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Event-based prospective memory performance in autism spectrum disorder

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Abstract The purpose of the present study was to investigate event-based prospective memory performance in individuals with autism spectrum disorder and to explore possible relations between laboratory-based prospective memory performance and everyday performance. Nineteen children and adolescents with autism spectrum disorder and 19 matched neurotypical controls participated. The laboratory-based prospective memory test was embedded in a visuo-spatial working memory test and required participants to remember to respond to a cue-event. Everyday planning performance was assessed with proxy ratings. Although parents of the autism group rated their children's everyday performance as significantly poorer than controls' parents, no group differences were found in event-based prospective memory. Nevertheless, individual differences in laboratory-based and everyday performances were related. Clinical implications of these findings are discussed.

Keywords Autism · Prospective memory · Executive function · Visual cues · PDD

Autism Spectrum Disorders (ASD) are characterized by impairments in social interaction, communication and imagination along with restricted interests and activities [3, 66]. Moreover, the cognitive skill profiles of individuals with ASD are inconsistent. They show an uneven profile across Wechsler subtests [20, 29, 50]. This inconsistent cognitive profile is also reflected in executive function and retrospective memory tests. While planning deficits and impaired cognitive flexibility have been observed, inhibition seems to be rather spared [5, 33, 35, 53, 54, 57, 65]. Investigating different aspects of memory, several studies found impairments in free recall tasks that provide little memory support ([10, 12, 61], but see [43, 51]) whereas more supported tasks such as cued recall [7, 12] and recognition ([11]; but see [9]) seem to be spared (for an overview on memory research in autism see [6]). As Bowler et al. [8] pointed out this memory profile suggests involvement of the frontal and medial temporal lobes. For example, preserved recognition and reduced recall performance is associated with damage to the hippocampus [1, 14, 48]. Similarly, lesions of the frontal lobes can lead to a pattern of preserved and reduced memory performance [64] which is comparable to that observed in ASD [8]. Moreover, executive function deficits have been strongly related to the frontal lobes [32].

In contrast to retrospective memory, prospective memory (PM) has not been extensively studied in ASD. PM is defined as the delayed initiation of planned intentions at the appropriate moment [23, 37]. Everyday PM tasks in childhood include remembering to take the PE kit to school or remembering to go to piano lessons. Research on PM differentiates between different types of tasks according to their complexity and on the basis of the cue that signals the appropriate moment to re-instantiate the planned action. This cue may be an event (event-based tasks; e.g., picking up the PE kit when taking the satchel) or a specific time (time-based tasks, e.g., at 10 o'clock, [23]). In complex PM tasks an individual has to remember to perform a series of consecutive planned actions [38, 40, 59], whereas, simple tasks require a single, isolated act, typically pressing a designated key [22]. So far, PM in ASD has only been targeted in three studies. Farrant et al. [25] explored ASD

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children's strategies for "remembering to remember" and did not find any differences in comparison to controls. Two studies investigated PM performance; one used a simple, time-based PM task and one a complex multitasking paradigm [2, 46]. Mackinlay et al. [46] asked children to work on three interleaved tasks within a given time period and restricted by certain rules. Children with ASD had difficulties to plan, carry out and switch between different tasks and to inhibit rule-breaking. Using a simple time-based PM task, Altgassen et al. [2] found reduced performance in ASD as compared to controls. Analyses of participants' time-monitoring indicated that inferior PM performance was related to poorer self-initiated strategy application and task organization in ASD. Overall, individuals with ASD monitored the time less often and differed in their time-checking behavior from controls who increased time-monitoring more strongly when the target times approached. Importantly, time checking is postulated to indicate the amount of executive resources allocated to the PM task and to self-remind the individual of the planned action and hence, not to miss the target times [19, 39].

The reported deficits are not surprising given that successful prospective remembering involves retrospective memory (e.g., remembering what needs to be done and when) and executive functioning (e.g., monitoring for the prospective event or target time) and in both cognitive functions deficits in ASD have been found. Moreover, prospective remembering strongly relies on frontal and medial-temporal structures [17, 18, 63] which are assumed to be impaired in ASD. Importantly, frontally mediated (executive control) processes seem to influence PM performance more strongly than temporally mediated (retrospective memory) processes [15, 36, 49]. Thus, previous results fit nicely with clinical evidence of everyday difficulties of people with ASD. Across the entire spectrum individuals with ASD exhibit impaired organization abilities in daily life: They find it hard to coordinate and sequence activities and to plan ahead [46, 52]. This is reflected in childhood in poor time management and organization in school, for instance, children forget their homework at school [46] and in adulthood in difficulties to live independently (e.g., housekeeping, financial matters, [34]).

