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Event-based prospective memory in mildly and severely autistic children

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1. Introduction

Prospective memory (PM) is distinguished from remembering past information or retrospective memory, and refers to the ability to carry out a planned action in the future without any explicit prompts, for example, remembering to take a medication, post a letter or pay bills on time (Einstein & McDaniel, 1990; 2005). Intact PM is crucially important for the management of everyday activities not only in adults but in children as well. Indeed, children are routinely expected to remember to deliver messages, to put books away at the end of reading time, or to do homework and take it to school by the deadline (Altgassen, Schmitz-Hubsch & Kliegel, 2010; Kvavilashvili, Messer & Ebdon, 2001). Autistic children¹ are commonly reported to have difficulties in organizing and coordinating everyday activities and have a general impairment in the ability to plan ahead (Ozonoff & Strayer, 2001). These difficulties have been related to deficits in PM (Altgassen, Koban & Kliegel, 2012; Mackinlay, Charman & Karmiloff-Smith, 2006) and suggest that autistic children may be impaired in everyday PM tasks as well. However, there is a notable absence of studies on PM in autistic children. For example, in a recent comprehensive review of retrospective memory in autistic children, PM is not mentioned (Boucher, Mayes & Bigham, 2012). Interestingly, this review demonstrated a varied pattern of impairments in autistic children, with performance on some retrospective memory tasks (e.g., digit span, free recall of unrelated items and most notably cued recall) remaining intact when compared to controls. The review also emphasized the necessity of including children with more severe autistic symptoms in studies investigating memory.

Unlike retrospective memory, there are currently only a handful of studies on PM in autistic children and none have included a severely autistic group (Altgassen et al., 2010; Altgassen, Williams, Bölte & Kliegel, 2009; Brandimonte, Filippello, Coluccia, Altgassen & Kliegel, 2011; Henry et al., 2014; Jones et al., 2011; Williams, Boucher, Lind & Jarrod, 2013). These studies employed tasks based on the standard laboratory paradigm used in research with adults, i.e., based on Einstein and McDaniel (1990) and included autistic children and those with Asperger's syndrome, who were able to sit, and perform well in standard IQ tests. In the standard PM paradigm, participants are busily engaged in an ongoing cognitive task (often on a computer), which they have to interrupt on several occasions in order to carry out a PM task (e.g., pressing a key) either in response to a particular target event (e.g., a word) or at a particular time, which measure event- and time-based PM, respectively. The lack of severely autistic samples in these studies is therefore not surprising given: a) that

performance on standard IQ tests was employed as an exclusion measure, which may not be suitable or valid for those with severe autism (Burack, Larocci, Flanagan & Bowler, 2004) and b) the challenges that such tasks may pose for these children. The importance of choosing tasks which are engaging, suitable and appropriate for the age of children in PM research was noted by Kvavilashvili, Kyle and Messer (2008), and this is particularly pertinent for severely autistic children for whom even simple everyday activities can be challenging. Therefore, in this study, we investigated performance on several simple and engaging event-based PM tasks in mildly and severely autistic children to add to the little that is currently known about this population, both theoretically and to inform therapy. In comparing mild and severe autism groups to non-autistic controls, knowledge of PM in typically developing children would also be broadened. Below, we will briefly review the available literature on PM in mildly autistic children, discuss issues concerning appropriate matching when including into a study a group with severe autism, and outline aims and hypotheses of the study.

One of the first studies to investigate processes related to PM in autistic children was conducted by Mackinlay et al. (2006). Fourteen high functioning autistic children, including those with Asperger's syndrome, (mean age, 12 years) were given a test of multitasking (Battersea Multitask Paradigm) and were found to have deficits in the prospective organization of activities compared to younger, typically developing children with a mean age of 11 years. The few subsequent studies that followed this initial investigation have used mostly the standard Einstein and McDaniel, (1990) laboratory paradigm to study event- and time-based PM in autistic children.

In one such study, Altgassen et al. (2009) examined time-based PM in 11 children with high functioning autism and Asperger Syndrome (aged 7 – 15) and 11 typically developing children (aged 7 – 16) who had to remember to press a specific key on the keyboard once in every two minutes during the computer-based visuospatial working memory test (the ongoing task). Results showed that autistic children checked the time less frequently and produced significantly less correct PM responses than controls. In another study, using the same computer-based ongoing task, Altgassen et al. (2010) investigated event-based PM in 19 high functioning autistic children, including those with Asperger's syndrome, with a mean age of 10.5 years. The event-based PM task involved interrupting the ongoing visuospatial working memory task by pressing a key when the background changed to a certain color. Compared to the neurotypical control group, matched for age, gender and cognitive ability, no differences between groups were found. It was concluded that event-based PM may be preserved in autistic children, in contrast to impairments in time-based PM, demonstrated by Altgassen

et al. (2009), indicating that autistic children may have problems with self-initiated time checking rather than responding to target events.

This initial pattern was replicated by Williams et al. (2013) in one study using both an event-based and time-based tasks. Twenty one high functioning autistic children, including those with Asperger's syndrome, with good social response ratings and a mean age of 10.6 years were compared to 21 age and IQ matched neurotypical children. The ongoing task was modified to a more game-like context where coins were collected for points as a car was to be driven down a road on screen. The PM tasks involved pressing a key when a lorry appeared (event-based) and remembering to refuel the car every 60-80 seconds (time-based). Results showed that autistic children demonstrated impaired performance compared to controls only on time-based task, suggesting that event-based PM may be preserved in autistic children.

