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Gaze-based rehearsal in children under 7: A developmental investigation of eye movements during a serial spatial memory task

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Research Highlights

- Adults look progressively less at late-list items in a spatial serial memory task, possibly because they spend time during presentation on cumulative rehearsal.
- This pattern was reduced in children 8-10 years old and even more so in children 5-7 years-old, consistent with the idea that children under 7 do not rehearse.
- However, 5-7 year-old children engaged most in beneficial sequential looking during a retention interval.
- Together, these findings suggest that 5-7 year-old children try to remember, but favor reactive rather than proactive strategies.

Abstract

The emergence of strategic verbal rehearsal at around 7 years of age is widely considered a major milestone in descriptions of the development of short-term memory across childhood. Likewise, rehearsal is believed by many to be a crucial factor in explaining why memory improves with age. This apparent qualitative shift in mnemonic processes has also been characterized as a shift from passive visual to more active verbal mnemonic strategy use, but no investigation of the development of overt spatial rehearsal has informed this explanation. We measured serial spatial order reconstruction in adults and groups of children 5-7 years old and 8-11 years old, while recording their eye movements. Children, particularly the youngest children, overtly fixated late-list spatial positions longer than adults, suggesting that younger children are less likely to engage in covert rehearsal during stimulus presentation than older children and adults. However, during retention the youngest children overtly fixated more of the to-be-remembered sequences than any other group, which is inconsistent with the idea that children do nothing to try to remember. Altogether, these data are inconsistent with the notion that children under 7 do not engage in any attempts to remember. They are most consistent with proposals that children's style of remembering shifts around age 7 from reactive cue-driven methods to proactive, covert methods, which may include cumulative rehearsal.

Keywords: spatial working memory, spatial memory, working memory, short-term memory, eye tracking

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The idea of *rehearsal* implies expenditure of effort toward remembering something. Although the process of rehearsing is believed to occur passively after the to-be-rehearsed sequence is initiated (Naveh-Benjamin & Jonides, 1984), the act of engaging in rehearsal is strategic. It has long been assumed that children under 7 do not rehearse (Flavell, Beach, & Chinsky, 1966). The emergence of rehearsal is believed to lead to a shift in how children remember, contributing to continuous increases in performance on memory tasks across childhood (Gathercole, 1998; Jarrold, Danielsson, & Wang, 2015). Many propose that a qualitative shift in mnemonic processes occurs, specifically reflecting the emergence of verbal rehearsal processes (Hitch, Halliday, Schaafstal, & Schraagen, 1988; Palmer, 2000). Alternatively, improvement in memory across childhood could reflect a broader transition towards more proactive cognitive strategies (Camos & Barrouillet, 2011; Chevalier, James, Wiebe, Nelson, & Espy, 2014), encompassing rehearsal, but not limited to it.

Despite its appeal, the conventional story that verbal rehearsal specifically undergoes a qualitative shift around age 7 is receiving justified scrutiny (Jarrold & Hall, 2013). Researchers often try to detect verbalization (which may indicate rehearsal) indirectly, via classic indicators of covert verbalization like poorer recall of visually-presented verbal items with phonologically similar than dissimilar names, or poorer recall of items with long compared to short names (e.g., Henry, Messer, Luger-Klein, & Crane, 2012). Interestingly, phonological similarity and word length effects have been detected in children younger than 7 (Henry, et al., 2012), suggesting that the onset of any qualitative shift might occur earlier than previously thought. Discerning whether these effects are truly absent in young children is challenging (e.g., Jarrold & Citroën, 2013). Nevertheless, observational evidence suggests that children under 7 do not spontaneously verbalize memoranda, which gives credence to the idea that they do not verbally rehearse. Flavell, et al. (1966) recorded childrens' articulation behavior during a picture order reconstruction task. They found that kindergarteners only rarely articulated during the task and scarcely reported verbalization as a mnemonic strategy, in contrast with older children. However, the meaning of these differences in verbalization is elusive. Possibly, specific cognitive processes needed to support verbal rehearsal are insufficiently developed in children under 7. Alternatively, these findings could indicate a shift towards proactive mnemonic strategies, including verbal rehearsal, as children develop. Overall, evidence certainly suggests that some shift in behavior occurs around ages 5-7, but its precise nature remains debatable.

