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Event-based prospective memory in children with autism spectrum disorder: The role of executive function

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ABSTRACT

The present study investigated event-based prospective memory (PM) and its cognitive correlates in children with autism spectrum disorder (ASD) compared to age- and ability-matched typically developing (TD) peers. Participants included 25 children with ASD, 25 age-matched TD peers, and 28 ability-matched TD peers. Participants completed one PM task, and several executive functioning tasks assessing working memory (Block Recall Task), inhibitory control (Stroop Task), and cognitive flexibility (Dimensional Change Card Sorting Task). Results indicated that children with ASD had significantly lower scores on the PM task than children in the TD groups. Additionally, PM performance of children with ASD was significantly predicted by their nonverbal IQ, whereas PM performance of TD children was significantly predicted by their inhibitory control. These results provide evidence for the PM deficit in children with ASD and the effect of cognitive functioning, rather than a specific aspect of executive function, on the development of PM.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by socio-communication impairments, and restricted and repetitive behaviors. Many individuals with ASD also have impairments in executive functioning skills (see Hill, 2004 for review), and thus have difficulty with tasks that require planning, organizing, inhibiting behavior, keeping track of multiple things simultaneously, and keeping track of time. Day to day living skills, as well as some types of memory functions requires implementation of executive functioning skills.

One type of memory that requires executive functioning skills is prospective memory (PM). PM is the type of memory required to conduct future actions (e.g., McDaniel & Einstein, 2007; Williams, Boucher, Lind, & Jarrold, 2013). PM plays an important role in daily cognition and activities of daily living, ranging from relatively simple tasks (e.g., remembering to buy groceries) to more fundamental tasks (e.g., remembering to take necessary medication). There are two ways in which PM retrieval can occur, by an event, event-based PM, for example remembering to call a friend for their birthday; or by a specific time

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point, time-based PM, for example remembering to make a phone call in 20 minutes. Due to the presence of an external cue, event-based PM tasks are relatively simpler than time-based PM tasks, which require more self-initiation (Williams et al., 2013).

PM requires the integration of several complex processes. First, one has to plan the future action, and maintain the intention to complete the action while processing other information. Second, when either an event-based or a time-based cue is presented, one has to retrieve the PM, inhibit, and flexibly switch from an on-going task to the planned action (Kliegel, Martin, McDaniel, & Einstein, 2002). Therefore, successful PM requires a certain level of executive functioning ability, which typically involves three functional domains: working memory, cognitive flexibility, and inhibitory control (Altgassen, Williams, Bölte, & Kliegel, 2009; Mackinlay, Charman, & Karmiloff-Smith, 2006; Miyake et al., 2000). Impairments in these aspects of executive functioning have been highlighted in several studies of children with ASD (e.g., Cui, Gao, Chen, Zou, & Wang, 2010; Dichter et al., 2010; Ozonoff & Jensen, 1999; Prior & Hoffman, 1990; Yi et al., 2012). In light of these executive functioning deficits, it is reasonable to postulate that individuals with ASD would also have associated deficits in PM.

The few studies that have examined PM in individuals with ASD have had contradictory findings. While several studies have repeatedly demonstrated impaired time-based PM in individuals with ASD (Altgassen et al., 2009; Altgassen, Koban, & Kliegel, 2012; Williams et al., 2013), studies examining event-based PM have been less conclusive. Some studies have reported intact event-based PM skills in ASD (Altgassen, Schmitz-Hübsch, & Kliegel, 2010; Williams et al., 2013), while other studies have reported impairments (Altgassen et al., 2012; Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Jones et al., 2011). Two factors may be contributing to this discrepancy–heterogeneity of the sample and heterogeneity of the types of PM tasks used. Participants in the Altgassen et al. study (2012) were adults, while participants in other studies were primarily children and adolescents (Altgassen et al., 2010; Williams et al., 2013). In terms of task heterogeneity, tasks used in previous studies included standard PM tasks, such as the Red Pencil test, the Dresden Breakfast task (Altgassen et al., 2012), the Rivermead Behavioral Memory test (Jones et al., 2011), and several computer-based games (Altgassen et al., 2009; Williams et al., 2013). These tasks are varied in their nature and complexity, as such the performance of PM in individuals with ASD varied dependent on task difficulty. For example, in the Dresden Breakfast task, a naturalistic prospective memory task which has high demands on inhibition and switching, adult participants with ASD demonstrated more impaired event- and time-based PM performance than typical controls (Altgassen et al., 2012).