However, Brandimonte et al. (2011) found that 30 mildly to moderately autistic children, based on a mean Childhood Autism Rating Scale (CARS) score of 35.46 (Schopler, Reichler, DeVellis & Daly, 1980; Schopler, Reichler & Renner, 1988), performed less well than their age and IQ matched non-autistic peers ($n = 30$) on event-based PM. In this study, the computer-based ongoing task presented line drawings of objects including food and animals (80 trials in total), and children had to press a red key when they saw an animal and a green key when they saw an image of food. The PM task was to press a yellow key on presentation of the two target items (one from food and one from animal category), which occurred four times each. The discrepant findings of Brandimonte et al. (2011) may be explained by differences in memory and attentional demands of the tasks (i.e., two PM targets instead of one, the length of trials and motivation to do the task), or due to the slightly younger age of the children (some as young as 6 years). It may also be due to the differences in the symptomology of the autistic children as, in this study, none of the children had Asperger's syndrome and some had moderate symptomology.

Apart from Brandimonte et al. (2011) the only other study to test children with a range of autism diagnoses, including some children with more severe symptomology, was conducted by Jones et al. (2011). They investigated everyday memory including PM tasks in 94 autistic children with a mean age of 15.6 years. This group included 49 children with a diagnosis of childhood autism and 45 with other autism. They used four tasks from the Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn & Baddeley, 1985) to measure PM and retrospective memory, which were suggested to be more generalizable to everyday memory and better suited to the varied attentional and motivational abilities of the autistic group than standard computer-based tasks. Thus, retrospective memory was measured by showing a photo of a man and telling the child the man's

name (i.e., John Smith) and after a delay the children were asked to recall the name of the man. The PM tasks included the child observing the hiding of a pen and having to remind the experimenter of its location, and to collect it, upon hearing the words ‘we have finished the testing’. The second PM task required the child to ask ‘What is the time?’ when an alarm sounded during the session. In the final task the children had to follow a route demonstrated by the researcher around the room and to pick up an envelope.

Results showed that autistic children and controls did not differ in the retrospective name recall task, which supports some previous findings with other simple retrospective recall tasks (Frith, 1970a, 1970b; Hermelin & O'Connor, 1970). However, in line with Brandimonte et al. (2011), autistic children were found to be impaired in event-based PM, specifically in remembering to remind the researcher about the location of the pen and in asking what the time was when the alarm sounded. It is also interesting that Jones et al. (2011) reported a negative association between the severity of autistic social and communication behaviors and event-based PM performance. However, one important confound in this study, as pointed out by Williams et al. (2013), was that Jones et al. (2011) did not exclude from the analysis children who could not remember the PM tasks after being prompted, which indicates that these children forgot due to a retrospective memory failure to retain PM instructions. When Williams et al. (2013) excluded these children from the analyses reported by Jones et al. (2011), the group differences on event-based PM tasks disappeared.

Finally, Henry et al. (2014) investigated cognitive variables such as IQ, executive control and self-direction in relation to PM functioning using time-based and event-based tasks. High functioning autistic children, including those with Asperger’s syndrome, were compared to typically developing peers and differed only on time-based PM tasks (not event-based PM). The results showed that of the cognitive variables, only IQ correlated with PM performance and only with time-based PM tasks. Findings also suggested that retrospective memory did not explain the PM performance of autistic children.

In summary, the available literature shows that time-based PM is impaired in high functioning autistic children as demonstrated by Altgassen et al. (2009) and Williams et al. (2013), who used very different ongoing and time-based tasks but obtained similar results. The significant impairments in time-based PM have been also obtained in a sample of adults with ASD (Altgassen et al., 2012; Williams, Jarrold, Grainger & Lind, 2014), which further supports the idea that time-based PM is impaired in mildly autistic individuals, irrespective of their age. In contrast, findings concerning event-based PM are mixed. Altgassen et al. (2010) and Williams et al. (2013) did not find any impairment in event-based PM in mildly autistic children. Similarly, in the a more naturalistic study of Jones et al. (2011), no group differences emerged between ASD and control children after

participants who could not remember PM instructions were excluded (see Williams et al., 2013). However, a significant impairment in event-based PM was obtained by Brandimonte et al. (2011). Similarly, in two studies with adults, event-based deficits were found in autistic participants, compared to matched controls (Altgassen et al., 2012; Kretschmer, Altgassen, Rendell & Bölte, 2014).

Therefore, it is currently unclear whether event-based PM is impaired in mild autism. Indeed, deficits reported by Brandimonte et al. (2011) could be due to reliance on demanding computerized tasks, such as having two PM target events (instead of one) and a fairly long and demanding ongoing categorization task (80 trials), which could have been disproportionately difficult for autistic children. In addition, the PM tasks did not seem to have any personal relevance and/or interest to children, even when more naturalistic non-computer based tasks were used by Jones et al. (2011) and Altgassen et al. (2012) (e.g., why would children want to ask ‘what is the time’ in response to a bell ringing, or to repeat the words ‘red pen’ upon hearing them during the session?).

On the other hand, it is possible that event-based PM is impaired in severely autistic, but not mildly autistic children. Indeed, Brandimonte et al., (2011) is the only study that did not include children with Asperger’s Syndrome, and tested children whose mean Childhood Autism Rating Scale (CARS) score of 35.46 fell into moderately autistic range. It is therefore possible that impairments in event-based PM reported in this study were not due to task difficulty as mentioned above, but the fact that this study used a group of more severely autistic children.

Therefore, to answer the question whether event-based PM is impaired or not in autism, we conducted a study that included, for the first time, a group of severely autistic children in addition to mildly autistic children and typically developing children. However, including severely autistic children in a study poses several challenges, which perhaps explain why this group has rarely been studied within autism research. Severely autistic children can experience impaired communication and social skills, alongside impaired attentional capabilities, complex sensory needs (i.e. may have an over sensitivity to light, noise, touch etc.), repetitive self-stimulatory behaviors (head banging, hair pulling etc.) and high levels of anxiety (American Psychiatric Association, 2013). Therefore, the selection of experimental tasks that they are able to complete becomes of paramount importance to ensure that they have the necessary understanding and motivation to complete these tasks and that they are not disproportionately disadvantaged in comparison to typically developing children.