A complementary way to assess whether children under 7 actively rehearse is to examine eye movements during a spatial serial memory task. Spatial information may be kept active by sequential eye movements performed to target locations. Tremblay, Saint-Aubin, and Jalbert (2006) observed superior spatial serial order reconstruction when participants fixated some of the target positions in their correct order during a 10-second retention interval. This evidence is consistent with the idea that gazes during retention reflect attempts to keep the spatial list in mind, analogously to using speech to support memory for verbal information. Other evidence is likewise consistent with the hypothesis that overt fixations toward to-be-remembered spatial positions boost memory (e.g., Guérard, Tremblay, & Saint-Aubin, 2009; Guérard & Tremblay, 2011; Lilienthal, Hale, & Myerson, 2014), though overt fixations are apparently of limited use for supporting recall compared to covert oculomotor planning (Godijn & Theeuwes, 2013; Pearson, Ball, & Smith, 2014).

Helpful or not, overt behaviors like speech and gazes give us valuable clues about how participants are engaging with tasks. When a participant favors speech over silence, or produces targeted gaze shifts during retention, we can infer that the participant is engaged with the to-be-remembered stimuli in some way. Compared with considering overt speech, an advantage of analyzing gazes is that it does not depend on children's understanding about what sorts of behaviors are allowed or forbidden during the task. Unlike in many paradigms, participants are not explicitly instructed to interact with the experimental stimuli in a particular manner; they simply know that their gazes are being recorded. Analyzing fixations during a spatial memory task provides novel information for understanding how young children approach memory tasks, likely to advance knowledge both about how spatial sequences are remembered and what bounds should be assumed on the development of strategic mnemonic processes more generally.

We measured spatial serial order reconstruction in samples of young adults, children 5-7 years old, and children 8-11 years old, recording their free gazes throughout stimulus presentation and retention. This enabled us to examine fixations during presentation in order to learn whether these patterns were consistent with the use of a cumulative rehearsal strategy (e.g., Dewar, Brown, & della Sala, 2011) in all age groups, as shown previously in adults (Lange & Engbert, 2013). We also conceptually replicated Tremblay et al.'s (2006) observations relating sequential looking with recall accuracy in adults to establish whether beneficial sequential looking behavior during retention likewise appears for children. According to the popular conception of rehearsal development, we should see more evidence of beneficial looking behaviors in adults and in children over 8 years old than in our youngest sample. During presentation of the stimuli, the decreasing tendency to dwell on late-list items identified by Lange and Engbert (2013) should be present in adults, and gradually less apparent in children depending on their ages. Furthermore, we would expect to observe little or no evidence of sequential looking during retention in the youngest children, or perhaps no relationship between sequential looking in children and recall accuracy. Observing sequential looking patterns during retention in the youngest children, particularly if they relate to recall accuracy, would dispel the idea that children under 7 do not engage in some kind of mnemonic strategy.

Method

Participants

We recruited 23 adults and 51 children from the Edinburgh community with self-reported normal or corrected-to-normal vision, and no history of psychological disorders. Our sample of 5-7 year-old children (*M*=6.74, *SD*=0.68) included 11 females and 11 males. Our sample of 8-11 year old children (*M*=9.50, *SD*=0.92) included 16 females and 13 males. Adults (17 female, 6 male) ranged from 19-34 years old (*M*=22.98, *SD*=3.58). Adult participants provided written informed consent on their own behalf. Parents gave written consent for their children. Additionally, children's willingness to participate was assessed first with written assent and continuously throughout the session through their interaction with the researcher. Participants took part in exchange for a small honorarium. Our procedure was approved by the Psychology Department research ethics committee.

Apparatus and Stimuli

Experimental sessions took place in the developmental laboratory at the University of Edinburgh, equipped with a remote arm-mounted EyeLink 1000 system sampling at 500 Hz. Participants were seated 50-60 cm from the display monitor, which was adjusted to suit their seated height. Their right pupils were calibrated on EyeLink's 5-point procedure. The experimenter was seated behind the participant, out of the participant’s field of view.

Stimuli included 6 small photos of puppies culled from a Google Image search. Onscreen, each photo was surrounded by a 2-pixel wide teal border (RGB: 144, 254, 219) and in total occupied a 40 x 40 pixel area on the 1024 x 768 display. Locations of the photos were randomly determined at run time with the constraint that all locations should fall in the central 492 x 344 area and that no two locations could lie within 110 pixels of each other or the center of the screen. Stimuli were displayed on a light gray (RGB: 191,191,191) background. The lengths of the to-be-remembered sequences varied by age group. Adult participants received sequences of 7 positions, 8-11 year-old children sequences of 5 positions, and 5-7 year-old children sequences of 4 positions. We chose these list lengths so as to avoid ceiling or floor effects, based on published performance on similar tasks and pilot-testing (e.g., Orsini, Grossi, Capitani, Laiacona, Papagno, & Vallar, 1988; Tremblay, et al., 2006). Stimulus display and response collection were controlled using custom E-Prime software (Schneider, Eschmann, & Zuccolotto, 2002). Our materials are available at https://osf.io/c6nkh/.

