Benefits of active control of study in autistic children

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Abstract

Previous research with typically developing (TD) children and adults show an advantage of active control for episodic memory as compared to conditions lacking this control. The present study attempts to replicate this effect in autistic children. Six- to 12-year-old autistic children (n = 30) were instructed to remember as many of 64 presented objects as possible. For half of the materials presented, participants could decide the order and pacing of study (Active condition). For the other half, they passively observed the study decisions of a previous participant (Yoked condition). We found that recognition memory was more accurate for objects studied in the active as compared to the yoked condition, even after a week-long delay. The magnitude of the effect was comparable to that obtained in previous studies with TD children and adults, suggesting a strong robustness for the benefits of active learning. We discuss how pedagogical approaches may be encouraged to utilize self-directed learning strategies to promote inclusive learning.

Keywords: active learning; Autism Spectrum Disorder; Enactment Effect; recognition memory; pedagogy

Introduction

The opportunity to exert active control over the learning experience, often referred to as active, or self-directed learning, has been shown to 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, studies with adults show an advantage of active control for episodic memory of objects (Voss, Galvan & Gonsalves, 2011), faces (Liu, Ward, & Markall, 2007), and in spatial learning tasks (Plancher, Barra, Orriols, & Piolino, 2013; for a review see Markant, Ruggeri, Gureckis, & Xu, 2016), as compared to conditions lacking this control. A more recent study suggests that the benefits of active learning for episodic memory of objects might already emerge during early childhood, and become comparable to adults' by age 8 (Ruggeri, Markant, Gureckis, Bretzke, & Xu, 2019). Difficulties in active selection (and thus control) of the contents of learning may emerge in situations where exploratory behaviours are limited. In this paper we explore the effects of active control of learning on episodic memory in autistic children. The examination of atypically developing children might help to further understand the full spectrum of development (Graham & Madigan, 2016) and support the development of novel pedagogical approaches to promote inclusive learning.

Benefits of active control of study and enactment effect. To investigate the effects of active control for episodic memory, studies have typically employed *yoked* designs, which implicate a pair of learners: An active participant who controls the flow of information during learning (e.g., selecting what to study and for how long), and a yoked participant, who observes the experience generated by the active participant (Markant et al., 2016). By matching the content experienced during study across conditions, yoked designs isolate the effects of active decision making on learning and memory. For example, Ruggeri and colleagues (2019) presented 5- to 11-year-old children with a simple memory game in which they were tasked to remember and later recognize a set of 64 objects. For half of the materials presented, participants could decide the order and pacing of study (Active condition). For the other half, they passively observed the study decisions of a previous participant (Yoked condition). The authors showed that recognition memory was more accurate for objects studied in the active as compared to the yoked condition, and that this memory advantage persists over a week-long delay. This advantage of active learning has been shown to be fairly robust across different types of tasks, developmental stages, and even populations of learners of different nationalities (Brandstatt & Voss, 2014; Ruggeri et al., 2019).

Self-performed tasks (SPT) (Cohen, 1981) present a similar design: Participants are presented with action phrases (for example, “Clap your hands”) that they either have to read/perform (Active condition) or that are read/performed by somebody else (Verbal task/Experimenter performed task; Engelkamp & Zimmer, 1989). Participants are then usually tested through a recall or recognition memory task for the action phrases presented. Results from studies using the SPT have convergently indicated advantages for learning associated with the active condition (Engelkamp, 1998). For example, Baker-Ward and Colleagues (1990) found that children as young as six years old exhibited better recall for actions they performed compared to the observed actions of someone else. This effect, referred to as the e*nactment effect*, is extremely robust and is thought to improve memory mainly through motor actions (Engelkamp & Zimmer, 1998). Along these lines, Engelkamp and Zimmer (1994) found that participants, when they physically performed an action, remembered it better than when they just read a distractor phrase similar to the target action.