The second and even more challenging problem concerns matching the severely autistic children with controls. Although there are debates about matching autistic children and typically developing children, it is a standard practice to match on gender and mental age (IQ and in some cases verbal ability) to ensure that any differences obtained between the groups is due to autism status rather than age and/or mental abilities (Jarrold & Brock, 2004; Mottron, 2004). However, the demands of standard IQ tests such as WASI (Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999) or even BPVS (British Picture Vocabulary Test; Dunn & Dunn, 2009) make this type of matching unsuitable for severely autistic children due to their communication, attentional and motivational deficits (see Hoekstra, Happé, Baron-Cohen & Ronald, 2009 for a discussion of issues and clinical ascertainment bias).

Potentially because of these issues, investigations have so far primarily focused on mildly autistic, and/or cognitively high functioning children and we know almost nothing about the performance of severely autistic children. This has not gone unnoticed in the literature and Burack et al. (2004) argue that rather than circumventing research in severely autistic children, there is a need to creatively adopt matching criteria guided by specific research goals which would enable more severely autistic groups to be included.

Thus, to include our group of severely autistic children, the majority of whom were unable to complete standard IQ tests, we measured children's cognitive abilities via their educational attainment on National Curriculum (NC) assessments. These are routinely conducted in UK schools by teachers with the advantage of continuous observation and assessment in the familiar school-environment (Kasari, Brady, Lord & Tager - Flusberg, 2013). Instead of a single measure of vocabulary or IQ, these tests provide scores on numerous cognitive and language abilities which correlate strongly with the cognitive aptitude test (intelligence measure) previously used in schools and equally predict academic achievement and other outcomes, thus providing a reliable and valid measure of cognitive abilities (Schagen, 2007).

It is inevitable that in matching the developmentally delayed severely autistic children with the typically developing children on cognitive functioning as specified above, the mean chronological age of the typically developing children will be lower than the autistic children. Bearing in mind that the choice of tasks should be suitable for all the children (including the ongoing tasks), matching by chronological age would be inappropriate as typically developing children would perform at ceiling and meaningful statistical analysis could not be performed.

In this study, the purpose was to compare the performance of children clinically diagnosed with autism with severe autistic symptoms/behaviors, to those with mild autistic behaviors as measured by the CARS, as

well as to typically developing controls. The tasks in this study were therefore purposefully simplified and made to be naturalistic to ensure that the task demands were suited to the varied attentional and motivational abilities of all the children, including the autistic groups, so that all the children had every chance of succeeding in the tasks. For example, the Rivermead appointment task was modified so that rather than hearing an alarm bell and remembering to say 'what is the time' to the researcher, a more familiar clapping to music game was employed. This task included music as the cue for the children to clap along with a hand puppet. The reward task was also motivational across all groups, providing participants with a desirable toy, which they had to remember to collect. In addition, a PM task based on Kvavilashvili et al. (2001) used a puppet to provide a purpose for the task and the children were required to feed the puppet. These games were interspersed with the distractor game which included the hand puppet and provided visual, auditory and kinesthetic sensory stimulation in-between the PM tasks.

On the basis of using these naturalistic PM tasks, we expected that the typically developing children and mildly autistic children would perform similarly and that the severely autistic children would perform less well, given that studies that included some moderately autistic participants (Brandimonte et al., 2011) found differences in event-based PM. Furthermore, in line with Jones et al. (2011), we expected all groups to perform similarly on the retrospective memory task. Finally, we explored whether severity of autism symptoms correlates with performance on PM tasks in autistic children.

2. Method

2.1 Participants

Twenty-eight autistic children (27 males) participated in the study, ranging in age from five to thirteen years ($M = 9.97$, $SD = 2.06$). All the participants had received a formal clinical diagnosis (DSM IV) for autism. This diagnosis was supported by teacher assessment using the CARS (Shopler et al., 1988), which has been shown to identify autistic children from other populations and reliably distinguish mild to moderate from severe autism. The CARS is a standardised test developed over 15 years on the basis of 1,500 autistic children and measures development in the areas of social, language and communication, playing and imitation, emotion, and auditory, visual and haptic responses. Specifically, CARS measures core deficit behaviors in the relationship to people, imitation, emotional response, body use, object use, adaptation to change, visual response, listening response, taste-smell-touch response and use, fear and nervousness, verbal communication, non-verbal communication, activity level, level and consistency of intellectual response and general impressions. The

measure quantifies the severity of behaviors (symptoms) associated with autism with each item/behavior rated on a scale from 1 (age-appropriate behavior) to 4 (severely autistic behavior) in 0.5 increments. The scores range from 15-60 and the lower end (mild autism symptoms) cut-off score of 25 is said to be appropriate and commonly used clinically for younger children (Chlebowski, Green, Barton & Fein, 2010), whereas for adolescents the cut-off score is suggested to be 27 (Mesibov, Schopler, Schaffer & Michal, 1989). The cut-off score for severe autism symptomology is above 36. Based on the total composite CARS score, the autistic children were allocated to one of two groups: Mild symptom severity (Mild Aut; $n = 14$) with a mean score of 30.29 (range 24 to 34) and severe symptom severity (Severe Aut; $n = 14$) with a mean score of 42.25 (range 36-55)².

