Active control of study leads to improved recognition memory in children

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Abstract

This paper reports an experiment testing whether volitional control over the presentation of stimuli leads to enhanced recognition memory in 6- to 8-year-old children. Children were presented with a simple memory game on an iPad. During the study phase, for half of the materials children could decide the order and pacing of stimuli presentation (active condition). For the other half of the materials, children observed the study choices of another child (yoked condition). We found that recognition performance was better for the objects studied in the active condition as compared to the yoked condition. Furthermore, we found that the memory advantages of active learning persisted over a one-week delay between study and test. Our results support pedagogical approaches that emphasize self-guided learning and show that even young children benefit from being able to control how they learn.

Keywords: active learning, recognition memory, exploration, metacognition, inquiry learning, cognitive development.

Introduction

Research in both psychology and education has argued that the opportunity to exert active control over what is experienced during learning can lead to improved outcomes as compared to more passive forms of instruction (see Bruner, Jolly, & Sylva, 1976; Gureckis & Markant, 2012; Montessori, 1912; Piaget, 1930). In particular, past research has highlighted the important role of active control in cognitive development (Held & Hein, 1963). Self-guided learning is particularly interesting to consider from a developmental perspective because it requires the coordination of a range of cognitive processes including decision making, metacognition, attention, memory, and learning. However, it is currently unknown whether active control is associated with improved episodic memory during development, specifically early childhood. In this paper we explore the effects of active learning on episodic memory in 6- to 8-year-old children.

Recent experimental evidence with adults shows that active control of the learning experience can lead to improvements in episodic memory for objects (Harman, Humphrey, & Goodale, 1999; Voss, Galvan & Gonsalves 2011; Voss, Gonsalves, Federmeier, Tranel, & Cohen 2011; Voss, Warren, Gonsalves, Federmeier, Tranel, & Cohen 2011), faces (Liu, Ward, & Markall, 2007), and in spatial learning tasks (Meijer & Van der Lubbe, 2011; Plancher, Barra, Orriols, & Piolino, 2013; for a review see Markant, Ruggeri, Gureckis, & Xu, 2016), as compared to conditions lacking this control. Most of the studies investigating the benefits of active control for episodic memory adopt "yoked" experimental designs involving pairs of learners. In each pair, one person is the *active* participant, who controls the flow of information during learning (e.g., selecting what to study and for how long) and the other is the *yoked* participant, who observes the learning experience generated by the active participant. By matching the content experienced during study across conditions, yoked designs isolate the effects of active decision making on learning and memory. For example, Voss et al. (2011a; 2011b; 2011c) presented adult participants with a memory task involving a set of objects arranged in six 5×5 grids, with only one object visible at a time through a moving window. Participants alternated between active study blocks and yoked blocks. In active study blocks, participants controlled the study sequence and timing by deciding how to move the window, whereas in the yoked blocks they observed the study sequence a previous participant had generated in an active study block. Participants were then tested on two different components contributing to accurate memory encoding: Their recognition memory of the studied objects (whether they had been studied before or not) and their ability to recall the locations on the grid where the objects were presented during study. The results showed an advantage for the active study condition for both object recognition and spatial recall that persisted a week after the initial study session (Voss et al., 2011a). The authors also showed that the benefits of active encoding were influenced by participants' study patterns. Objects studied for longer durations (Voss et al., 2011a) and revisited more than once within a short period of time (Voss et al., 2011c) were recognized more accurately, but only in the active learning condition (i.e., recognition of objects studied in the yoked condition did not correlate with study time or with revisits).