The ecological validity of self-performed tasks might be limited though, for instance, as SPTs use stimuli exclusively associated with specific actions. Yet, learning processes, particularly those based on recognition memory, involve interactions of different abilities, functions, semiotics, and experiences with a variety of stimuli. Furthermore, SPT paradigms make it difficult to isolate the sources of enactment effects as the content of the tasks differ across verbal, or experimenter performed conditions. As a participant remembers an action they performed more accurately it becomes challenging to separate motor involvement from other kinds of self-representation, for example. Aside from motor actions, there may be different factors influencing enactment effects like metacognition, attention, motivation, or agency. Further work incorporating different stimuli and target behaviors aimed at isolating motor involvement is needed to expand our knowledge on the function and implications of enactment effects in developmental and learning processes.

Learning strategies in autistic individuals. Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by persistent social communication difficulties as well as restricted interests, repetitive activities and sensory abnormalities (American Psychiatric Association, 2013). Autistic children seem to explore both space and objects less than others. In autistic children, restricted interaction with objects, or an insistence on exploring only a few features of an object may limit the possibilities for learning (Bjorne, 2007). As a consequence, autistic children might be at risk of missing important opportunities for learning, except for those things that lie within their interests, and this might have important consequences for their development (Pierce & Courchesne, 2001). Bondy and Frost (1994) indicate that 80% of autistic children, aged 5 years and younger, who enter special education are non-verbal, and 30% are minimally verbal at 9 years old (see also Anderson et al., 2007). Verbal tasks may thus not be the most methodologically appropriate to assess active learning in autistic children, considering their well-known communication and other general learning difficulties.

As memory enhancements from active learning paradigms seem to be extremely robust in typically developing individuals, research evidence suggests that the enactment effect may also be intact in autistic individuals (see; Grainger, Williams, & Lind, 2014a; Grainger, Williams, & Lind, 2017; Lind & Bowler, 2009; Summers & Craik, 1994; Williams & Happé, 2009). Summers and Craik (1994) found no significant differences in recognition memory for action-phrases between autistic and typically developing (TD) children from an SPT design. These results were confirmed in a study by Yamamoto and Masumoto (2018), who examined the enactment effect for recall and recognition memory in autistic adults and a TD comparison group through an SPT. They found that although overall recall performance was lower for autistic individuals than for the TD group, there were no differences in the enactment effect between groups. Overall, there seem to be no significant differences in the magnitudes of enactment effects for memory tests in autistic children compared to TD children (see Grainger et al., 2014a for a review), measured through research paradigms adopting self performed tasks.

The present study. The present study aimed to explore the benefits of active learning on episodic memory in autistic children by examining their recognition memory for objects studied in an active compared to a yoked learning condition. The design we have adopted is one step beyond the SPT paradigm used by previous studies to elicit the enactment effect, presenting several advantages: First, we used images of objects that are not explicitly associated with performing an intended action. Second, due to its yoked design, the content experienced during study was carefully matched across conditions, so that we could isolate the effects of active control of study on learning and memory. Third, participants were instructed to perform the same motor actions in both active and yoked conditions. In this way, we could also disentangle the effects of active control from the effects that, in SPTs, have often been attributed to motor engagement. Along these lines, a study by Williams and Happé (2009) designed a task in which autistic children were asked to self-perform an action and to perform the same action on behalf of a doll that represented a separate agent. The authors found that memory was better for the actions that had been self-performed, suggesting that even the enactment effect cannot be exclusively attributed to motor engagement.