All participants were recruited either through an autism family support group, or through schools. The severely autistic children had the characteristic deficits of severe verbal and nonverbal social communication, highly restricted and repetitive behaviors and extreme (hyper/hypo) sensitivity to sensory input. They had minimal verbal ability, used single words, signs or symbols in a solely functional capacity, and regularly failed to engage in social interactions. They had a need for routine and predictability, and found change highly distressing. Their complex sensory deficits included being over sensitive to light, noise, touch etc. Distress and anxiety often resulted in repetitive self stimulatory behaviors (head banging, hand flapping etc). These characteristics were evident in the high CARS scores, which were most frequent for the categories of emotional response, fear and nervousness, adaptation to change, listening response and general impression. The children with severe autism were able to understand simple instruction, supported in some cases by key signs and effective scaffolding (e.g. "Can you remember his name? His name is.....?"). Comprehension was determined by the ability to successfully repeat a requested action after demonstration.

There were 26 typically developing children (16 males and 10 females), aged 5 to 6 years ($M = 5.50$, $SD = 0.27$). The typically developing children had no diagnosis or history of learning or psychological impairment and their typical development was supported by teacher report.

The autistic children and the typically developing children were matched using a measure of children's cognitive and educational abilities from their teacher-assessed NC assessments³ and corresponding point scores to facilitate analysis (Pott, 2011). The NC assessments we selected are categorized as reading, writing and number, measuring abilities such as receptive and expressive vocabulary, language comprehension and production, number skills and problem solving. For reading, the skills include vocabulary understanding and use of simple language, reading for meaning and understanding main events, ideas and characters. Writing skills

include the use of simple words and phrases to convey meaning, joining ideas together, using and talking about ideas for writing. Number skills include mental problem-solving and explaining the answers, visuo-spatial problem solving, pattern repetition, measuring, estimating and the understanding of 2D and 3D shapes. A one-way ANOVA confirmed there were no significant differences between groups on measures of educational attainment, including reading, writing, and number skills ($p = .41$, $p = .15$, $p = .19$ respectively, all $F_s < 1.93$).

Table 1. Participant characteristics and national curriculum point scores^a.

Group	Sex		Mean Age (SD) Range	Reading	Writing	Number
	F	M		Mean (SD) Score	Mean (SD) Score	Mean (SD) Score
Severe Aut. <i>N</i> = 14	1	13	9.30 (1.95) 6;0 - 14;5	9.21 (5.67)	7.36 (4.50)	9.43 (5.89)
Mild Aut. <i>N</i> = 14	0	14	10.05 (2.55) 5;5 - 15;5	11.42 (6.43)	9.28 (4.56)	12.50 (7.06)
Typically Developing <i>N</i> = 26	10	16	5.05 (0.27) 5;10 - 6;5	9.85 (1.78)	9.54 (1.73)	10.12 (1.40)

^a TD (typically developing children) were at norm.

2.2 Materials and Procedure

A distractor task was employed several times throughout the testing session, for which the game ‘Wac-a-mole’ was used; this included a small square-shaped base from which moles would pop up, and two toy hammers, colored either green or red, with which to hit them. For the ‘Feeding’ PM task, ten plastic food items were used; for the practice trial, two extra food items were used as well as the target item (grapes), which were reused for the subsequent trials. The wide variety of different food groups (including fruit, vegetables, pastries and fast food) and food colors and dimensions (which ranged in length from approximately 7cm (strawberry) to 12cm (the ice cream) reduced the distinctiveness of the target item. Each food item was concealed within a 31cm x 20.5cm x 12.5cm shoe box, which were stacked in two towers of five boxes each. A small opening in the front of each shoe box, through which food could be reached but not easily seen, was 15cm x 7cm. A small

plastic bin was provided in which the target item was to be placed. The music used for the Clapping PM task was a well known pop song by a popular band, played on a small CD player which was placed out of sight of the children. Finally, a toy spring was the gift offered in the Reward PM task, which was placed in a small green, semi-opaque tub, measuring 17.5cm x 9.5cm x 8cm.

Children were tested individually in a small room containing a table in the centre and some chairs. All autistic children were accompanied by an adult familiar to them but who remained silent and uninvolved throughout the testing. The session involved several memory tasks and a distractor task, all disguised as games with a hand puppet (played throughout by the researcher) to engage the autistic children and controls equally. Table 2 shows the timings and the sequence of these tasks during the session.

Introductions and retrospective memory task (encoding a name). Upon arrival, the experimenter introduced himself and asked for the child's name to confirm the necessary comprehension and communication ability. The child was then introduced to the hand puppet, 'Wally' the wolf (played by the researcher), and was asked to repeat his name immediately to confirm understanding: "His name is Wally – can you say 'Wally'?". Other than when asked to recall his name for the later memory tasks, the name 'Wally' was never again repeated. The children were then asked if they would like to play some games with him. Upon confirmation, the procedure commenced. For all tasks, described below, a score of 1 was given for unprompted and prompted remembering and a score of 0 was recorded where the child did not remember.

Instructions for PM Clapping task. It was explained to the children that Wally loved dancing and clapping to music and were told that if they clapped when they heard music it would make Wally very happy. The children demonstrated their willingness and understanding by way of a 'practice' when the music was surreptitiously turned on and their reaction observed. When they successfully clapped, Wally briefly 'danced and clapped' along with them, which he did during both subsequent trials. Once the children had shown they knew to clap upon hearing the music, the distractor task was introduced.

Distractor game. The distractor task involved playing the electronic 'Wac-A- Mole' game, whereby the children were challenged to hit more moles than Wally with the hammer. The game lasted for approximately one minute, including the celebration of who won, during which the children were asked to count the number of moles they hit in either multiples of one, ten, or five, depending on curriculum level, to maximize cognitive load. This task was later repeated to distract the children between the different memory tasks. To avoid causing

frustration and distress, particularly for those with severe autism, all children 'beat' Wally, on all occasions, and were congratulated on their performance.