Up to now, event-based PM performance has not been investigated in ASD. This is surprising given that, in general, most studies on PM have focused on event-based tasks [13, 41]. With respect to ASD performance on simple, event-based tasks two predictions can be delineated. First, since prospective remembering typically involves executive control and retrospective memory and given empirical evidence of reduced performance in these functions in ASD, impaired event-based performance may be expected [37, 60]. Second, on the other hand, event-based PM tasks are very structured in comparison to time-based tasks or complex multitasking paradigms. Event-based tasks (mostly) provide visual cues (the event) that may prompt retrieval of the intended action and with this may put lower demands on self-initiated processing and thus executive control [21, 22]. In line with this argument, the provision of visual cues as part of interventions for ASD has shown to benefit individuals with ASD. For example, the TEACCH approach employs visual cues and environmental organization to train new skills and behaviors or to provide a structured, predictable environment that enables individuals with ASD to learn and contribute to class or work relatively independently [27, 58]. Importantly, cued recall is spared in ASD and hence, unimpaired event-based PM may be expected. However, this has not been investigated in ASD yet.

The present study set out to test those two alternative predictions (impaired versus spared performance). Therefore, the current event-based task closely followed Altgassen et al.'s [2] time-based task in which group differences had been found. Specifically, we used the same ongoing task and the only difference to the time-based task was that individuals were to press a designated key whenever the prospective cue was presented instead of at specific target times. As a second aim, the present study targeted possible relations between laboratory-based PM performance and everyday performance. To this end, participants' parents were asked to rate their children's difficulties with everyday executive functioning tasks. We expected ASD parents to rate their children's everyday performance as poorer than controls' parents. As a final aim the predictive value of laboratory-based test performance for individual differences in everyday life performance was explored. Here, we tested whether laboratory-based and everyday performance was related.

Method

Participants

Nineteen children and adolescents on the autism spectrum and 19 typically developing children and adolescents participated. Controls were parallel for age, gender and cognitive ability to individuals with ASD (see Table 1).

Nine individuals of the clinical group had been diagnosed with Asperger's syndrome and the rest with autism. All individuals with autism were high-functioning (IQ>85). Diagnoses were established through expert clinical evaluation in accordance with DSM-IV-TR criteria [3] and two structured diagnostic instruments, namely the Autism Diagnostic Interview (ADI-R, [45]) and the Autism Diagnostic Observation Schedule (ADOS, [44]). Individuals with ASD were recruited through local autism centers and controls

Table 1 Participant details

Variables	ASD M (SD)	Controls M (SD)	Statistical analyses	
Age	10.56 (3.38)	10.61 (3.86)	$F(1,36)=.003$	$\eta^2_p=.00$
Gender	1G, 18B	3G, 16B	$\chi^2(1)=.12$	
Vocabulary	9.63 (4.5)	11.79 (2.8)	$F(1,36)=3.47$	$\eta^2_p=.09$
Block design	10.11 (4.3)	11.00 (2.6)	$F(1,36)=.61$	$\eta^2_p=.02$

G girls; *B* boys

from the participants' pool of the Department of Psychology. The study was approved by the local ethic committee. Any human data included in this manuscript was obtained in compliance with the Helsinki Declaration. All participants and parents gave informed consent. Each participant was tested individually. Testing took about 1 h with a short break after 30 min.

Materials and procedure

Individual difference variables

As an assessment of participants' *verbal* and *nonverbal ability*, children were presented with the vocabulary test and the block design test (Wechsler Intelligence Scale for Children—Third Edition, WISC-III, [62]).

PM measures

Objective laboratory-based measures The ongoing task and PM task closely followed a procedure introduced by Altgassen et al. [2]. For the *ongoing activity*, participants performed a visuo-spatial working memory task in which they were presented with eight different symbols [55]. Participants were asked to remember the location of symbols, which were presented for 3,000 ms on an invisible circle (memorization interval). After a 1,500 ms long interstimulus interval (a colored blank screen), the same symbols were displayed for 3,000 ms (recognition interval), whereupon the screen turned black (intertrial interval). Participants were required to decide via keypress, whether the symbols were presented at exactly the same locations in the recognition trial as they were in the memorization trial (green button) or not (orange button). A new trial started after a response was made. The background color remained the same for one trial (consisting of memorization interval, interstimulus screen, recognition interval), but changed randomly for each trial (blue, green, red, pink). Each symbol appeared only once within one screen. Symbols and locations of symbols changed randomly.

After a brief explanation of the task with the help of a print-out, participants performed six *practice trials*. These practice trials consisted of three one-symbol and three two-symbol presentations. If participants did not respond correctly to at least four of six trials, a new practice block started until all tasks were correctly completed. In a next step, participants performed a *calibration block*. This was to adapt task difficulty to individual's ability level. The calibration block started with two trials with one symbol and increased in the number of presented symbols until the individual failed to correctly respond to both trials of a given symbol number or until a maximum of eight symbols was reached. For the rest of the task (single-task condition, dual-task condition) the participant was presented with the highest amount of symbols, where he/she had answered at least one trial correctly. After the calibration block an ongoing task block followed, that consisted of ten trials (*pure ongoing task block*; single-task condition). Dependent measures were accuracy (correct/incorrect) and reaction times.