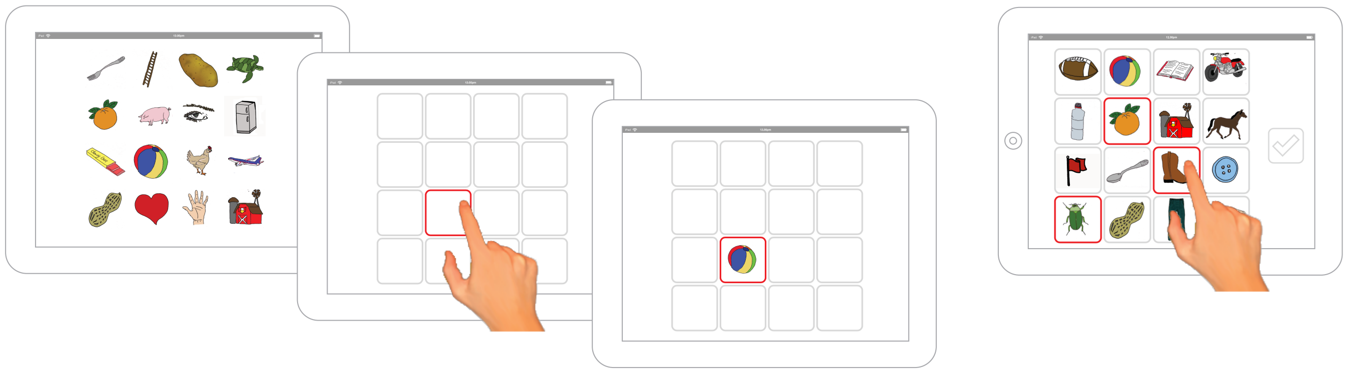

Figure 1. Each study round began with the objects displayed for two seconds. After the objects disappeared, the participant either selected a location to study (*active* condition), causing a red frame to appear, followed by the object, or clicked on the location where the object appeared (*yoked* condition), anticipated by a red frame. During each test block, participants clicked on objects that were recognized from the study phase.

Active learners in the above studies might have benefited from multiple levels of control over the study experience. For example, active study entails control over the content (i.e., choosing which object to study next), as well as the timing of the study sequence (i.e., when to move the window and for how long to study an object). In a series of experiments that varied the amount of control experienced during active study, Markant et al. (2014) found that active exploration (i.e., decisions about how to navigate the grid) was not necessary for the advantage from active study to emerge. Simpler forms of control (for example, merely controlling the timing of presentation for new objects) also led to a benefit in recognition as compared with yoked observation of the same study sequences, suggesting that multiple levels of active control contribute to improvements in episodic memory. Moreover, the authors showed that the active learning advantage for spatial recall was relatively inconsistent across different versions of the memory task, and their results did not support the correlation between recognition memory performance and objects visited more often or revisited after a short period.

The present study compares the effects of active and yoked study on episodic memory in 6- to 8-year-old children, using a variant of the task from Markant et al. (2014). Based on some of the previous literature, we expected that active control of study would generally improve learning outcomes in children. Indeed, Sim et al. (2015) showed that 7-year-olds learn more effectively when they are allowed to make decisions about what information they wish to gather, as compared to yoked observations. Previous findings also suggest that episodic memory, in particular, may benefit from the opportunity to actively control the learning process even at an early age. For example, active navigation has been shown to lead to memory improvements by age five (Feldman & Acredolo, 1979; McComas, Dulberg, & Latter, 1997; Poag, Cohen, & Weatherford, 1983), and self-directed learning has been shown to enhance short-term memory retention for novel object-word pairings in 3- to 5-year-old children (Partridge, McGovern, Yung, & Kidd, 2015).

However, there are also contradictory views in the literature. In particular, the benefits of active learning might crucially depend on children's use of metacognitive process to control study, as well as on their ability to implement successful studying strategies. Previous work suggests that the ability to allocate study time based on the difficulty or familiarity of the material develops over the course of childhood (Dufresne & Kobasigawa, 1989; Metcalfe, 2002; Metcalfe & Finn, 2013). For instance, although 6-graders demonstrate sensitivity to the strength of their own memories (Metcalfe, 2002), they are inefficient in controlling how long to study particular items in order to achieve the best level of recall. Given these conflicting results it is an open question whether active control would lead to benefits in episodic memory of 6- to 8-year-old children.

Method

Participants

Participants were 29 6- to 8-year-old children (15 female, M_{age} = 89.92 months; SD = 8.31 months), recruited in Berkeley, California, from a participants database. Due to technical difficulties, the data of three additional children were not recorded and therefore could not be included in the analyses.

Materials

Because some children might not have been familiar with some of the objects included in the original set of stimuli used by Voss et al. (2011a; e.g., accordion, chisel), we developed a new set of stimuli. Our set consisted of 192 line drawings of the most frequent objects mentioned by children younger than 5-year-olds in their everyday conversations, as recorded by the CHILDES database (MacWhinney & Snow, 1985), which includes transcripts of children's natural speech collected over many years.