Remembering PM Clapping task - trial 1. Once the game was over, the experimenter surreptitiously pressed 'play' on the hidden CD player, starting the music, and awaited the children's reaction, by slowly tidying up or preparing the next task. The children were awarded one point if they independently began clapping. If, after approximately ten seconds, the children failed to react to the music they were prompted with the statement, "Can you hear the music?". If they then began clapping and/or dancing they were awarded one point. If the children did not clap after this prompt, the experimenter surreptitiously turned off the music and continued with the next task.

Retrospective memory task – recalling the name - trial 1. Once the music had been turned off, then children were asked to recall the wolf's name: "Can you remember his name? His name is...?". If the children remembered the wolf's name they scored one point, if they did not remember no reminder was given and they moved on to the next task.

Instructions for PM Feeding task. The children were told that Wally was a "greedy wolf" who very much enjoyed eating and would be happy if they fed him lots of delicious toy food. It was explained that Wally could not eat grapes (PM target item) as grapes would make him sick, so the children were to remember to put any grapes into the bin, out of Wally's sight. A brief practice session with three food items, including the grapes, followed to ensure the participants understood the instructions. The wolf 'ate' toy food items from the participants' hands, making happy, snuffling and growling sounds (made by the researcher) which the children enjoyed; the eaten items were then hidden from view. All the children remembered to put aside the grapes in the practice task.

Distractor game. All the participants then played a distractor Wac-a-mole game, which lasted for one minute as before.

Remembering PM Feeding task - trial 1. The children were then told that Wally was hungry, and that it was time to feed him. The children sat on the floor with the experimenter and the wolf, in front of the two towers of five shoe boxes, in which there was one food item per box (making a total of ten food items). They had to reach into the box at the top of the left tower to see what food item lay inside which they could feed to Wally, who greedily ate the item from their hand. They were asked to work their way down each box in the

tower, and repeat for the right tower. The task was counter-balanced in that half of the children first encountered the target item in the fourth box for trial one and in the eighth box for trial two; the converse was true of the other half of children (i.e., eighth box and fourth box for trials one and two, respectively). The bin, into which the target items were to be deposited if recognized, was placed out of sight (but within reach) to the left of the children. They were awarded one point for placing the grapes in the bin unprompted.

Remembering PM Clapping task - trial 2. On completion of the feeding task (approximately three minutes duration) the children were required to sit back at the table. The experimenter surreptitiously switched on the music and scored their performance, first without a prompt and then with the prompt “Can you hear the music?”, if they did not clap spontaneously.

Retrospective memory task – recalling the name - trial 2. Again, as before, they were then tested on the ‘Name?’ task.

Distractor game. The participants played Wac-a-Mole game.

Instructions for PM Reward task. At this point, the children were told that Wally had had so much fun that he wanted to give them a present (the toy spring). They were shown the reward and watched as it was put ‘in a safe place’; they were told that, upon hearing “The games are now finished, time to go back to class” they should collect the reward and return to class. The ‘safe place’ was the small, lidded green box, placed out of sight although it was reachable from their path out of the room.

Remembering PM Feeding task - trial 2. The children then played the Feeding game and the experimenter noted whether the children remembered to hide away the grapes.

Remembering PM Reward task. At the end of the Feeding trial the participant was told “The games are now finished, time to go back to class.” The participant was awarded one point if they remembered to collect their reward. If they did not remember, a prompt was given “Have you forgotten anything?”. All children received the reward irrespective whether they remembered or not, and returned to class.

Table 2. *Sequencing of tasks and approximate timings.*

Task	Timings (seconds)
Introductions, informed of Wally's name	60
Instructions for PM task 1 Clapping	60
Distractor game (Wac-A-Mole)	60
Remembering PM Clapping task - trial 1	30
Retrospective memory task – recalling the name - trial 1	30
Instructions and practice for PM task 2 Feeding	30
Distractor game (Wac-A-Mole)	60
Remembering PM Feeding task - trial 1	180
Remembering PM Clapping task - trial 2	30
Retrospective Memory task – recalling the name - trial 2	30
Distractor game (Wac-A-Mole)	60
Instructions for PM task 3 Reward	30
Remembering PM Feeding task - trial 2	180
Remembering PM Reward task	30

3. Results

Severely autistic children, mildly autistic children and typically developing children were compared across one retrospective and three PM tasks. Results will be presented separately for the three PM tasks (Tables 3, 4, and 5) and the retrospective task (Table 6). In the research to date, gender effects have not been reported, however, to ensure that the gender was not a confounder all the analyses reported below were re-run with all female participants removed (10 in the typically developing group and 1 in the severely autistic group), resulting in 13, 14 and 16 children in the severely autistic, mildly autistic and typically developing groups, respectively. One way between groups ANOVAs on the mean National Curriculum point scores for reading, writing and number did not result in significant main effects of group (reading $p = .57$, writing $p = .43$, number $p = .34$, all

$F_s < 1.58$) nor were there group differences on the composite scores ($F(2, 42) = .68, p = .51, \eta_p^2 = .03$). The mean ages of the groups remained virtually the same (Mild Aut $M = 10.0$ ($SD = 2.55$), Severe Aut $M = 9.38$ ($SD = 1.99$), TD $M = 6.0$ $SD = .26$). As the results with the female participants removed were identical, the analyses with full samples are reported.