Procedure

An experimenter explained the task using a story in which a dog walker is walking several puppies and one of them gets loose. The puppy moves from place to place on the screen, and the participant tries to remember all the places in order to help the dog walker find the lost puppy. Each trial began with a 4000-ms blank screen. Then a teal "+" appeared in the center of the screen for 1000 ms to let the participant know that the puppy was about to appear. After a delay of 250 ms, the puppy appeared in a location for 500 ms, followed by a blank delay of 250 ms, before appearing again in the next location, and so on. After the final location presentation, all of the positions the puppy visited re-appeared outlined in teal, providing placeholders for participants to fixate during the 10-second retention interval. A spoken prompt, in which an artificial female voice said "Where did my dog go?", occurred 1500 ms before the 10-second retention period ended. Then, the outlines of the positions all changed to black, and the participant was to point to the positions in the order in which they were presented. The experimenter recorded the participant's responses by clicking the indicated location with the mouse. Experimenters took explicit care to keep the mouse pointer still until the participant indicated their next choice. As each location was selected, it changed from black to teal and could not be selected again. Gaze data were recorded from the beginning of the trial until the response screen appeared.

Participants completed a 3-trial practice session with 3-position sequences before beginning the experiment. The experiment was divided into two blocks of 12 trials each. The eye-tracker was calibrated before each block. Children were allowed to take a break between the blocks and to play in the lab's area for as long as they wished.

Analysis plan

We estimated the extent of ordered looking during presentation and retention using a pairwise analysis similar to that described by Tremblay et al. (2006)[1]. After removing fixations to non-targets from the observed fixation sequence, we searched for pairs of fixations toward adjacently presented items (e.g., position 1 followed by position 2, position 2 followed by position 3, etc.). We counted these adjacent fixations for each participant, trial, and trial period and entered the sums into our omnibus analysis. We also analyzed the proportion of time gazing at each position during its presentation window, in order to learn whether children's fixations toward late-list items were briefer than fixations to early-list items (Lange & Engbert, 2013).

All of our inferential analyses were performed with the *BayesFactor* R package (version 0.9.12-2, Morey & Rouder, 2015). Bayesian ANOVA (Rouder, Morey, Speckman, & Province,

[1] The data analysis supplement available on our OSF page additionally includes a more lenient analysis of longest common subsequences, using the method of Coco and Keller (2012).

2012) provides Bayes factors favoring each possible combination of model parameters, affording the possibility to compare models and quantify evidence both for and against each possible factor and interaction. In our approach, we report the factors and interactions present in the best Bayes factor model and quantify evidence for including or excluding each term by comparing the Bayes factor for the winning model with the Bayes factor for the model omitting the considered term. Bayes factors are intended to be assessed continuously, with values further from 1 denoting increasingly strong evidence. While there is no universally-agreed Bayes factor criterion for inclusion or exclusion of terms from models, Bayes factors between 1 and 3 are generally regarded as inconclusive. Each model was estimated with 100,000 samples using the default prior settings.[2]

Results

Behavioral responses

We first informally examined behavioral responses. Figure 1 shows serial reconstruction responses by input serial position for each age group. Accuracy range and the extent of serial position effects indeed appeared comparable across groups, with no sign of floor or ceiling effects in any group. In each group, first-item primacy and last-item recency effects were clearly apparent. Thus the behavioral responses do not point to obvious group differences in processes selectively affecting the typical serial position function. We used the gaze data to further consider whether each age group interacted with the stimuli in the same manner.

Gazes

[2] Corresponding frequentist ANOVAs always agreed with the Bayesian ones, yielding significant p-values for factors and interactions included in the winning models in the Bayesian analysis and null p-values for those excluded.

Two participants from each age group were excluded from all gaze analyses due to poor acquisition of data. Table 1 provides mean fixation counts during presentation and retention periods for each age group, in order to give an idea of the amount of data acquired per condition.