Despite its theorized relationship with PM, the exact role that executive functioning plays in PM in individuals with ASD has been difficult to establish. It has been postulated that event-based PM tasks have less of a demand for executive functioning than time-based PM tasks (Altgassen et al., 2012); as such, these skills may not be as affected when an individual has executive functioning deficits. In school-aged children with ASD, Williams et al. (2013) did not find a relationship between executive functioning and PM; and in adults with ASD, only time-based PM tasks were related to executive functioning skills (Altgassen et al., 2012).

An important aspect to consider however is the effect of age on executive functioning skills. These skills develop with age, and studies have found significant age effects on executive functioning in typically developing children (e.g., Kvavilashvili, Messer, & Ebdon, 2001; Somerville, Wellman, & Cultice, 1983). In a longitudinal study examining the development of executive functioning in typically developing children, Lee, Bull, and Ho (2013) demonstrated that the organization of these skills change from early childhood to adolescence, with older children having better developed inhibitory control. In ASD, while some executive functioning skills improve over time, it is at a slower rate, and it generally remains impaired compared to typically developing children (O'Hearn, Asato, Ordaz, & Luna, 2008). Thus, some of the differences observed across studies may in fact be related to the age difference of the participants, as executive functioning may play a more important role in the PM development in younger children. An alternative explanation is the possible effect of intellectual functioning on executive functioning skills.

Executive functioning skills are difficult to disentangle from cognitive skills. Many of the cognitive processes that are associated with intellectual functioning, for example working memory and processing speed also involve executive functioning skills. Studies have found that some aspects of executive functioning are associated with IQ. However, the previous studies that have examined the PM abilities of individuals with ASD have primarily included a homogeneous group of participants with average to above average cognitive skills (Altgassen et al., 2009, 2010, 2012; Brandimonte et al., 2011; Jones et al., 2011; Williams et al., 2013).

The current study has three aims: (a) to compare the performance of event-based PM in young children with ASD to their typically developing age- and ability-matched peers; (b) to investigate the role of executive functioning on event-based PM in young children with ASD with below average nonverbal IQ (NVIQ); and (c) to examine the role of age and cognitive functioning in the development of event-based PM in young children with ASD with below average NVIQ compared to age- or ability-matched typically developing peers. Based on the few studies examining PM in children with ASD, we expected that this young group of children with ASD would demonstrate poorer performance on the event-based PM task than their typically developing peers. Additionally, we expected that the PM performance in children with ASD would be related to cognitive functioning and to some aspects of executive functioning.

2. Method

2.1. Participants

Participants included 25 preschool or school-aged children diagnosed with ASD (range = 4–10 years, M_{age} = 7.66 years, SD = 1.56; 6 female), 25 age-matched typically developing children (TD; range = 4–11 years, M_{age} = 7.68 years, SD = 1.72;

Table 1
Participant characteristics of each group.

	ASD	Age-matched TD	Ability-matched TD
N	25	25	28
Male (*n*, %)	19 (76)	19 (76)	22 (79)
Age range	4.91–10.25	4.75–11.16	4.25–9.91
Age in years (*SD*)	7.66 (1.56)[a]	7.68 (1.72)[a]	5.79 (1.34)[b]
VMA (*SD*)	4.56 (1.73)	N/A	4.75 (1.07)
NVIQ-raw scores (*SD*)	21.12 (12.59)[a]	31.84 (11.68)[b]	21.43 (11.76)[a]
NVIQ-standardized scores (*SD*)	79.17 (21.83)[a]	91.12 (14.04)[b]	90.61 (13.80)[b]

Note. ASD = autism spectrum disorder; TD = typically developing. Differing superscripts in the same row denote means that differ significantly at $p < .05$.