In contrast to Altgassen et al. [2], participants were then given *event-based PM* instructions (e.g., see Park et al. [56] for a similar PM task). They were asked to work on two tasks simultaneously, the ongoing task and the PM task. For the PM task, they were to press the pink key whenever the background color changed to yellow. The PM task consisted of ten blocks; each of them comprised ten ongoing task trials (dual-task condition). Prospective cues appeared in block 2, 4, 5, 7, and 10. Dependent measures were accuracy (correct/incorrect) and reaction times. All described colored buttons were keys on a computer keyboard and part of the last line. Each colored button was one button apart from the next one.

Subjective everyday measure The DEX questionnaire measures *everyday executive function* problems such as planning, inhibition, temporal sequencing deficits, perseveration, distractibility and abstract thinking and is part of the Behavioural Assessment of the Dysexecutive Syndrome test battery (BADS, [67]). Items include, for example, "He/she has difficulty thinking ahead or planning for the future" or "He/she gets events mixed up with each other and gets confused about the correct order of events". Thus, the DEX is closely conceptually related to abilities needed for successful prospective remembering. In total, the DEX comprises a 20 item checklist on which proxies (here: parents) rate participants' everyday executive functioning on a 5-point Likert scale ranging from 4 (=*very often*) to 0

(= *never*). Higher Scores indicate a higher frequency of dysexecutive problems. The test manual presents negative correlations between the DEX and BADS total score (r=−.62, p<.01) and between the DEX and BADS subtests (ranging between r=−.31, p<.05 and r=−.45, p<.01) as indices of validity. Other studies have provided further evidence for the reliability (e.g., Bennett et al. [4]) and validity of the DEX (e.g., Burgess et al. [16]).

Results

Ongoing task performance

Overall, groups did not differ in task difficulty level, that is, in the mean number of symbols presented (ASD M=7.47, SD=1.34; controls M=7.68, SD=.95; F(1,36)=.31, p>.05, η^2_p=.01). Repeated measures ANOVAs were conducted to evaluate groups' ongoing task performance across single- and dual-task conditions. Regarding accuracy scores (correct/incorrect) a significant large-sized task-block effect emerged with both groups showing better performance in the single-task condition in comparison to the dual-task condition (F(1,36)=12.42, p<.001, η^2_p=.26). In contrast, no significant effects were revealed for group (single-task: ASD M=.88, SD=.12; controls M=.89, SD=.11; dual-task: ASD M=.81, SD=.11; controls M=.82, SD=.12; F(1,36)=.05, p>.05 η^2_p=.001) or interaction (F(1,36)=.01, p>.05, η^2_p=.000). Regarding reaction times no significant effects were found (single-task: ASD M=1696.49, SD=620.07; controls M=1402.75, SD=253.47; dual-task: ASD M=1494.84, SD=455.83; controls M=1392.86, SD=321.07; task block effect F(1,36)=1.36, p>.05 η^2_p=.04; group effect F(1,36)=3.3, p>.05 η^2_p=.09; interaction effect F(1,36)=1.11, p>.05, η^2_p=.03).

PM performance

ANOVAs on participants' *laboratory-based PM* performance revealed no group effects, neither for accuracy (correct/incorrect) nor for reaction times (Table 2). In contrast, regarding *subjective everyday* ratings significant large-sized group effects were indicated. Parents of the ASD group rated their children's performance as significantly poorer than controls' parents.

Correlational analyses were conducted to explore links between individual differences in laboratory-based and individual differences in subjective everyday planning measures. Significant relations between objective and subjective performance were revealed across the combined groups (PM hits with DEX r=−.36, p<.05) and for the ASD group (PM hits with DEX r=−.48, p<.05), but not for controls (PM hits with DEX r=−.31, p>.05). Better laboratory-based performance was associated with better everyday performance.

Discussion

The purpose of the present study was to investigate event-based PM performance in individuals with ASD as compared to age- and ability-matched controls in the laboratory and relate this to participants' everyday executive functioning performance. With respect to ASD performance on simple, event-based tasks two possible predictions were derived from the literature. Given previous findings of impaired PM performance (e.g., [2, 46]) and deficits in cognitive functions that have been associated with successful PM (e.g., retrospective memory, executive functions), reduced event-based performance could be expected [37]. On the other hand, in comparison to time-based tasks or complex multitasking paradigms simple, event-based PM tasks are very structured, and similarly to cued (retrospective) recall provide (here: visual) cues that may support retrieval of the intended action and put lower demands on self-initiated strategy application which may decrease executive control demands and thus enable individuals with ASD to preserved event-based PM performance [23]. Data clearly support the latter prediction, as no significant group differences emerged. Children with ASD were as good as neurotypical controls in event-based PM performance.