Fixation time during presentation by serial position. We ran an analysis of proportion dwell time per location during presentation, inspired by the results of Lange and Engbert (2013). The proportions of time spent fixating the target position during its 750-ms presentation window are plotted in Figure 2. Just as Lange and Engbert found, adult participants devoted less time to overtly fixating items as the list progressed. A Bayesian ANOVA with serial position and age group as potential factors supported a model containing both of these factors and their interaction, $BF = 2.11 \times 10^{62}$, ± 2.78%. Inclusion of the interaction was favored by a factor of more than 25,000. To diagnose the source of the interaction, we simplified the serial position factor by contrasting the first position with the average of all other positions in every group. We compared models including our simplified serial position factor plus one of three ways of coding the age group factor: 1) the three-level coding distinguishing between adults and both groups of children, 2) coding group such that adults were contrasted with all children, or 3) such that the youngest children were compared with the rest. The best model, which included an interaction between serial position and the coding of age group distinguishing between all three groups, was favored over the next best option (the same interaction but with the youngest children age group distinguished) by a factor of >200. These analyses suggest that the interaction between age group and serial position arose because adults spent a smaller proportion of time fixating each incoming item after the first item (M=0.11, SD=0.11) than 8-11 year-old children (M=0.22, SD=0.13), who likewise fixated late-list items for less time than 5-7 year-old children (M=0.27, SD=0.10), while all participants fixated the first item for similar proportions of its presentation time (*M*s=0.34-0.42, *SD*s=0.12-0.13). Note that if participants of each age required different amounts of time to encode a spatial position, we would have expected to observe systematic group differences for the first position as well as the later positions.

The unstructured, randomly-determined spatial positions we used precluded conclusive analysis of whether adults and older children were more likely to re-fixate previously presented items than younger children. Most non-target fixations fell within the central area of the screen but between target positions, and could not be definitively assigned to a target, unlike the fixations recorded from Lange and Engbert's (2013) adjacent grid stimulus.

Analysis of ordered looking. We entered counts of adjacent pairs fixated as a proportion of the maximum possible depending on list length into Bayesian ANOVAs with age group as a between-participants factor and recording period (presentation or retention) and response accuracy (correctly or incorrectly recalled the whole list) as within-participants factors. We included recording period in this analysis to establish whether any effects of accuracy differed when considering looking during presentation (when items overtly appeared onscreen) and retention (when only static placeholders were present). We followed this omnibus analysis with a separate analysis including data only from the retention period, which best enables inference about gazes serving as a means of rehearsal.

The best ANOVA model included effects of age group, recording period, and response accuracy, plus interactions between period and accuracy and between period and age group, $BF=1.12\times10^{175}$, ±1.74%. These data are plotted in Figure 3. Inclusion of all main effects was decisively favored by *BF*s of at least 1 million:1. The interaction between age group and recording period (favored by a factor of > 1 million) reflects a decreasing difference between the proportions of adjacent pairs fixated during the presentation and retention periods. In each group, participants unsurprisingly fixate a larger number of adjacent pairs during presentation than during retention. However, this difference is greatest in the youngest children (40%) and declines in older children (24%) and still further in adults (19%). Note though that Figure 3 makes clear that this cannot be due to an *increase* in overt sequential looking during retention across childhood; overt sequential looking during retention obviously decreases with age. The interaction between period and accuracy was favored > 1 million:1 and reflects stronger relations between gazes and accuracy during retention (11% increase in ordered fixations for correct compared to incorrect responses) than during presentation (2% increase in ordered fixations for correct responses). Excluding an interaction between age group and accuracy was slightly favored (BF=4.44), but difficult to interpret because it incorporates data from both presentation and retention in its calculation. To gain further clarity into whether overt eye movements can be considered a basis for rehearsal, we analyzed the data acquired during retention separately. The best model included main effects of age group and response accuracy, but no interaction, $BF=3.47\times10^{13} \pm 0.79\%$. Exclusion of their interaction was strongly favored by a Bayes factor of >20. We observed similar differences between proportions of adjacent pairs fixated with correct and incorrect responses in each age group, ($M_{5\text{-}7\ Years}$=14%, $M_{8\text{-}10\ Years}$=9%, M_{Adults}=11%). These results suggest that adjacent looking is at least as beneficial for 5-7 year-old children as for older children and adults.