3.1 Total PM score

Initially, we analyzed children's total PM scores by calculating the proportion of unprompted responses out of five trials (two trials for clapping and feeding tasks and one trial for the reward task). The mean proportion of correct responses were .50 ($SD .27$), .67 ($SD .38$), and .83 ($SD .20$) in the severely autistic, mildly autistic and typically developing children, respectively. A one way between groups ANOVA found a main effect of groups ($F(2,51) = 6.73, p = .03, \eta_p^2 = .26$). Games Howell post hoc tests revealed a significant difference between the typically developing children and the severely autistic group ($p = .002$). However, there were no differences between the typically developing children and the mildly autistic group ($p = .26$) or the severely autistic and the mildly autistic groups ($p = .31$)⁴. To see if this pattern was present in each of the PM tasks completed, the results for each task are reported below.

3.2 PM Clapping task

In this task, after playing the distractor game, the children had to clap in response to hearing the music. We calculated mean proportions of correct responses (unprompted) across two trials (see Table 3) and entered these into a one way ANOVA. The main effect of groups was significant, $F(2,53) = 3.90, p = .027, \eta_p^2 = .13$. Games Howell post hoc comparisons revealed a significant difference between the severely autistic children and typically developing children ($p = .03$), while the difference between severely and mildly autistic children, and the latter and the typically developing children, were not significant ($p = .65$ and $p = .37$, respectively).

Table 3 also shows that on the first trial, 50 % of severely autistic children, 64% of mildly autistic children and 69% of typically developing children remembered to clap. There was no difference between the groups ($p = .49$). Almost all of the children who did not clap unprompted on trial 1, remembered to clap after hearing the prompt 'can you hear the music?', demonstrating that they had retrospective memory of the task (see Table 3). In the second trial, more typically developing children remembered to clap unprompted (trial one 69% and trial two 96%) compared to the autistic children (see Table 3) and the difference between groups on trial 2 was significant ($\chi^2(2) = 12.0, p = .002$). The typically developing children, after having being prompted in trial 1, significantly improved their performance on trial 2 ($W(26) = 28.00, Z = 2.64, p = .01$), but no such

improvement was found in the autistic children as the percentages of children who remembered across two trials was almost identical in both autism groups.

Table 3. Proportion of correct unprompted and prompted answers in trial 1 and trial 2 of the clapping task by group and proportion of correct unprompted and prompted responses averaged across two trials.

Group	Unprompted Trial 1	Prompted Trial 1	Unprompted Trial 2	Prompted Trial 2	Proportion correct unprompted	Proportion correct prompted
Severe Aut. (<i>N</i> = 14)	.50	1.00	.50	1.00	.50	1.00
Mild Aut. (<i>N</i> = 14)	.64	.93	.64	.79	.64	.86
Typically Developing (<i>N</i> = 26)	.69	1.00	.96	1.00	.83	1.00

3.3 PM feeding task

This task required the children to feed the puppet and remember to put aside grapes. A one way ANOVA on the mean proportions of correct responses across two trials revealed a significant main effect of group, $F(2,51) = 4.28, p = .02, \eta_p^2 = .14$ (see Table 4). Post hoc (Games Howell) comparisons revealed the difference was between the typically developing children and the severely autistic children ($p = .02$), but not between severely and mildly autistic children ($p = .56$), or mildly autistic and typically developing children ($p = .32$). This pattern was present on both trial 1 ($\chi^2 = 7.15, p = .02$) and trial 2 ($\chi^2 = 6.22, p = .045$). Table 4 also shows that in each group proportion of children who remembered across two trials was fairly similar.

Table 4. Proportion of children who remembered the feeding task in trial 1 and 2 by group

Group	Trial 1	Trial 2
Severe Aut. (<i>N</i> = 14)	.43	.43
Mild Aut. (<i>N</i> = 14)	.64	.57
Typically Developing (<i>N</i> = 26)	.85	.81

3.4 PM reward task

In the final reward task (see Table 5), the proportion of children remembering the reward unprompted was not significantly different across the three groups ($\chi^2(2) = 2.69$ $p = .26$). The majority of the children who had not remembered unprompted, did remember after the prompt, suggesting intact retrospective memory. When prompted, group differences approached significance but two of the groups were at ceiling ($\chi^2(2) = 5.18$ $p = .054$, Cramer's $V = .25$).

Table 5. Proportion of children who remembered the reward task unprompted and prompted by group

Group	Unprompted	Prompted
Severe Aut. ($N = 14$)	.60	.80
Mild Aut. ($N = 14$)	.86	1.00
Typically Developing ($N = 26$)	.83	1.00

3.5 Retrospective memory

This incidental recall task required children to remember the name of the puppet on two occasions. All groups performed well on both trials (above 70% remembered the name) and the between group comparisons revealed no significant differences on either the first or second trials (both $\chi^2 < 1$). There were also no group differences on mean proportions across two trials $F(2,51) = .80$, $p = .45$, $\eta_p^2 = .03$ (see Table 6).

Table 6. Proportion correct on the retrospective memory task by group.

Group	Recall Name Trial 1	Recall Name Trial 2	Proportion correct across both trials
Severe Aut. ($N = 14$)	.79	.86	.82
Mild Aut. ($N = 14$)	.93	.86	.89
Typically Developing ($N = 26$)	.73	.77	.75

3.6 Correlational analyses

Finally, we conducted an exploratory correlation analyses between total unprompted PM scores (all the PM tasks combined) and the severity of autistic symptoms as measured by the total CARS scores. The correlation between the total PM scores and the total CARS scores approached significance ($r_s(28) = -.34, p = .07$). In line with Jones et al. (2011), we also examined whether the total PM scores were associated with any of the CARS five subscale scores (Social Communication, Emotional Reactivity, Social Orienting, Cognitive and Behavioral Consistency, and Odd Sensory Exploration) (Stella, Mundy & Tuchman, 1999). No correlations were found ($r_s(28)$, all p 's $> .08$).

