PREDICTABLY DIFFERENT? PROSPECTIVE MEMORY IN AUTISM

Daniel Patrick Sheppard
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Proefschrift

ter verrijking van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. dr. J.H.J.M. van Krieken,
volgens besluit van het college van decanen
in het openbaar te verdedigen op donderdag, 24 mei 2018
om 12:30 uur precies

door

Daniel Patrick Sheppard

geboren op 2 augustus 1979

te Londen (Verenigd Koninkrijk)
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CHAPTER

GENERAL INTRODUCTION

Prospective memory: Critical for everyday life!

Is prospective memory difficult for autistic people?
1.1 INTRODUCTION

Upon waking, one might think immediately of the important email that must be sent to one’s supervisor, in advance of the 10am meeting. This thought may then trigger the recollection of a cascade of intentions that must also be realised later that morning, day, or even week, such as cancelling a tv channel subscription, posting an important tax return, and/or picking up cat food after work. Once embarked upon one’s morning routine, one must likely retrieve many more intentions and execute them after a much shorter delay, such as replacing the cap on the tube of toothpaste, remembering to unplug the clothes iron and taking antibiotics in an hour.

It is thus clear that the demands placed upon us in contemporary daily life are varied, complex and many. Integral to meeting such demands is the ability to anticipate them, and then plan, coordinate and execute their resolution at the appropriate moment in the future, usually in the face of ongoing activities. This process is commonly referred to as prospective memory (PM; Einstein & McDaniel, 1996). PM tasks are highly prevalent, and their failures account for 50%-80% of all daily memory failures (Terry, 1988), the consequences of which range from personally or socially inconvenient, such as forgetting to post a letter or pass on a message to a friend, to disastrous, such as forgetting vital medication or forgetting to unplug the iron and causing a fire. Thus, good PM performance is critical to the effective navigation of daily life, and the ability to live happily, safely and independently; conversely, serious difficulties with PM would likely result in problems with social functioning, employment and independent living, problems characteristic of the autistic population (Anderson, Shattuck, Cooper, Roux, & Wagner, 2014; APA, 2013; Howlin, Goode, Hutton, & Rutter, 2004; Shattuck et al., 2012). Low levels of independence have been linked to mental health problems such as depression and anxiety in other clinical populations (Andersen, Wittrup-Jensen, Lolk, Andersen, & Kragh-Sørensen, 2004) so poor independence may well be contributing to the mental health problems also prevalent in autism (Salazar et al., 2015; Simonoff et al., 2013; Simonsen et al., 2012).

The purpose of the current thesis is to focus on PM and its underlying mechanisms in the autistic population, to better understand the environment under which optimal PM performance can be achieved. This understanding could then be used to inform effective interventions and strategies to improve daily functioning, supporting autistic individuals in realising their potential for independence and well-being. A full, detailed introduction to the PM process, autism and PM in autism is given in the review presented next, in Chapter 2, and so the current introduction will provide only a broad outline of these issues, followed by a chapter summary.

1.2 PM PROCESS

While the everyday PM tasks described above exemplify well their complex and varied nature, common to all PM tasks is an underlying process comprised of four phases: 1) forming and encoding an intention; 2) delaying the intention whilst engaged in other (ongoing) task (OTs); 3) inhibiting and switching from OTs to retrieving the intention at the appropriate/planned moment in the future; 4) and, finally, executing the intention (Kliegel, Martin, McDaniel, & Einstein, 2002). The cognitive processes serving each phase are thus also common to all tasks: episodic memory processes are needed to encode and retrieve the intention (Einstein & McDaniel, 1996; Smith & Bayen, 2004; West & Krompinger, 2005), whilst executive control is needed to monitor the environment for cues, and then to inhibit and switch from the OT to perform the PM task (e.g., Marsh, Hicks, & Watson, 2002; Smith & Bayen, 2004; West, 2011). Recently, theory of mind (ToM) has been implicated in the PM process (Altgassen, Vetter, Phillips, Akgun, & Kliegel, 2014; Ford, Driscoll, Shum, & Macaulay, 2012) as has episodic future thinking (Altgassen, Kretscher, & Schnitzspahn, 2017; Negro, Brandimonte, Cicogna, & Cosenza, 2014), thought important to projecting oneself into the future to imagine various PM tasks, and their execution.