Discussion

Our data provide clear evidence of developmental change in gaze patterns during a serial spatial reconstruction task. Crucially, our findings are inconsistent with the idea that overt rehearsal emerges abruptly around 7 years of age and then increases into adulthood, complementing other recent findings in the verbal domain (Jarrold & Citroën, 2013). Overt looking, proposed to be analogous to overt speech as a means of supporting memory (e.g., Tremblay, et al., 2006), decreases with age. We observed greater commonality between the to-be-remembered sequence and gazes during retention when sequences were correctly recalled regardless of age group. This confirms Tremblay et al.'s findings that overt gazes support memory, extending this observation to children as young as 5 years old. Young children spent more presentation time fixating late-list items than older children and adults, which is consistent with the presumption that as they develop, children increasingly spend more time during presentation rehearsing earlier list items (Lange & Engbert, 2013).

These patterns are consistent with the proposal that proactive control processes needed to organize and plan responses (Braver, 2012) emerge at about age 7 (Chevalier, et al., 2014). Invoking this framework allows for an explanation of our findings that is parsimoniously consistent with evidence that children under 7 do not spontaneously engage in cumulative verbal rehearsal (Flavell, et al., 1966; Lehmann & Hasselhorn, 2012), without claiming that speech-based versus occulomotor-based mnemonic processes have distinct developmental trajectories. Awaiting stimulus cues to act, younger children tended to fixate each item as it was presented, whereas adults (and to some degree, older children) presumably used some of the late-list presentation time for covert mnemonic processes. Prompted by the presence of static placeholders, the youngest children sequentially looked at the placeholder cues during the retention period, consistent with adoption of a reactive cognitive strategy, not with doing nothing at all. The increasing tendency to verbalize documented in children over 7 years old (e.g., Flavell, et al., 1966; Henry, et al., 2012; Palmer, 2000) may likewise be explained as a tendency toward a proactive cognitive style. If not explicitly elicited, verbalization can be considered a proactive technique, especially if it proceeds beyond mere naming and progresses to cumulative organization of the presented materials. Covert verbalization when overt verbalization is forbidden (e.g., Al-Namlah, Fernyhough, & Meins, 2006; Palmer, 2000) reflects a proactive organization of the memory items or proactive planning of the eventual motor response (Chevalier, et al., 2014). Although our results differ from others in showing that children under 7 engage in activity that seems to reflect rehearsal, both the absence of verbalization during presentation in previous work and the presence of gaze shifts during retention that we observed may be accommodated by the same framework.

Alternatively, the appropriate contrast could be between visual-spatial strategies and verbal ones (e.g., Hitch, et al., 1988; Palmer 2000), regardless of whether the strategies tend toward proactivity or not. Possibly, younger children prefer to adopt visual strategies while older children and adults prefer verbal ones. This would explain the decrease we observed in overt sequential looking during retention with age, but it fails to accommodate the finding that the youngest children looked longest at incoming items as they were presented, thus devoting less time to reflecting on early-list items while later items were presented. Notably, most studies aiming to compare verbal rehearsal in children and adults via phonological similarity or word length effects employed immediate recall tests (e.g., Al-Namlah, et al., 2006; Hitch, et al., 1988; Palmer, 2000), which would afford limited opportunities for effects of rehearsal to be observed in participants who begin rehearsing only after the whole list has been presented. Possibly, imposing a brief retention interval would allow covert verbalization to be observed in younger children, although it seems that overt verbalization is nearly absent during retention in children under 6 and increases with age (Flavell, et al., 1966). We therefore think that the proactive-reactive framework (Braver, 2012) handles these developmental differences at least as well as a proposed visual-verbal strategy shift. Further experimentation with both possible distinctions in mind would resolve this ambiguity, contributing new evidence either supporting or disconfirming assumptions about modular function made by various working memory models (Baddeley, 2012; Barrouillet & Camos, 2015).

Overt sequential gazes were related to recall accuracy, confirming that sequential gaze somehow subserves spatial serial order memory. However, as Tremblay et al. (2006) also noted, though this relationship is present, its impact is rather small. Possibly, overt gaze does not pick up on the processes crucial to covert maintenance that somehow rely on the oculomotor system. Pearson, Ball, and Smith (2014) argue that oculomotor planning, not actually carrying out the gaze movements, supports spatial memory (see also Postle, Idzikowski, della Sala, Logie, & Baddeley, 2006). However, serial looking in our paradigm was not guided in any way by the experimental apparatus or researcher, and therefore should reflect oculomotor planning as well as execution. Another possible reason for the weak relationship between eye movements and memory is that the information afforded by the oculomotor system is not as well-suited for informing recall as speech-based cues are for informing recall of verbal information. Furthermore, although rehearsal plays a large role in theorizing about short-term memory, it is important to note that it is not the sole process proposed to support memory in any working memory model. Even for verbal materials, the impact of rehearsal on recall may be limited (Lewandowsky & Oberauer, 2015), and models of working memory that assume rehearsal processes also assume that rehearsal is one of multiple functions available to support memory (e.g., Baddeley, 2012; Barrouillet & Camos, 2015; Cowan, 2005; Logie, 2011). Another way of explaining verbal short-term memory is to suppose that it emerges from speech planning and aural perception (e.g., Hughes, Chamberland, Tremblay, & Jones, 2016). Evaluating differences between the perceptual and motor affordances available for supporting spatial and verbal memories, which are likely not equivalent (e.g., Morey & Bieler, 2013; Morey & Miron, in press; Morey, Morey, van der Reijden & Holweg, 2013) may prove a rich source for theorizing about apparent differences between verbal and non-verbal immediate memories.