4. Discussion

The present study is the first to examine event-based PM in severely autistic children, comparing their performance to mildly autistic children and to typically developing children; it was also the first to employ a range of naturalistic tasks, designed to ensure the motivation and engagement of severely autistic children, including the distractor task. In addition, all the children performed a simple retrospective memory task (remembering the puppet's name). In line with previous research on retrospective memory (Frith, 1970a, 1970b; Fyffe & Prior, 1978; Hermelin & O'Connor, 1970; Jones et al., 2011), no group differences were found in this name recall task. In relation to PM tasks, we expected that while mildly autistic children would perform similarly to the typically developing children, severely autistic children would perform worse than the other two groups.

Several important findings emerged. First, for the unprompted PM performance on the clapping task and for the feeding task, significant group differences only emerged between the typically developing children and the severely autistic children, while the mildly autistic children were no different from either of these groups. Second, these group differences in the unprompted responses in the clapping task, emerged only on trial two (there were no group differences in trial one). The third important finding was that there were no group differences on the reward task. Importantly, results also showed that autistic children benefitted from indirect cues (prompts) in the clapping task. Finally, bearing in mind the sample size, we explored whether there was a correlation between the total PM scores and the CARS scores. Though the correlation approached significance, no correlations between the total PM scores and any of the CARS subscales were found. Taken together, the results show that although event-based PM is impaired in the severely autistic children, this impairment can be diminished with highly motivating and developmentally appropriate tasks.

The first finding concerning no significant differences between the mildly autistic children and typically developing children replicates findings of Williams et al. (2013), Altgassen et al. (2010) and Henry et al. (2014), but contradicts those obtained by Brandimonte et al. (2011). We believe that one of the potentially important variables which explains the differences we found, compared to Brandimonte et al. (2011), are the tasks used to measure performance. Brandimonte et al. (2011) used a computer-based abstract task which would be more demanding for autistic children, especially those with more moderate symptoms. The tasks in this study were modified to suit the severely autistic children and to be meaningful in the context of such simple tasks as feeding food to the puppet and clapping to music. The verbal demands were also reduced, as the children were not required to verbalize (i.e., to say 'what is the time' on hearing an alarm) or say anything when they saw the grapes. Furthermore, in the reward task, the target object was an attractive toy spring, which the children were allowed to take back to class.

In relation to this point, and perhaps most surprisingly, the results showed no group differences for the reward task, where even severely autistic children were able to remember to collect the reward at the end of the session (60% of the severely autistic group remembered to collect the toy, as did 86% of the mildly autistic children). This finding is in line with several developmental studies that have shown beneficial effects of motivation with highly desirable tasks over relatively short delay periods even with very young children. For example, Causey and Bjorklund (2014) found that 2- to 4-year-olds were more successful in remembering to get a sticker for themselves at the end of the session than to remember to turn a sign over. In a study by Ślusarczyk and Niedźwieńska (2013), 30% of 2-year old children remembered to retrieve a sticker (high motivation condition) in comparison to 9% children who remembered to put pencils aside (low motivation condition) (for similar findings, see Kliegel, Brandenberger & Aberle, 2010; Sommerville, Wellman & Cultice, 1983).

Another important finding was that in the clapping task, the significant improvement of the typically developing children from trial one to trial two (69% to 96%) was not seen in the autistic children. The typically developing children who remembered on trial one after being prompted, were then able to carry this forward to trial two. Although the autistic children remembered on trial one after being prompted (can you hear the music?), this did not carry forward to the second trial. In trial two, most of the typically developing children responded correctly, but this was not the case with the autistic children. This finding mirrors results from studies of language and reading comprehension where autistic children are consistently reported to be impaired in connecting or integrating meaning from one sentence/paragraph to another in discourse (Bishop, 1989; Williams, Goldstein & Minshew, 2006). Explanations generally suggest that autistic children have an impaired

ability to create organizational structure to facilitate memory and to connect information across tasks (focusing instead on the detail of the task in hand). Others (e.g., Happé & Frith, 2006) suggest that global understanding is made difficult in autism due to differences in the use of executive functions focusing on detail rather than the global picture (weak central coherence theory). Therefore, autistic children may be less likely to improve PM performance across trials.

Even though the autistic children did not benefit from the prompt across trials one and two, it is interesting that they correctly interpreted the prompt despite it being subtle and communicatively indirect. Autistic children are widely reported to be over-literal in their interpretation of language, particularly when the expression is indirect (Bishop, 1989). For example, when asked ‘can you pass the salt’ they typically interpret this literally, replying ‘yes’. Yet in this task, the autistic children did not interpret the prompt literally, but as a cue to the PM task, as did the typically developing children. It is also interesting that both the feeding task and the clapping task were social in their nature (i.e., clapping for Wally and feeding him) and less motivating than the reward task, but performance was not at floor in autistic children. This suggests that autistic children can succeed in everyday PM tasks, which are often social in nature, but have strong focal cues.

Taken together, the pattern of results obtained in the present study, can be explained by Einstein and McDaniel (2005) multi-process model which suggests that PM can be sub-served by both controlled strategic as well as more spontaneous processes depending on the type of task, cue events, ongoing activities, motivation and context. We deliberately used easy and engaging event-based tasks with fairly strong and focal cue events that would encourage more spontaneous retrieval processes. This was the case in both the clapping task and the feeding task where the music and the toy grapes had to be processed as part of the ongoing activity. Although the target for the reward task was somewhat less salient (i.e., finishing the session) it was highly motivating to children. However, this does not mean that no strategic processes were used by the children. For example, in relation to the reward task the informal observation of the researcher was that during the feeding task, which lasted 3 minutes, some of the children, including severely autistic children, were occasionally looking in the direction of the box where the toy was hidden, which indicates the involvement of some strategic processing (see Leigh & Marcovitch, 2014). Further research is needed to investigate strategic monitoring with highly motivating PM tasks in autistic children.