6 female), and 28 ability-matched TD children (age range = 4–9 years, M_{age} = 5.79 years, *SD* = 1.34; 6 female). In order to match the nonverbal and verbal abilities of the ASD group to the TD group, we recruited younger typically developing participants, thus, these participants matched on NVIQ and verbal mental age (VMA). NVIQ was measured using the raw scores of the Combined Raven Test (CRT, second version, CRT-C2). VMA was measured using the Chinese version of the Peabody Picture Vocabulary Test, Revised (PPVT-R). See Table 1 for demographics.

All participants in the ASD group were previously diagnosed by experienced pediatric clinicians, and met the DSM-IV (American Psychiatric Association, 1994) diagnostic criteria for an autism spectrum disorder. As standardized diagnostic scales such as the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) have not been widely used in China, diagnosis was confirmed by using the Chinese version of the Autism Spectrum Quotient: Children's Version (AQ-Child; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008) and clinical judgment. The AQ has been used in several studies, and has demonstrated good validity in Chinese and Western populations (Brydges, Reid, Fox, & Anderson, 2012; Davis, Pierson, & Finch, 2011; García-Molina, Tirapu-Ustárroz, Luna-Lario, Ibáñez, & Duque, 2010). All children in the ASD group scored at or above the cut-off score of 76 on the AQ (range 76–114; mean score = 91.79 ± 10.48). Children with specific comorbid psychiatric disorders, severe intellectual disability, congenital deafness, and other developmental disorders were excluded from the ASD sample. Children in the TD groups were recruited from Chigangyuan Kindergarten and Ruibao Primary School in Guangzhou, China. None of the children in the TD groups were reported by their teachers or parents to have any identified or suspected disorders or impairments.

2.2. Materials and procedure

2.2.1. The PM task

The procedure used in the PM task from Kvavilashvili et al. (2001) was adapted for this study, as it was age-appropriate for the current sample. Participants were asked to name a set of cards (which mirrored an on-going activity), and to remember to perform an action when they saw the predefined target cards (event cue), thus creating a situation in which event-based PM is needed. In order to reduce the cognitive load of retrospective memory, remembering the content of the target cards, we simplified the task to adjust for the developmental level of our ASD participants. For the current task, participants were asked to perform an action (name the card and hand it to the experimenter) when they saw a red heart-shaped sticker on the target card, instead of memorizing the content of the target cards. The PM task consisted of 59 color-printed cards (10.6 cm × 10.2 cm), depicting one of the four following categories: objects (e.g., clock), natural scenes (e.g., mountain), animals (e.g., cat) and actions (e.g., running). Nine cards were used in a practice session (3 sets, 3 cards per set), and the other fifty cards were used in the experiment (5 sets, 10 cards per set). One card was randomly chosen as the target card for each set, and a red heart-shaped sticker was placed at the upper right corner of the target card in each set.

Participants were interviewed individually in a quiet room with an experimenter. A prize was awarded for correctly naming and handing the target card to the experimenter. Participants were asked to continue to name the rest of the cards in the set. The presentation order of the cards was randomized.

Participants were required to complete three practice sets (3 cards per set) to proceed to the experiment. The purpose of the practice session was to ensure that they understood the ongoing task and the PM task. Participants who failed to name the card or failed to hand the target card to the experimenter in the practice session were excluded from the sample. Participants were awarded 1 point per set for correctly handing the target card to the experimenter (*pass*); they were not awarded points if they did not correctly name and hand the target card to experimenter (*fail*). Therefore, PM scores could range from 0 (*all fail*) to 5 (*all pass*).

2.2.2. Executive functioning tasks

The role of executive functioning in children's PM performance was examined with several tasks: the Block Recall Task, the Day–Night Stroop Task, and the Dimensional Change Card Sorting (DCCS) task. These tasks measure spatial working memory, inhibitory control, and cognitive flexibility respectively.