Our research shows that the conventional but controversial story of the emergence of strategic verbal rehearsal around age 7 cannot be extended to efforts to memorize more generally. Children 5-7 years old engaged in sequential looking during short-term retention and this behavior was as related to improved recall accuracy as it was in adults. These findings do not support the idea that young children do nothing to attempt to remember spatial locations. With increasing age, participants also spent less time during stimulus presentation fixating each incoming stimulus, a pattern believed to reflect covert cumulative rehearsal. These contrasting findings may be explained by supposing that young children *can* rehearse, but do not proactively begin rehearsing during stimulus presentation as older children and adults do (cf. Chevalier, Martis, Curran, & Munakata, 2015). Understanding that young children are not merely doing nothing, but instead engage in different mnemonic strategies than older children and adults use, should lead to beneficial changes in the ways in which we help children remember and learn. In confirming that rehearsal can occur in children under 7, our findings also offer hope that younger children may be induced to adopt beneficial proactive strategies.

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Table 1. *Mean fixation counts toward areas of interest during presentation and retention by age group.*

	5-7 year-olds	8-11 year-olds	Adults
Presentation			
Center	1.14 (0.80)	1.71 (1.03)	2.60 (1.58)
Object	5.13 (1.49)	5.52 (2.15)	5.73 (2.59)
Total	8.24 (1.76)	10.00 (3.01)	11.36 (3.41)
Retention			
Center	0.60 (0.86)	1.07 (1.43)	2.11 (2.01)
Object	10.59 (5.30)	12.68 (6.18)	13.89 (5.33)
Total	16.71 (6.23)	19.35 (6.70)	22.41 (4.56)

Note. Standard deviations in parentheses. Total includes fixations to central and objects areas, and fixations toward other non-target positions.