The relative preservation of event-based PM abilities in mildly and severely autistic children is somewhat reminiscent of their preserved performance in tasks of cued recall and paired associate learning (for review see Boucher et al., 2012) The potential similarities between event-based PM tasks and cued recall have

been emphasized in the literature by Einstein and McDaniel (2005) (see also McDaniel & Einstein, 2007) who point out that as in cued recall, event-based PM tasks involve forming mental associations between the PM target event and the to-be-performed action and encountering the cue may activate the associated action. Despite this similarity, the relationship between event-based PM and cued recall has not been directly investigated. The present findings indicate that this might be an interesting avenue for future research.

It is possible that group differences will emerge with event-based tasks that have less distinctive cues and less motivating tasks as was the case with Brandimonte et al. (2011) and Jones et al. (2011). In addition, delay intervals between PM instructions and opportunities to carry out PM tasks were short. Future research should investigate effects of autism on performance on different types of tasks on varying dimensions and longer time delays. What is important at this point is that we provide strong evidence that if the task parameters are favorable, even severely autistic children can pass the tasks. This has several implications for practice. Teachers can use reward as motivation in the classroom to improve PM in autistic children in the everyday setting. The use of reward to motivate autistic children has been recognized in approaches aiming to modify challenging behaviors in a meaningful way in children and adults (e.g., applied behavioral analysis). It is also widely reported in retrospective memory research that autistic children appear to have a particular skill for remembering when motivated, whilst at the same time being unable to memorize other facts (and in particular, personal experiences) (Hoekstra et al., 2009).

It is customary in PM studies to probe those participants who fail to pass the PM task to check whether they have preserved retrospective knowledge for receiving PM instructions (e.g., Williams et al., 2013). In the present study, certain proportions of children did forget some of the PM tasks. However, in the clapping task, almost 100% of these children remembered in response to the indirect cue “can you hear the music?” (see Table 3). Similarly, in the reward task, the vast majority of these children remembered in response to the more direct cue “have you forgotten anything?” (see Table 5), which indicates that even severely autistic children did not forget due to retrospective memory failure. This is further corroborated by no group differences in the retrospective name recall task. In the feeding task, in which prompting was not used, six severely autistic children, five mildly autistic children and four typically developing children failed both trials. This raises the possibility that they failed the PM task because of retrospective memory failure (i.e., could not remember PM task instructions). Although we cannot completely exclude this possibility, we carefully examined how these children performed on the other two PM tasks (clapping and reward tasks). The rationale was that if their retrospective memory was at fault, these children would have also shown retrospective memory impairment for

the other two tasks. The analysis showed that out of the six severely autistic children who forgot the feeding on both trials, all showed intact retrospective memory for the clapping task; however two children could not remember the reward task even after prompting, indicating a failure of retrospective memory. Out of five mildly autistic children who forgot the feeding task on both trials, all showed intact retrospective memory on the reward and only one child could not remember the clapping task after a prompt on both trials. All four typically developing children demonstrated intact retrospective memory for both clapping and reward tasks. Therefore, there were three children (two severely autistic children and one mildly autistic child) who could have potentially failed the feeding task due to retrospective memory impairment. When these three children were excluded from the analysis the findings remained the same. It is worth noting that a recent study by Henry et al., (2014) investigated the role of retrospective memory as a confounder in PM performance and found that it was not the major cause of autism-related impairment in time-based or event-based PM.

In summary, the inclusion of severely autistic children highlights the need to consider the heterogeneity of autism and the severity of specific traits in relation to performance on event-based PM tasks. The results of the present study replicate and extend previous findings by showing that autistic children, including those with more severe symptoms, are able to succeed on some of the event-based PM tasks (i.e., with a distinctive target event and high motivation). However, unlike the typically developing children, the autistic children did not appear to carry forward successful performance after receiving the prompt in trial 1 to trial 2. However, the autistic children were able to benefit from fairly indirect cues (prompts to remember) and two out of the three PM tasks were social in nature which suggests that some rudimentary social abilities may be preserved in autistic children in the context of the event-based PM tasks. This opens up interesting avenues for future research in terms of interventions and educational support.

Footnotes

¹ The ‘disability-first’ terminology used here (i.e., ‘autistic children’), and throughout the paper, reflects the preferences of autistic people, and their family and friends, reported recently in a large survey by Kenny et al. (2015).

² Two participants were just outside the cut-off scores for the mild and the severely autistic groups (with CARS scores of 24 and 36, respectively). However, when the data of these two participants were removed from the analysis, the overall pattern of findings did not change, hence they were retained in the sample.

³ These assessments are regularly subjected to rigorous evaluation by the Office for Standards in Education (OFSTED), to ensure they are assessed in a standardized and systematic manner against detailed attainment criteria (see Qualifications and Curriculum Authority (QCA), 2000/2009, for an overview of educational attainment level criteria).

⁴ Age did not correlate with performance on any of the three PM tasks (all $r_s < .10$). However, given that groups were matched on cognitive/educational ability and the autistic children ranged from 5;5 to 13 years, an additional analysis of variance was conducted with age as a covariate. The results did not change, there was a significant effect of group (severe, mild and typically developing) on overall PM performance ($F(2, 50) = 4.56, p = .02, \eta_p^2 = .15$). Post hoc tests again revealed a significant difference only between the typically developing children and the severely autistic group ($p = .005$).

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