Despite these commonalities, the extent to which these mechanisms are needed, and to which they interact, varies broadly depending on the task composition and context. One major between-PM-task difference involves the nature of the moment the intention is to be retrieved and executed, that is, either at a specific time (time-based prospective memory; TBPM) or at a specific event, or cue (event-based prospective memory; EBPM). TBPM is supposed to be the most cognitively demanding, given that, in the absence of an external cue or prompt, one must rely on only internal processes, and must regularly monitor the time necessitating continuous employment of executive control (Einstein & McDaniel, 1996). In the case of EBPM, however, one can offload much of the attentionally demanding monitoring processes (Gilbert, 2015) pre-retrieval, and instead await the occurrence of the cue. According to the influential multiprocess framework (McDaniel & Einstein, 2000; see figure 2) a model referred to throughout the current
CHAPTER 1

1.3 AUTISM

Autism spectrum conditions (henceforth, autism) are characterised by social communication difficulties, repetitive behaviours and atypical (hypersensitive/hyposensitive) reactivity to sensory input (APA, 2013). In addition to these established diagnostic traits, autism is also characterised by evidence-based cognitive and behavioural differences, including executive difficulties with, for example, planning (Mackinlay, Charman, & Karmiloff-Smith, 2006; Ozonoff et al., 2004) and switching flexibly between different tasks or foci of attention (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Kenworthy, Yerys, Anthony, & Wallace, 2008; Leung & Zakzanis, 2014; Ozonoff et al., 2004), impairments in episodic memory and theory of mind (e.g., Baron-Cohen, Leslie, & Frith, 1985; Leekam & Perner, 1991; Perner, Frith, Leslie, & Leekam, 1989; see Baron-Cohen, 2000 for a review) and reduced episodic future thinking (e.g., Lind & Bowler, 2010; Lind, Bowler, & Raber, 2014; Lind, Williams, Bowler, & Peel, 2014; Terrett et al., 2013). These memory and executive difficulties may well be related, given their correlations found in other clinical populations (Baudic et al., 2006; de Vito et al., 2012; Greene, Hodges, & Baddeley, 1995).

It is interesting to note here, that executive function, seen as important to PM, is posited to be driven by attentional processes (Garon, Bryson, & Smith, 2008; Posner & Rothbart, 2000). Attentional processes have been shown as impaired in autism, evidenced by, for example, problems with disengagement, (Landry & Bryson, 2004) visual attention (Mann & Walker, 2003), joint attention (e.g., looking at or listening to people, Klin, Jones, Schultz, & Volkmar, 2003; Schultz, 2005) and reduced divided attention (Althaus, deSonneville, Minderaa, Hensen, & Til, 1996; Giesielski, Prince, Harris, & Handmaker, 1995) (cf. a review, Allen & Courchesne, 2001). It may be, therefore, that impaired attentional processes are in fact driving the aforementioned executive and (possibly associated) memory impairments seen in the population (e.g., Corbett et al., 2009; Lind & Bowler, 2010). Indeed, as will be discussed in greater detail in Chapter 2, problems with attending to relevant sensory information have even been suggested to be driven by attentional processes (Garon, Bryson, & Smith, 2008; Posner & Rothbart, 2000). Attentional difficulties in autism in the above-mentioned cognitive functions. That is, autism PM performance parallels non-autistic performance when the cognitive demand of the PM task is low, and automatic intention retrieval is facilitated. The more demanding a PM task is, as are TBPM tasks, or EBPM tasks with cues of low salience/focality, and so the more strategic monitoring is needed, the worse is autism performance (see Figure 2).

The myriad of possible ways in which these various characteristics develop and interact, with each other and with the environment, quite possibly underlie the heterogeneity common to autism. However, irrespective of varied and idiosyncratic phenotypes, the majority of autistic individuals experience difficulty with daily functioning, exemplified by low levels of independent living and employment, even compared to other disability groups (Anderson et al., 2014; APA, 2013; Howlin et al., 2004; Shattuck et al., 2012). Given the prevalence of PM in everyday life, it may be that problems with PM contribute to problems with independent and safe daily living, problems which themselves have been linked to mental health problems in other clinical populations (e.g., patients with dementia; Andersen et al., 2004). It is further possible therefore, that difficulties with PM are indirectly linked to the high prevalence of mental health problems in autism (Salazar et al., 2015; Simonoff et al., 2013; Simonoff et al., 2012). It is thus critical to further investigate PM in autism to better understand the underlying mechanisms and possible causes of any impairment, to inform tangible ways with which to improve daily living and well-being.

