adapt their use of rehearsal to maintain verbal information according to the type of words but only at 8. Finally, it enlightens the difference between the classic PSE and the rhyming effects. The age-related difference in the patterns concerning these effects raises the question that they do not emerge from the same cognitive mechanism.

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