Design and procedure

The experimental materials were presented as a simple game where children were tasked with remembering as many of the presented objects as possible. The design and procedure were modeled after Experiment 2 in Markant et al. (2014). However, we made several modifications to the previous design to make it suitable for children. First, all the stimuli were presented on an iPad touchscreen instead of a computer screen. To select objects, children did not have to use a mouse, but could touch the objects on the screen directly. We added two familiarization blocks at the beginning of the first experimental session, aimed at introducing the goal of the game and the study procedures, and at making children comfortable playing with the tablet. To reduce the total testing time and the general cognitive load experienced by children, the main experimental session consisted of two *active* and two *yoked* study blocks (four total blocks, instead of six as in the original study), presented in alternating order (i.e., active, yoked, active, yoked). The active block was always presented first, so that children's initial active study pattern would not be influenced by the study pattern observed in the yoked condition. Each study block included 16 pictures representing different objects (see Materials), arranged on a 4×4 grid (instead of 25 pictures arranged in a 5x5 grid as in the original study), so that, in total, children were asked to memorize 64 pictures.

In contrast to the original design, all 16 objects were shown on the screen for 2 seconds at the beginning of each study block, before disappearing under occluders (see Figure 1, left). In the active blocks, children had 90 seconds (instead of a minute, as in the original design) to study the 16 objects in order to memorize them. To study an object, the child touched the corresponding occluder button once. A red frame appeared for 500ms, followed by the removal of the occluder that would reveal the hidden object. Before studying another object, the child had to touch the current object once more to make it disappear behind the occluder. In each of the yoked blocks, children were presented with the 90-second video showing the same objects and study pattern of one of the previous children's active learning blocks, and had the same task (to memorize the objects). To keep their engagement and attention level comparable to the active blocks, during yoked blocks children clicked on the objects as soon as they appeared during the video, although this click had no effect on the display. As in the active blocks, a red frame preceded each object for 500ms so that children had time to allocate their attention to the new study location before the object appeared. At the end of each block there was a twenty second break in which children were briefly reminded of the study procedure for the next block.

The study phase was immediately followed by a test phase, comprised of 8 blocks. In each test block, 16 objects were presented in a 4×4 grid, as in the study blocks (see Figure 1, right). Across the 8 test blocks, 64 objects were *old* objects the children had studied, and 64 were *new* objects that were not presented during study. The proportion of old objects in each block was randomly determined and all objects were arranged in random locations in the grid. For each block, participants indicated the objects they had studied earlier by touching them on the screen. Selected objects were framed in red (see Figure 1, right) to help participants keep track of the objects selected as recognized. The children could deselect any of the previously selected objects by clicking them again and making the red frame disappear. When finished selecting objects, participants were prompted to click on a button to proceed to the next test block, until the last test block was completed. Children were not given any feedback about their performance during or after the test phase. Note that, to shorten the testing time, the test phase was radically different from that of Markant et al. (2014), where participants were presented with individual objects and asked whether they were "Definitely OLD," "Probably OLD," "Probably NEW," and "Definitely NEW." Moreover, participants in our study were not tested on their spatial recognition memory.

After about one week (range 6 to 15 days; $M = 8.45$ days; $SD = 1.93$ days), children came to the lab for a second experimental session in which they were asked to complete 8 new test blocks. The 64 objects studied in the first session were randomly mixed with 64 *new* objects (i.e., objects that were not presented during the previous session, neither as study nor as test objects), again placed in random locations in the grid. The testing procedure was identical to the test phase from the first session.

Results

Results were analyzed with respect to: (1) the number of objects recognized among the ones studied; (2) the *false alarms*, that is, the number of objects recognized in the test blocks that had not been presented in the study blocks; and (3) the correlations between study experience and performance, to test whether certain participants' exploration strategies and patterns lead to better recognition accuracy. In particular, we examined the correlation between the recognition accuracy for a certain object and the time spent studying it, as well as the number of times it had been visited during study. We also examined the correlation between participants' average recognition accuracy and the distance between subsequent study locations (that is, the average distance on the grid between the object currently visible and the one selected next), a basic measure of how systematically a child explored the grid. Finally, although we did not test participants' spatial recognition directly, we analyzed the correlation between the location on the grid of the objects in the study phase and in the test phase, to investigate whether participants were more likely to recognize an object when it was presented in the same location as in the study phase.

Because six children did not come to the lab for the retest session, we analyzed the data using mixed model ANOVAs with study condition (2 levels: active versus yoked) and session (2 levels: test versus one-week-later retest) as within-subject variables. We also analyzed the data using a univariate between-subjects ANOVA, considering the yoked pairs (i.e., comparing children's yoked study conditions with the active study conditions of the participants they were yoked to). Because we found no differences between these two sets of analyses, we only report the results of the mixed model ANOVAS.