2.2.3. The Block Recall Task

Working memory was measured using the Block Recall Task, following the procedure of the Corsi Block Tapping Test (Corsi, 1972; Kessels et al., 2000). In the Block Recall Task, nine red wooden blocks (25 mm × 25 mm × 25 mm) are dispersed randomly on a baseboard (30 cm × 21 cm). The experimenter tapped a sequence of blocks at the rate of one block per second and asked the child to reproduce the sequence by tapping the blocks in the same order as the experimenter. The initial spatial sequence included 2 blocks, and increased incrementally until the child was unable to reproduce two out of three trials of a given length. The block span was defined as the longest length the child passed. If children failed to pass the initial sequence, they would be tested with only one block (span = 1).

2.2.4. The Day–Night Stroop Task

Inhibitory control was measured by the Day–Night Stroop Task (Gerstadt, Hong, & Diamond, 1994; Lagattuta, Sayfan, & Monsour, 2011). The Day–Night Stroop Task involved using a set of cards with cartoon pictures featuring a sun, or a moon, presented randomly on a computer screen using the E-Prime software. Children were asked to say "day" when they saw the moon card and "night" when they saw the sun card. A four-trial practice phase was completed before the test phase. The 16-trial test phase began if the participant was correct in at least three out of four practice trials. Participant responses on this task were videotaped and coded by two trained coders. A response was coded as correct only if the correct answer was initially provided; later self-corrected answers were coded as incorrect. Response latency (RL) was defined as the duration of the interval between the onset of the stimuli and participant responses. The inter-rater reliability of response accuracy was tested using the percent of agreement ($r = 1.00$) and inter-rater reliability of the response latency was tested using the Pearson correlation ($r = .98$).

2.2.5. The Dimensional Change Card Sort Task (DCCS)

We used the DCCS task to measure cognitive flexibility; the protocol used by Zelazo (2006) was adopted for this study. Participants were asked to sort a series of cards, including the two-dimensional bivalent test cards and the target cards. The DCCS task consisted of three phases: the pre-switch phase, the post-switch phase, and the border phase. Children were instructed to sort the test cards by one dimension (e.g., color) in the pre-switch phase, and by the other dimension (e.g., shape) in the post-switch phase. The border phase began after children passed the pre-switch phase and the post-switch phase by correctly sorting at least 5 out of 6 cards in each phase. In the border phase, children were asked to sort cards by color if there was a border, and by shape if there was no border. To pass the border phase, children had to correctly sort at least 9 out of 12 cards. The DCCS score was defined by the phase the participant passed: if participants failed in the pre-switch phase, they received a score of 0; if only the pre-switch phase was passed, they received a score of 1; if both the pre- and post-switch phase were passed, they were given a score of 2; and a score of 3 was given if all phases were passed.

3. Results

All analyses were conducted using R and SAS. Significance was set at $p < .05$. As there was no variability in scores in the TD groups, all children earned the highest possible score, we conducted a series of Wilcoxon–Mann–Whitney tests to compare the PM performance between groups. The Wilcoxon–Mann–Whitney test is a nonparametric test used to compare differences between populations; this test does not require that samples are normally distributed, and is thus appropriate for the current sample. Participants in the ASD group performed poorer on the PM task than both the age- and ability-matched TD groups, $p < .001$, and $p = .008$ respectively; the age-matched TD children performed significantly better in the PM task than the ability-matched TD group, $p = .01$. A series of independent-sample one-way analysis of variance (ANOVA) found group effects on the Block Recall Task, $F(2,74) = 12.90$, $p < .001$, DCCS scores, $F(2,75) = 6.80$, $p = .002$, Stroop accuracy (ACC), $F(2,68) = 5.76$, $p = .005$, and Stroop RL, $F(2,61) = 6.31$, $p = .003$. Planned contrasts indicated that children with ASD performed significantly poorer on the Block Recall Task than participants in both the age-matched TD group, $F(1,74) = 25.80$, $p < .001$, and the ability-matched TD group $F(1,74) = 7.40$, $p = .008$. Interestingly, on the DCCS task, the ASD group had significantly lower scores than the age-matched TD group, $F(1,75) = 11.06$, $p = .001$, but did not differ from the ability-matched TD group, $F(1,75) = .12$, $p = .73$. The ACC of the Stroop task for the ASD group was lower than the ACC of both the age- and ability-matched TD groups, $F(1,68) = 8.91$, $p = .004$, $F(1,68) = 8.68$, $p = .004$, respectively. The ASD group took longer to respond on the Stroop task than age- and ability-matched TD groups, $F(1,61) = 12.26$, $p < .001$, $F(1,61) = 4.93$, $p = .030$. Table 2 lists the means and standard deviations for the PM, block span, DCCS, Stroop tasks.