The present result is in accords with clinical evidence that shows that environmental support in form of visual

Table 2 PM performances

Tests	ASD M (SD)	Controls M (SD)	F-Value (df)	η^2_p
PM task				
Objective measures				
prospective hits (accuracy)	.48 (.46)	.59 (.41)	.55 (1,36)	.02
prospective hits (reaction times in ms)	2140.25 (1443.1)	2021.18 (1273.5)	.05 (1,24)	.002
Subjective measure				
DEX	41.54 (9.2)	21.64 (9.3)	43.89 (1,36)***	.55

***p<.001

structures may help individuals with ASD to complete everyday tasks and to live (more) independently [30, 58]. Moreover, from a conceptual point of view, the present findings support models arguing that event-based PM tasks not only put less demands on self-initiated strategy use, but even provide fewer opportunities for applying strategic monitoring approaches than time-based tasks [24, 42]. In time-based tasks there are defined time intervals in which clock checking is more important in order not to miss the critical target time (i.e., the last interval before the target time) and individuals who do bear this in mind typically show better PM performance [23]. In contrast, in event-based tasks the prospective target can appear any moment and there are no times in which monitoring might be more helpful. Thus, controls may not have outperformed the ASD group as they did not benefit as much from self-initiated monitoring as in the time-based task. One may argue that power was not sufficient to detect this group effect. However, effect size was small (η^2_p=.02 i.e. f=.125) and a power analysis based on this effect size showed that 253 participants per sample would have needed to be included for this group difference to become significant (when alpha=.05 and power=.80, see Faul et al. [26]). Thus, we may conclude that the insignificant group differences are not due to insufficient power and moreover, the small size of group differences does not point to a clinical relevant deficit in ASD. We acknowledge that this pattern is restricted to visual task material. Auditory or intermodal tasks may have been more sensitive detecting performance differences between groups since studies indicate difficulties in ASD in integrating complex audiovisual stimuli (e.g., [47]). This should be investigated in future studies.

As expected, ASD parents rated their children's everyday executive functioning as significantly poorer than controls' parents. Thus, while showing spared performance in a laboratory-based event-based task, based on these subjective ratings ASD children seem to be impaired in everyday tasks involving planning and cognitive control which are assumed to strongly influence PM performance. As to why no impairments emerged in the laboratory-based task in contrast to everyday performances, several reasons are possible. Planning and PM tasks in everyday life do strongly differ from laboratory-based tasks: They are more complex, open-ended and less structured. These differences in structure may underlie ASD's performance differences in and outside the laboratory since, in general, individuals with ASD greatly benefit from visual structure [30, 58]. Moreover, the event-based task may not have been sensitive enough to measure differences in children's performance. However, what argues against this explanation is that across both groups and particularly for the ASD group everyday and laboratory-based performances were significantly correlated and hence, children that demonstrated more deficits in daily life also performed poorer in the laboratory. This is remarkable because generally subjective ratings tend not to be correlated to objective measures in most memory domains [31]. This relationship was mainly driven by the ASD group which might indicate that an intact PM may be directly linked to more efficient (everyday) executive functioning in ASD (most likely especially to the planning and temporal sequencing components targeted by the DEX, but this needs to be examined further in future research). These findings are in line with previous research suggesting that especially executive functions and thus, frontal structures support prospective remembering in general (e.g., [36, 49]) and that these structures may underlie the memory profile of ASD in particular [8, 32]. Moreover, there was no ceiling or floor effect for event-based PM performance for both groups that may have prevented significance of differences.

Both groups were parallel for age and ability and thus, spared laboratory-based PM performance of the ASD group cannot be attributed to generally higher cognitive ability. Moreover, with respect to ongoing task performance both groups showed a similar dual-task effect with a reduced performance in the visuo-spatial working memory task when it had to be performed simultaneously to the PM task as compared to the ongoing task alone. Thus, the ongoing task seems to have been equally difficult for both groups. Possibly, a higher working memory load of the ongoing task may have led to larger group differences. However, ongoing task performance was not at ceiling and hence, data do not suggest that its working memory component was too easy. To allow for a greater generalization of findings, future studies should apply more complex prospective memory tasks and have a greater titration of working memory load.

The present study has important clinical implications. Possibly, the environmental support of event-based tasks may have enabled individuals with ASD to unimpaired prospective memory performance in the laboratory. The provision of visual cues and external structures may help people with ASD to complete everyday planning and memory tasks. This needs to be investigated by future studies.

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