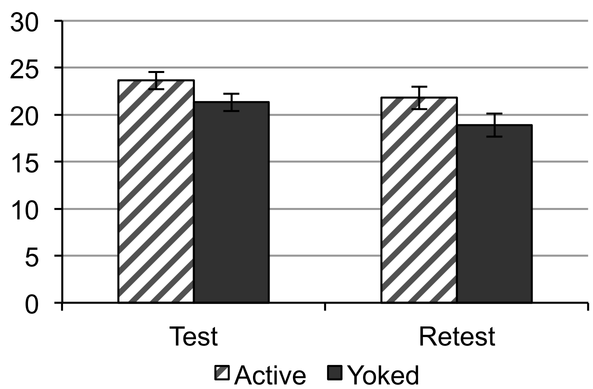

Figure 2. Number of objects correctly recognized in the test trials, displayed by study procedure (active vs. yoked) and session (test vs. retest).

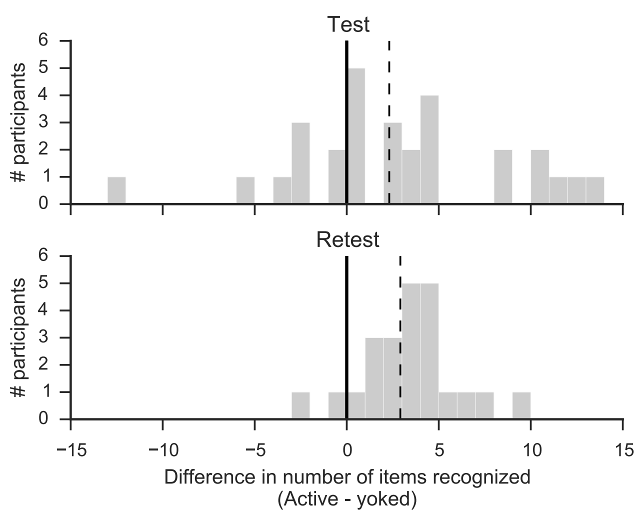

Figure 3. Distribution of within-subject differences in hit rate (active versus yoked) for studied items in the immediate test (top) and retest following a week delay (bottom). Dashed lines indicate the average difference.

Recognition of studied objects. On average, participants in the active study condition studied 30.45 (*SD* = .66) of the 32 objects presented (i.e., 95%).

The key analysis reveals a main effect of study condition, $F(1, 100) = 6.15$, $p = .015$. Children recognized more of the objects studied in the active study condition ($M_{active} = 22.81$; $SD = 5.31$) as compared to the objects studied in the yoked study condition ($M_{yoked} = 20.23$; $SD = 5.47$; see Figure 2), a 10% difference. The distributions of within-subject differences are shown in Figure 3. We also found a main effect of session, $F(1, 100) = 4.13$, $p = .045$. Children recognized more of the objects studied in the first test session ($M_{test} = 22.47$; $SD = 5.05$) as compared to the one-week-later retest session ($M_{retest} = 20.33$; $SD = 5.90$; see Figure 2). There was no reliable interaction effect between study condition and session ($p = .775$).

False alarms. We did not find a main effect of session on the number of objects recognized in the test blocks that had not been presented in the study blocks, $p = .122$. However, in general participants made more false alarms in the retest ($M_{retest} = 5.91$; $SD = 7.25$) as compared to the first test session ($M_{test} = 3.41$; $SD = 4.07$).

Correlations between study experience and performance. We found that object recognition accuracy was positively correlated with the time spent studying an object, as well as with the number of times the object had been visited, for both test and retest and for both the active and the yoked study conditions (see Table 1).

Active study condition				
Test	Correlations between tests			
	1	2	3	4
1. Accuracy in test				
2. Accuracy in retest	.459**			
3. Study duration	.212**	.174**		
4. Number of visits	.216**	.092*	.511**	
5. Distance from study position	.036	.013	.011	0
Yoked study condition				
Test	Correlations between tests			
	1	2	3	4
1. Accuracy in test				
2. Accuracy in retest	.448**			
3. Study duration	.139**	.142**		
4. Number of visits	.163**	.058	.412**	
5. Distance from study position	-.02	-.015	-.023	-.035

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 1. Correlations between the recognition accuracy in test and retest, time the objects were studied, number or times they were visited and distance between the position in which the object was presented on the study grid and its position on the test, for objects presented in the active (top) or yoked (bottom) study condition.