Finally, a number of studies have revealed diminished recall but intact recognition memory in autistic individuals (see Boucher, Mayes, & Bigham, 2012 for a review). For this reason, we thought testing recognition memory would be a sufficient task to isolate the effects of active control. Moreover, evidence has suggested that adopting interactive teaching strategies (i.e. visual-interactive materials paired with music) enhances active engagement and learning of autistic students (Carnahan, Musti-Rao & Bailey, 2009). In this sense, the use of a tablet device, with an interactive interface, to assess autistic children who might have communication impairments might be particularly suitable to deliver the paradigm. Past research has also shown that autistic children seem to be more attentive, and motivated resulting in better performance and enjoyment of intervention sessions implemented through tasks involving technological tools (Moore, & Calvert, 2000). This task can reveal the non-verbal learning strategies adopted by autistic children. Our results will add further information on visual object exploration strategies, and contribute to a broader picture of active learning. Based on the literature reviewed above, we expected that autistic children would show active learning benefits to memory similar to that found in TD children of the same age (Ruggeri et al., 2019). In particular, with this design we can explore whether and how the effects of active control of study depend on how participants explore the objects. These insights would bear relevant implications for future research directions and clinical practice.

Method

Participants

We recruited 30 6- to 12-year-old autistic children (4 female, M_{age} = 113.17 months; *SD* = 19.89 months) from the Neuropsychiatry and Neuroscience Unit, I.R.C.C.S. Bambino Gesù Pediatric Hospital (OPBG), Rome, Italy. Participants had been previously screened for a formal diagnosis of ASD using the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). To minimize differences between participants, we recruited individuals who had scored between 5 to 8 out of 10 on the ADOS (*M* = 6.13; *SD* = 1.04). Once we re-ran the ADOS test with the subjects recruited, we excluded one participant who scored below 5. Participants were also previously screened for IQ (*M* = 109.20; *SD* = 13.43) using the Raven's Coloured Progressive Matrices (Raven, Court, & Raven, 1990). The data from 5 additional autistic children were excluded for reasons due to behavioral issues, symptom severity, and technical difficulties.

Materials

As in Ruggeri and colleagues (2019), the stimuli set consisted of 200 line drawings of the most frequent objects mentioned by 2- to 5-year-old children in their everyday conversations with adults, as recorded by the CHILDES corpus (Child Language Data Exchange System; MacWhinney & Snow, 1985). Eight of the 200 drawings were used as training stimuli for the familiarization trials and 192 drawings were used as stimuli during the first and second experimental sessions. The experimental materials were presented on an Android touchscreen tablet using custom software.

Design and Procedure

The experimental procedure was identical to that implemented by Ruggeri and colleagues (2019). The stimuli were presented as a simple memory game whereby children were tasked with remembering as many of the presented objects as possible.

Familiarization phase. Participants were first presented with two familiarization trials aimed at introducing the goal of the game, the study procedures, and making children comfortable using the touchscreen. During each familiarization trial, children were presented with four objects arranged in a 2x2 grid. The objects were shown on the screen for two seconds before disappearing under occluders (same as for the main experimental session, see Figure 1, top). Participants were instructed that the goal of the game was to remember all the objects presented on the screen. The first familiarization trial introduced the study procedure of the active blocks. Participants were told that in some rounds they could decide which occluder button to touch in order to view the object hidden beneath. After a touch, a red frame appeared for 500 ms, followed by the removal of the occluder that would reveal the hidden object. Children were instructed that, before studying another object, they had to touch the object currently displayed once more to make it disappear behind the occluder. The experimenter modeled the touching actions while explaining the procedure. Children then had the opportunity to practice the active study procedure. If necessary, the experimenter provided feedback and repeated the instructions. Once children were familiar with the active study procedure, they moved on to the second familiarization trial, which introduced children to the study procedure of the yoked blocks. They were told that in other rounds the game would decide what objects they would see and for how long. Children were then presented with a randomly generated study sequence. As in the active blocks, a red frame preceded each object for 500 ms so that children had time to allocate their attention to the new study location before the object appeared. To keep engagement and attention level comparable to the active blocks, during yoked blocks children were asked to touch the objects as soon as they appeared, although this touch had no effect on the display.

There were no time constraints for the familiarization trials.