Table 2
Mean and standard deviations of performance on the prospective memory (PM) tasks and Block Recall, DCCS, and Stroop tasks.

	ASD ($n = 25$)	Age-matched TD ($n = 25$)	Ability-matched TD ($n = 28$)
PM	3.60 (1.98)[a]	5.00 (.00)[b]	4.57 (1.20)[b]
Block Span	3.17 (.82)[a]	4.56 (1.00)[b]	3.89 (1.03)[b]
DCCS	1.96 (.79)[a]	2.72 (.54)[b]	2.04 (1.00)[a]
Stroop ACC	.80 (.27)[a]	.95 (.08)[b]	.94 (.09)[b]
Stroop RL	2.13 (.94)[a]	1.23 (.36)[b]	1.62 (.88)[b]

Note. Stroop ACC = Stroop accuracy; Stroop RL = Stroop response latency. Differing superscripts in the same row denote means that differ significantly at $p < .05$.

Table 3
Intercorrelations between the PM performance and age, NVIQ, block span, DCCS performance, Stroop ACC, and Stroop RL.

Ability-matched TD\ASD	1	2	3	4	5	6	7
1. PM	–	−.37	.52**	.45*	.34	−.048	−.098
2. Age	.29	–	−.31	−.34	−.30	−.51*	−.29
3. NVIQ	.34	.71**	–	.42*	.43*	−.23	−.08
4. Block Span	.11	.45*	.61**	–	.023	.19	.37
5. DCCS	.17	.46*	.42*	.40*	–	.012	−.13
6. Stroop ACC	.56**	.36	.34	.27	.27	–	−.72***
7. Stroop RL	−.39	−.32	−.23	−.42*	−.44*	.13	–

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Pearson correlations between PM tasks, age, NVIQ and executive functioning task performance were conducted for the ASD and ability- and age-matched TD groups respectively. Results indicated that PM performance for the ASD group was positively correlated with NVIQ, $r_p = .52$, $p = .008$, and Block Span score, $r_p = .45$, $p = .028$. For the ability-matched TD group, PM performance was correlated with their ACC in the Stroop task, $r_p = .56$, $p = .003$. No correlations were observed for the age-matched TD group. See Table 3 for results.

Stepwise multiple regressions were performed to examine the impact of age, NVIQ, block span, DCCS performance, Stroop ACC, and Stroop RL or RT on PM performance on the ASD, and the ability-matched TD groups. For the ASD group, NVIQ significantly predicted the PM performance and explained 21% of the variance in the PM performance, $R^2 = .21$, $t = 2.30$, $p = .032$. For the ability-matched TD group, the accuracy in the Stroop task was significantly predictive of the PM performance and explained 31% of the variance in the PM performance, $R^2 = .31$, $t = 3.20$, $p = .004$. Table 4 presents the significant predictors of the models.

4. Discussion

The aims of the current study were (a) to compare the performance of event-based PM in young children with ASD to their typically developing age- and ability-matched peers; (b) to investigate the role of executive functioning on event-based PM in young children with ASD with below average NVIQ; and (c) to examine the role of age and cognitive functioning in the development of event-based PM in young children with ASD with below average nonverbal IQ (NVIQ) compared to age- or ability-matched typically developing peers. Results of the event-based PM task indicated that children with ASD performed poorer compared to both age- and ability-matched typically developing peers. The current findings were consistent with the findings of impaired event-based PM in individuals with ASD (Altgassen et al., 2012; Brandimonte et al., 2011; Jones et al., 2011), but inconsistent with studies that have found intact event-based PM in individuals with ASD (Altgassen et al., 2010; Williams et al., 2013).