Figure 1

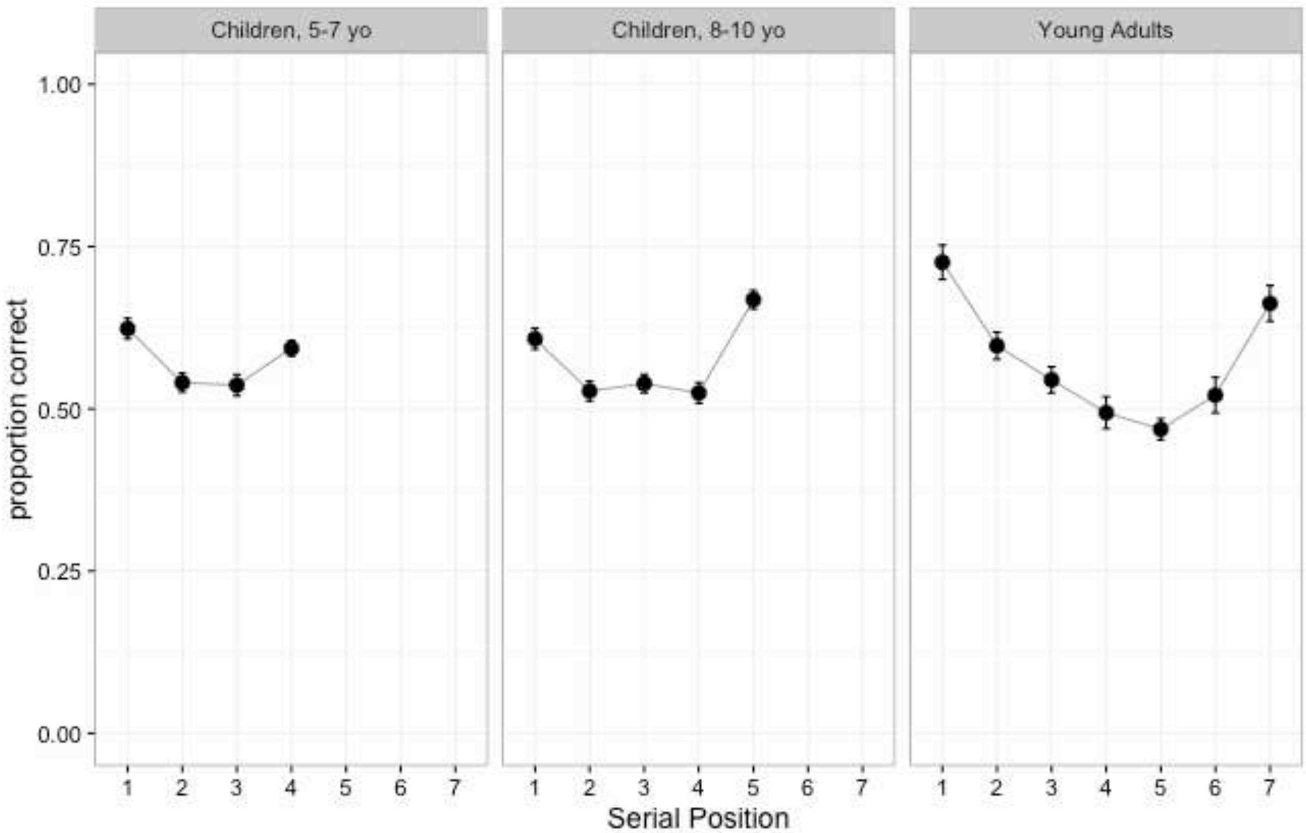

Figure 1. Serial position curves for young children, older children, and young adults. Error bars depict within-participants standard errors of the mean, with the Cosineau-Morey (2008) correction applied.