Study phase. The main experimental session consisted of two active and two yoked study blocks (four blocks total), 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 blocks. Each study block presented children with 16 objects arranged in a 4x4 grid. All 16 objects were visible on the screen for 2 seconds at the beginning of each study block, before disappearing under occluders (see Figure 1, top). Across the four blocks, children were asked to memorize 64 objects. In the active blocks, children had 90 seconds to select and study the objects in order to memorize them. In the yoked blocks, children were presented with the 90-second study sequence (i.e., same objects and pacing) of one of the previous participant's active learning blocks. In between blocks, there was a 20-second break in which children were briefly reminded of the study procedure for the next block.

Test phase. The study phase was immediately followed by a test phase consisting of 8 blocks. In each test block, 16 objects were again presented in a 4x4 grid (see see Figure 1, bottom). Across the 8 test blocks, 64 of the objects had appeared during the study phase (old objects) and 64 were objects that were not presented during study (new objects). The number of old objects in each block was randomly varied between 1 and 15. The number of old objects from active and yoked blocks randomly varied across test blocks (active: *M* = 4:23, SD = 2:16; yoked: *M* = 4:3, SD = 2:25).

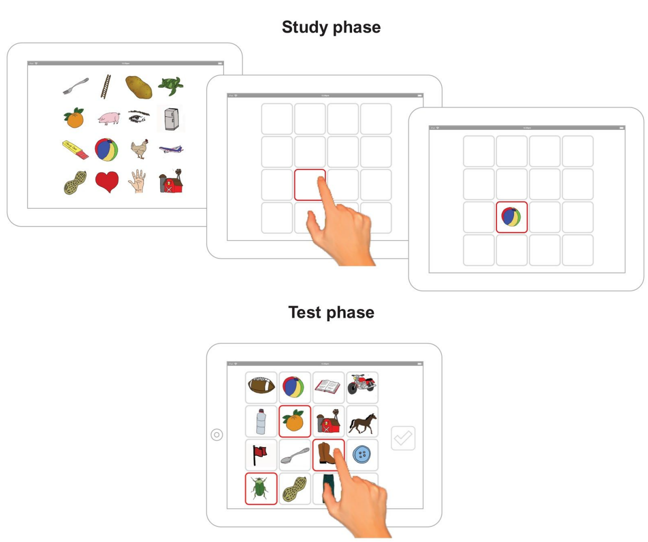

Figure 1. **Top:** Each study round began with all objects displayed for two seconds. After the objects disappeared, participants either selected a location to study (Active condition), causing a red frame to appear, followed by the object, or touched the location where the object appeared (Yoked condition), preceded by a red frame. **Bottom:** During each test block, participants selected the objects that they recognized from the study phase.

All objects were arranged in random locations on the grid. For each block, children were asked to indicate the objects they had studied earlier by touching them on the screen. Selected objects were framed in red to help participants keep track of the objects selected as recognized. Children could deselect any of the previously selected objects by touching them again on the screen and making the red frame disappear. After selecting all the objects they recognized from the study phase, children were prompted to touch a button to proceed to the next test block. Children were not given any feedback about their performance during or after the test phase.

About one week later (range 5 to 8 days; $M = 7.04$ days; $SD = 0.58$ days), children revisited the Hospital for a second 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 used during the first experimental session, neither as study nor as test objects).

Results

We analyzed (1) recognition accuracy (i.e., the number of objects recognized among the ones studied); (2) 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.

Recognition accuracy. We examined recognition accuracy using an ANOVA with study condition (2 levels: active versus yoked) and session (2 levels: test versus one-week-later retest) as within-subject variables. We found a significant main effect of study condition, $F(1, 81) = 16.44$, $p = < .001$. Children recognized more objects studied in the active learning condition ($M_{active} = 19.02$; $SD = 6.70$) as compared to the objects studied in the yoked condition ($M_{yoked} = 16.26$; $SD = 6.52$), a 9% difference (see Figure 2). We also found a significant effect of session $F(1, 82) = 19.09$, $p = < .001$. Children recognized more objects studied in the first test session ($M_{test} = 18.92$; $SD = 6.72$) compared to approximately one week later in the retest session ($M_{retest} = 16.22$; $SD = 6.51$). There was no reliable interaction effect between study condition and session ($p = .559$).