As previous findings regarding PM ability in ASD have been inconsistent, it is important to examine what factors may have contributed to the current findings. The PM performance in individuals with ASD may depend on the nature and complexity of the PM tasks. The present study used a classic PM task for children, which was age-appropriate and less complicated compared to previous studies, since we were targeting younger participants. Participant characteristics, such as age or NVIQ, may have also contributed to their PM performance. Previous studies used adults (Altgassen et al., 2012), 15-year-old adolescents (Jones et al., 2011) or 10-year-old children (Altgassen et al., 2009, 2010; Williams et al., 2013) with average IQ. In the current study, older typically developing participants scored higher than younger typically developing participants, which suggested that differences in PM skills may also be a function of chronological age. However, even after controlling for the age and IQ, children with ASD still had impairments on the PM task.

In terms of executive functioning skills, in the current study, children with ASD also showed impairments in the Block Recall Task and in the Day–Night Stroop Task, compared to age-matched and ability-matched typically developing peers. These findings were consistent with previous studies that have indicated impaired executive functioning in children with ASD (see Hill, 2004, for a review). However, in the DCCS task, while the ASD group scored significantly lower than age-matched typically developing children, there were no significant differences between the ASD group and younger

Table 4
Regression models predicting children's performance in the PM task.

Dependent variable	Variable	t	p	R^2	β
(a) ASD					
PM	NVIQ	2.30	.032	.21	.46
(b) Ability-matched TD					
PM	Stroop ACC	3.20	.004	.31	.55

ability-matched typically developing children. These findings suggest that while some aspects of executive functioning, such as working memory and inhibitory control, may be impaired in children with ASD compared to typically developing peers, some skills such as cognitive flexibility may be sensitive to other factors, such as age, and may develop later on regardless of the functioning level. Future studies should examine the developmental trajectory of different aspects of executive functioning in children with ASD with participants in a wider age range and with various executive functioning tasks.

We further investigated the role of age, IQ, and different aspects of executive functioning (i.e., working memory, inhibitory control, and cognitive flexibility) on the PM deficits in children with ASD. Results showed that the PM deficits in children with ASD were positively correlated with their NVIQ and working memory limitations. Children with ASD with higher NVIQ and better working memory performed better on the PM task. In order to perform a PM task, an individual has to keep in mind what to do in the present moment, and what to do in the future when the cue is retrieved. Thus, a certain level of working memory is required for the PM task, and as previous studies have indicated some individuals with ASD have impaired working memory (e.g., Cui et al., 2010). Our findings further indicated a correlation between the working memory deficits in children with ASD and their impaired PM performance. Stepwise regressions showed that the NVIQ significantly predicted the PM performance in children with ASD. Considering the intact PM in high functioning individuals with ASD with average IQ (Altgassen et al., 2010; Williams et al., 2013), and the impaired PM performance in mid-functioning children with ASD in our study, we speculated that cognitive functioning may also play an important role in the development of PM in children with ASD. This suggested that it is the general cognitive functioning that limits the PM performance in children with ASD, but not the specific aspects of executive functioning per se.

On the other hand, ability-matched typically developing children's PM development only correlated with and was significantly predicted by their inhibitory control. Typically developing children with better inhibitory control performed better in the PM task. This finding is consistent with Lee et al. (2013), which found that children's inhibitory control improved with age. PM tasks require children to inhibit the response tendency for the ongoing task when the target cue is presented, and to switch to the PM task. Thus, for TD children, their inhibitory control ability could play an important role in PM development.

5. Conclusions

In conclusion, the present study provides evidence for PM deficits with a younger and lower-functioning ASD group, and the important role of NVIQ in the development of PM in ASD. The study also suggests that executive functioning may play an important role in the development of PM in typically developing children, and that some aspects of executive functioning may be more sensitive to age than cognitive ability.

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