1.4 PM IN AUTISM

Despite the importance of PM to daily functioning, and the apparent daily functioning problems in autism, investigations into PM ability in autism are relatively scarce. However, the overall picture of PM ability in autism, gained from these studies (Altgassen, Koban, & Kliegel, 2012; Altgassen & Koch, 2014; Altgassen, Schmitz-Hubsch, & Kliegel, 2010; Altgassen, Williams, Bölte, & Kliegel, 2009; Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Henry et al., 2014; Kretschmer, Altgassen, Rendell, & Bölte, 2014; Sheppard, Kavaliashvili, & Ryder, 2016; D. Williams, Boucher, Lind, & Jarrold, 2013; D. M. Williams, Jarrold, Grainger, & Lind, 2014; Yi et al., 2014) appeared to be in line with the multiprocess framework, and the established difficulties in autism in the above-mentioned cognitive functions. This is, autism PM performance parallels non-autistic performance when the cognitive demand of the PM task is low, and automatic intention retrieval is facilitated. The more demanding a PM task is, as are TBPM tasks, or EBPM tasks with cues of low salience/focality, and so the more strategic monitoring is needed, the worse is autism performance (see Figure 2).

The prospective memory process, as described by the multiprocess framework, with associated autism performance.
In sum, the difficulties in processes, such as executive function and memory, deemed key to PM, apparently corroborated by (scarce) existing literature, point to problems with PM in autism. However, the influence of various task-based factors on the PM performance of autistic participants can thus far, aside from TBPM vs EBPM studies (e.g., Williams, Jarrold, Grainger, & Lind, 2014), only be inferred. For example, differences in cue salience could be inferred as important to EBPM performance of autistic participants, as studies employing cues low in salience (Brandimonte et al., 2011) found impaired performance, whilst studies employing cues high in salience (Altgassen et al., 2010) found intact performance. It is critical, then, to further investigate these factors more closely as experimental variables, which was a main aim of the current thesis.

1.5 THESIS OUTLINE

Chapter 2 first presents a systematic review of all current literature investigating PM in autism (including the studies described in Chapters 3, 4 and 6), and a traditional analysis based on autism, PM and the hitherto common conceptions of PM underlying cognitive mechanisms, namely, executive function, episodic memory and episodic future thinking. The second half of the chapter advances a new theory on autism, and, consequently, PM ability in autism, based on recent predictive coding accounts of autism.

Whilst previous studies had attempted to elucidate PM in autism, none had specifically investigated the way in which the severity of the condition influenced PM ability. Indeed, none of the previous work in autism, in any field, had included autism severity as an experimental factor. This is, perhaps, due to the difficulties inherent in including severely autistic individuals in traditional laboratory paradigms, such as participant task understanding and motivation, and control group matching. Thus, the aim of Chapter 3 was to include for the first time in autism research, a group of severely autistic children and compare their PM performance, on three (more) naturalistic EBPM tasks to mildly autistic group and a non-autistic group.

According to the MPF, task importance plays an important role in motivating the allocation of attentional resources during EBPM tasks. Previous studies with non-autistic participants had indeed found that if PM tasks were considered as important, either from a personal or a social perspective, then PM performance was better. Given the characteristic social difficulties experienced by autistic individuals, it is important to investigate the role of social and personal motivation and task importance in PM and autism, and is thus the focus of Chapter 4. In this study, autistic and non-autistic adolescents participated in a TBPM experiment whereby, via task instructions, perceived task importance was manipulated by way of three conditions, namely, a social, personal and standard condition.

Motivation for PM tasks was further investigated in Chapter 5, along with the effects of cue-intention association; that is, the extent to which cues associated with the intention facilitate intention retrieval, thus supporting those with less developed executive function and episodic memory. Given that, prior to this thesis, undeveloped/impaired executive function was considered an important factor in the hitherto impaired PM in autism, it was important to study PM and motivation in a different population with comparably undeveloped executive function. Therefore, the study of Chapter 5 compared the EBPM performance of young non-autistic children, aged 5- and 7-years-old, further comparing performance with and without a promised reward, and with target pictures that bore either a high or low association with the intention.

A further element of EBPM, critical to influencing the intention retrieval process is the salience of the PM cues, relative to the context/ongoing task. More specifically, the MPF claims that cues that are highly salient are more likely to more automatically evoke retrieval of the intention than cues that are low in salience. Salency in this context refers primarily to the perceptual, sensory (visual, auditory) characteristics of the cue, and is thus an important factor to consider for PM in autism, given the atypical sensory processing that characterises in the condition. Thus, in Chapter 6, we manipulate visual and auditory cue salience in autistic and non-autistic children, investigating whether increasing cue salience in these modalities does indeed support PM performance, especially in populations known to exhibit atypical sensory processing and atypical PM-dependent cognitive functions.