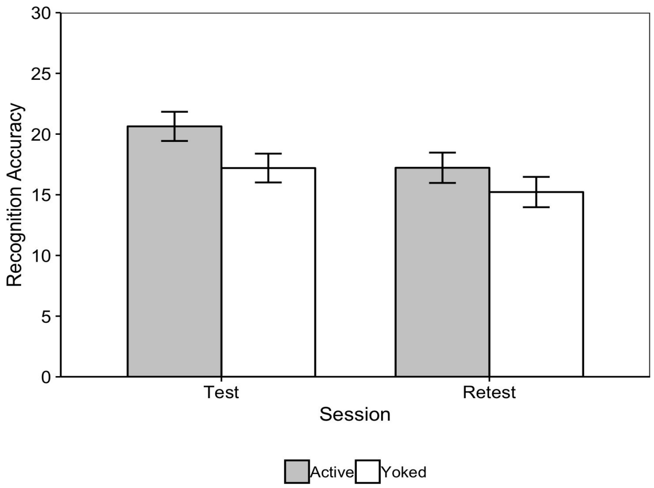

Figure 2: Number of objects correctly recognized in the test trials, displayed by study procedure (active vs. yoked) and session (test vs. retest). Error bars indicate 1 SEM.

Correlations between study experience and performance. Surprisingly, we found that object recognition accuracy was not correlated with the time spent studying an object, nor with the number of times the object had been visited in the active study condition, for both test and retest (see Table 1). However, we found a correlation between recognition memory for objects studied in the active blocks and the distance between the location in which the objects were presented on the study grid and their location on the test grid, $r = .577$, $p = < .01$.

Table 1: Correlations between study measures.

Active study condition				
	Correlations between tests			
Test	1	2	3	4
1. Accuracy in test				
2. Accuracy in retest	.810***			
3. Number of visits	-.093	.087		
4. Study duration	.099	.226	-.340	
7. Distance from study position	.577**	.363	-.242	-.184
Yoked study condition				
	Correlations between tests			
Test	1	2	3	4
1. Accuracy in test				
2. Accuracy in retest	.788***			
3. Number of visits	.067	-.088		
4. Study duration	.479*	.470	-.473*	
5. Distance from study position	-.067	-.356	.096	-.198

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
*** Correlation is significant at the 0.001 level (2-tailed).

Discussion

The present study investigated whether active control over a learning experience leads to benefits in episodic memory for 6- to 12-year old autistic children. As hypothesized, and similar to previous studies with TD adults and same-aged children, we found that participants' memory was more accurate for objects studied in the active learning compared to the yoked condition. Moreover, the strength of active control for memory encoding is strikingly comparable to the effect found with TD children from an identical recognition task (9% increase over the yoked condition; Ruggeri et al., 2019), and similar to that found in other studies examining the enactment effect in autistic individuals (see Grainger et al., 2014a for a summary). Thus, our results add to the universal robustness of active learning effects. Concurrently, this study complements and adds to the presence of the enactment effect in autistic individuals by employing an alternative paradigm to the commonly used SPTs. Considering our findings with respect to long-term memory, we found that memory improvement for objects studied by active control lasted for at least one week after testing. These findings lend support to established evidence suggesting improved long-term retention as a result of active control of learning (Ruggeri et al., 2019; Yamamoto, & Masumoto, 2018).

As mentioned in the introduction, bearing in mind possible mechanisms responsible for the active learning advantage, motor involvement has often been suggested to play an important role (Engelkamp, 1998; Markant et al., 2016). In experiments that implement SPTs, the participant enacts an action phrase like 'Wave Goodbye' in the active condition, and observes the experimenter performing a different action phrase in the passive condition. This idea (Engelkamp & Zimmer, 1989) supposes that performing an action involves motor components, which add rich contextual properties that help the encoding process of SPTs (Engelkamp, 1998). However, in our study participants are engaged in approximately the same motor actions in both active and yoked conditions. This result suggests that the process of physically performing an action is not necessary to scaffold memory performance.