Figure 2

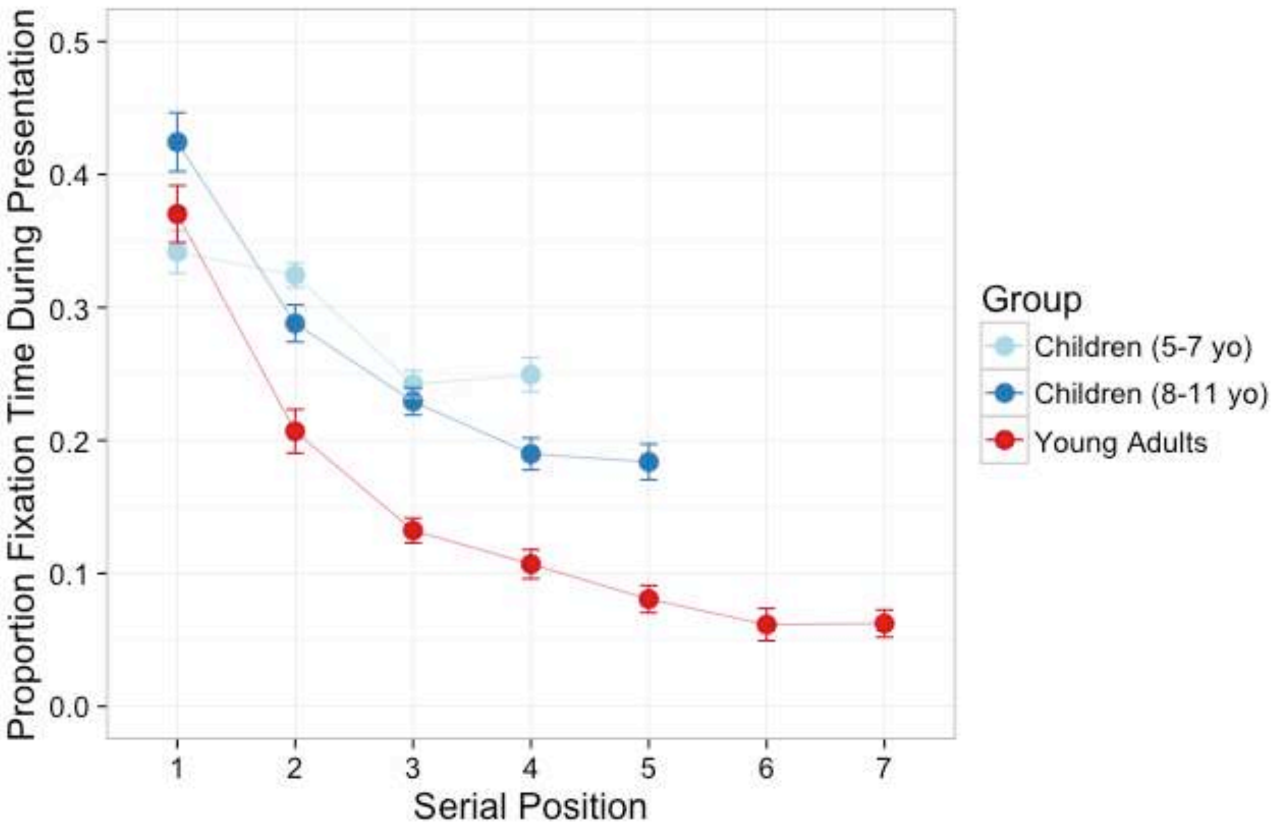

Figure 2. Mean proportion of the 750-ms presentation period for each position during which the presented position was fixated, by age group and serial order. Note that the position was only visible onscreen for the first 500 ms of each 750-ms period. Error bars are within-participants standard errors of the mean with the Cosineau-Morey (2008) correction applied.

Figure 3

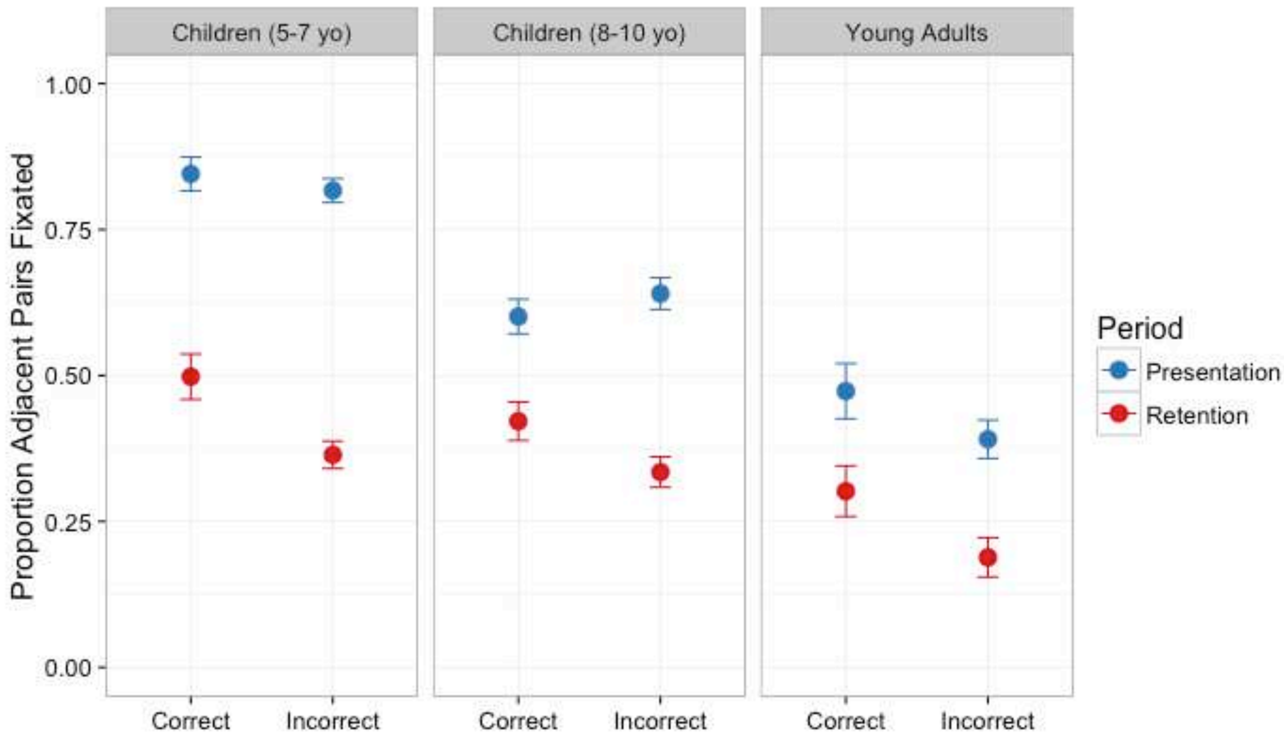

Figure 3. Average number of pairs fixated divided by the maximum possible for gazes recorded during presentation (blue) and retention (red), plotted by list-wise accuracy for each age group. Error bars are within-participants standard errors of the mean with the Cosineau-Morey (2008) correction applied.