Chapter 7 is a general discussion which summarises all findings on prospective memory in autism, as found in the empirical chapters and the review chapter. The embodied predictive coding account of autism and prospective memory are also summarised, and future research directions and clinical implications are discussed.
This chapter is based on:
ABSTRACT
Objective: The current article set out to review all research conducted to date investigating prospective memory (PM) in autism.
Method: All studies on PM in autism are first described, followed by a critical review and discussion of experimental findings within the multiprocess framework. PM in autism is then considered through an embodied predictive coding account of autism.
Results: Overall, despite somewhat inconsistent methodologies, a general deficit in PM in autism is observed, with evidence mostly in line with the multiprocess framework. That is, for tasks that are high in cognitive and attentional demand (e.g. time-based tasks; event-based cues of non-focality or low salience) PM performance of autistic participants is impaired. Building upon previous work in predictive-coding, and the way in which expected precision modulates attention, we postulate mechanisms that underpin PM and the potential deficits seen in autism. Furthermore, a unifying predictive-coding account of autism is extended under embodied predictive-coding models, to show how a predictive-coding impairment accounts not only for characteristic autistic difficulties, but also for commonly found differences in autistic movement.
Conclusions: We show how differences in perception and action, core to the development of autism, lead directly to problems seen in PM. Using this link between movement and PM, we then put forward a number of holistic, embodied interventions to support PM in autism.

2.1 GENERAL INTRODUCTION
Autism spectrum conditions (ASC; henceforth, autism) are characterized by impairments in social communication, restricted interests and activities and, most recently, atypical reactivity to sensory input (APA, 2013). The clinical picture and cognitive skills of autistic people may differ in severity (Hill, 2004). However, even autistic adults of average or above average cognitive ability find everyday life problematic (e.g., housekeeping, financial matters). They have, for example, difficulties obtaining and maintaining employment that corresponds to their intellectual ability (Howlin, 1998) and coordinating social activities, e.g., organizing appointments with peers (Häufler, 2008) and living independently (Anderson, Shattuck, Cooper, Roux, & Wagner, 2014). Autistic children often have problems in school due to poor time management and organization, e.g., homework is often left at school (Mackinlay, Charman, & Karmiloff-Smith, 2006). These apparent organisational difficulties in autism are supported by empirical work revealing problems with prioritizing, coordinating and sequencing activities and hence, with planning ahead (Mackinlay et al., 2006; Ozonoff et al., 2004); such difficulties have been related to deficits in prospective memory (Altgassen, Koban, & Kliegel, 2012; Mackinlay et al., 2006). PM describes the ability to remember to execute intentions after a delay at a certain time (time-based tasks; TRPM) or event (event-based PM tasks, EBPM, Einstein & McDaniel, 1996), such as remembering to go to the hairdresser at 3 pm, or to buy batteries in the corner shop on the way home. Many occupational and social demands require PM, and PM is essential for the development and maintenance of autonomy and independence. Frequent failures to remember to complete planned activities may endanger professional careers, social relationships or even impose serious risks on physical well-being (Kliegel, Jäger, Altgassen, & Shum, 2008).