Rather unexpectedly our results also seem to suggest, that episodic memory is not influenced by autistic children's study patterns, in both conditions. Objects studied for a longer time or visited more often were not recognized more accurately. This differs from all previous adults and children active learning studies that have used this paradigm (see Gureckis & Markant, 2012; Markant et al., 2014; Markant et al., 2016; Ruggeri et al., 2019). This might be related to the deficit in metamemory and metacognition demonstrated in autistic individuals (Grainger, Williams, & Lind, 2014b). That is, due to such deficits, autistic children may not have been strategically devoted to their study effort, allocating the same amount of time and visits to all object images. Therefore, we did not have enough variability to capture a correlational effect. It is extremely interesting to notice that the advantage of active learning for memory encoding does not seem to depend on the efficiency of children's study strategies and metacognitive decision making, and that it persists when such processes do not play a prominent role. Future studies should investigate more thoroughly the role of metacognition and metamemory, as well as attention and motivation on the active learning benefit for memory encoding.

Again in contrast with results from prior research, we found that recognition accuracy for object studied in the active condition is 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 did help children recognize them more accurately, but only in the active condition. These results might speak, though indirectly, in favor of an active learning advantage for spatial recall in autistic children. However, only a direct test of spatial memory would allow confirmation of this hypothesis.

The natural next step would be to extend this paradigm to include more real-world stimuli and tasks targeted to autistic children as well as other developmental disorders. For example, Ruggeri and colleagues (2019) designed a task to model real learning situations children encounter in school. Using a similar paradigm to our study, children were tasked to learn the French words for images of objects presented in a study space. The experimenters found that French words were remembered more accurately studied in an active as compared to a yoked condition. Based on this research, future studies might explore the role of active learning in learning new actions, words or behaviors. We are currently in the process of collecting a much larger sample, across different age groups and encompassing a wider range of symptom severity and cognitive maturity. On one hand, this would allow us to trace the emergence of the active learning advantage and compare the developmental trajectories of this effect in autistic and TD children. On the other hand, we are keen to explore whether and how general cognitive performance and symptom severity might impact the advantage of active learning and children's active study strategies, although previous research suggests that ASD traits do not impact memory for self-representations (Williams, Nicholson, & Grainger, 2018).

In conclusion, because autistic students often have difficulties participating in classroom activities (Sparapani, Morgan, Reinhardt, Schatschneider, & Wetherby, 2016), it is important to better understand how these children learn to improve and develop current and novel teaching methods. If active control over the learning experience can enhance episodic memory in ASD, then teachers and educators might think of supporting active learning approaches in pedagogical applications. Offering children with developmental disorders opportunities for concrete self-generated, active learning experiences could help promote greater learning outcomes (Haslam, Wagner, Wegener, & Malouf, 2017). Involving the student in their own learning can also be beneficial for reducing problematic behaviors, while at the same time improving skill acquisition (Toussaint, Kodak, & Vladescu, 2016). Alternative modes of teaching based on the use of images and pictures, rather than written words, are encouraging new therapeutic and instructional strategies for autistic children. Consequently, language and communication development devices (e.g. the Picture Exchange Communication System, PECS; Bondy & Frost, 1994) might aim to utilize active learning benefits to ameliorate memory.

Finally, this study tries to bridge atypical, developmental and cognitive research without relying on clinical variations to determine major differences between comparative groups. Rather, our results highlight that autistic individuals share the same memory advantage from active control of learning as TD individuals. This dimensional approach allows for researching *similarities* between typical and atypical groups, and while being as informative as revealing differences (Graham & Madigan, 2016), can support inclusive classrooms. Considering that active learning effects on memory are present in TD as well as autistic children, classrooms could adopt self-directed, active learning methods that would not only benefit both typical and atypical children, but also children who fall somewhere in between these categories.

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