However, we found no correlation between recognition memory and the average distance between subsequent study locations (that is, the distance on the grid between the object currently visible and the one selected next), neither in the active nor in the yoked conditions, for either test or retest (ps > .1). Finally, we found that recognition accuracy was not correlated with the distance between the location in which the objects were presented on the study grid and their location on the test grid.

Discussion

The present study examined whether active control of what to study (specifically, of when, for how long and how many times to process an object to be memorized) leads to advantages in memory encoding for 6- to 8-year-olds. Using a memory task modeled after Markant et al. (2014), we replicated most of the results previously found with adults.

First, children's episodic memory is more accurate for objects studied in the active control condition as compared to the yoked condition where children could merely observe the active study pattern of a previous participant. Note that the yoked experimental procedure allows controlling for study content and timing, which are identical across the two conditions. The magnitude of the advantage of active control for memory encoding (10% increase over the yoked-study condition) is comparable to the effect found with adults across several versions of the same recognition task (6% to 10%; see Markant et al., 2014), suggesting that such benefits are stable across development, in addition to being robust across different versions of the same tasks (see Voss, 2011a; Markant & Gureckis, 2014).

Second, we found that the benefits of active control for episodic memory persist a week after the study session (see also Voss et al., 2011a). Future work will be needed to assess if the advantage of active learning increases over longer delays between study and test, as seems to be suggested by our current results (M_{test} = .91; SD = 5.49; M_{retest} = 2.82; SD = 2.59).

Third, we found that episodic memory is influenced by children's study patterns. Objects studied for a longer time and objects visited more often were recognized more accurately, even after a week. However, different from Voss et al. (2011a; 2011c) and consistent with the results of Markant et al. (2014), we found that the correlations are present for the objects studied in the yoked condition as well: Studying objects more than once and for longer time generally led to a better memory encoding, without such study patterns being more beneficial in the active control rather than in the yoked study condition. The presence of correlations in both conditions suggests that, as in Markant et al. (2014), attentional cueing (that is, the appearance of a red frame anticipating the presentation of the next object) might be enough to extend the benefits of longer study to the yoked condition.

Finally, we found that recognition accuracy is not correlated with the distance between the location in which the object was presented on the study grid and its location on the test grid. Having the objects presented in the same location on the grid across the study and test blocks does not help recognizing them more accurately, neither in the active nor in the yoked study condition. These results might speak, though indirectly, against a robust active learning advantage for spatial recall (see Markant & Gureckis, 2014). However, only a direct test of spatial memory would allow confirmation of this hypothesis.

Although these results are largely consistent with adult behavior, it could be that an advantage from active control emerges only later on in child development, possibly as a result of formal education. To explore this hypothesis, we are currently replicating this study with 5-year-olds. The data we collected so far (N = 12) suggest that the active control of study does not lead to advantages in episodic memory for preschoolers (Test: M_{active} = 21.66; SD = 5.03; M_{yoked} = 22.75; SD = 4.41; Retest: M_{active} = 17.00; SD = 6.63; M_{yoked} = 18.80; SD = 8.69). Although preschoolers seem to perform as well as older children in the test session, their episodic memory declines faster than older children.

To explore these developmental differences further, we plan to develop new versions of the memory task used in this study in order to identify the underlying cognitive processes responsible for the memory improvement across different age groups. A number of mechanisms may mediate the effects of active control on episodic memory (Markant, Ruggeri, Gureckis, & Xu, 2016). In particular, it is important to investigate whether the advantage of active learning for memory encoding depends on the efficiency of children's study strategies and metacognitive decision making (and therefore being possibly linked to formal education and schooling), or whether it persists when such processes do not play a prominent role. For instance, Partridge et al. (2015) compared active and passive performance in a word-learning task, in which active control entailed selecting items from a grid to learn their labels, whereas passive learning involved observing items in a predetermined order. Active choice was associated with improved accuracy in an immediate test, even though the number of study events and study time was constant across conditions. Moreover, it is crucial to examine more thoroughly the role of attention and motivation on the active learning benefit for memory encoding.

In conclusion, in this paper we demonstrated that active control of study leads to advantages in memory encoding for 6- to 8-year-old children. These results have general implications for informing educational practice, which is increasingly incorporating the model of inquiry-based learning, by helping develop more generalizable insights into the effective implementation of active learning in educational settings.

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