Prospective remembering is complex, and comprises multiple processes and phases, across varying time-spans. First, the individual has to form the intention, and store it in (retrospective) memory while being engaged in other ongoing tasks (OT). This (filled) delay between encoding and retrieval of the intended action may range from seconds over minutes to several hours or days (Ellis & Kvalilashvili, 2000). When the appropriate moment for intention initiation arises, other ongoing activities have to be inhibited and the individual has to switch to the prospective action and execute it as planned (Kliegel, Martin, McDaniel, & Einstein, 2002). Research differentiates between a prospective (remembering ‘that’ you have to do something) and a retrospective component (remembering ‘what’ and ‘when’). The prospective component is supported by attention demanding processes that are closely aligned with executive functioning which serve to monitor the environment for prospective cues (e.g., Smith & Bayen, 2004), inhibit performing the ongoing activity, and to switch to the prospective intention at the appropriate moment (Marsh, Hicks, & Watson, 2002; West, 2011). The retrospective component supports the encoding and subsequent retrieval of the intention when a target stimulus is encountered and shares many processes with explicit episodic memory in recognition and cued-recall tasks (Einstein & McDaniel, 1996; Smith & Bayen, 2004; West & Krompinger, 2005). Recently, episodic future thinking, the ability to mentally simulate and thus pre-experience future events (Atance & O’Neill, 2001), has been
linked to the intention formation phase (Aulgassen et al., 2014). In line with these behavioural data, imaging studies indicate an involvement of frontal and medial-temporal structures in prospective remembering (for a recent review see Burgess, Gonen-Yaacovi, & Volle, 2011). Frontally mediated (executive control) processes seem to influence PM performance more strongly than temporally mediated (retrospective memory) processes (Brunfaut, Vanoverberghe, & d’Ydewalle, 2000; Kliegl, Eschen, & Thöne-Otto, 2004). Most recently, Cona and colleagues (2016; 2015) further specified the underlying neural networks and involved cognitive processes in their ‘Attention to Delayed Intention’ model. Specifically, they state that a dorsal frontoparietal network supports top-down attentional and memory processes that are needed to monitor for the PM cue and to keep the intention in mind, whereas a ventral frontoparietal network (in addition to the insula and posterior cingulate cortex) is mainly involved in the retrieval phase and supports bottom-up attentional processes (externally by the PM cue and internally by the mental representation of the PM cue and the intended action).

Importantly, different PM tasks vary in the extent to which they require these cognitive resources. EBPM tasks have been assumed to put higher demands on individuals’ executive control resources than event-based tasks; there is no external cue that may prompt retrieval of the intended action, and the individual has to actively keep track of the elapsing time (Einstein & McDaniel, 1996). However, depending on the specific task features, EBPM tasks may also put high demands on executive control processes. Specifically, with regards to EBPM, two prominent conceptual models have been developed that allow for theory-based predictions on factors that determine the involvement of executive control in PM; namely the multiprocess framework (McDaniel & Einstein, 2000) and the preparatory attention and memory processes theory (PAM, Smith, 2003; Smith & Bayen, 2004). For the multiprocess framework, McDaniel and Einstein (2000) suggested a range of factors and contexts that can determine the extent to which an EBPM task invokes relatively effortful or automatic retrieval processes: task importance, the type of PM cue (e.g., salient versus non-salient cues or cues that are more or less focal to the OT), the OT (e.g., more versus less demanding), and individual differences (e.g., in cognitive resources, personality). Given that PM tasks are dual task situations consisting of an ongoing activity and the embedded PM task, both tasks compete for (limited) attentional and executive control resources (Einstein & McDaniel, 1996).

Hence, characteristics of both task levels will affect the more or less controlled allocation of those resources (please see McDaniel, Umanath, Einstein, & Waldum, 2015, for a recent discussion of the multiprocess framework). In contrast, the PAM model posits that that all PM tasks require executive control resources for the PM cue to be detected, but that the extent to which these resources are needed depends on task characteristics.

Thus, there is good evidence that strong executive control, episodic memory and future thinking abilities, are critical for successful PM, particularly so when PM tasks involve, for example, cues of low salience or low focality (EBPM) that are difficult to detect, or no environmental cues at all (TBPM). It is therefore of concern that problems with executive control and memory are well known in autism. Executive difficulties are typically seen in planning (Mackinlay et al., 2006; Ozonoff et al., 2004) and switching flexibly between different tasks or foci of attention (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Kenworthy, Yerys, Anthony, & Wallace, 2008; Leung & Zakzanis, 2014; Ozonoff et al., 2004; but see Geurts, Corbett, & Solomon, 2009 for a critical review). Tasks assessing the inhibition of prepotent responses have resulted in more ambiguous findings (Corbett et al., 2009; Geurts, Vertié, Oosterlaan, Roeyers, & Sergeant, 2004; Lopez, Lincoln, Ozonoff, & Lai, 2005; Pellicano et al., 2017). Evidence from retrospective (episodic) memory studies indicate impairments in free recall tasks that provide little memory support (Bowler, Gardiner, Grice, & Saavalainen, 2000), whereas more structured tasks that put lower demands on self-initiated processing, such as cued recall and recognition tasks (Barth, Fein, & Waterhouse, 1995; Bowler, Gardiner, & Grice, 2000), seem to be spared. In line with the well-documented deficits of autistic individuals in episodic memory and theory of mind (e.g., Baron-Cohen, Leslie, & Frith, 1985; Leekam & Perner, 1991; Perner, Frith, Leslie, & Leekam, 1989; see Baron-Cohen, 2000 for a review), reduced episodic future thinking has been reported in autism (e.g., Lind & Bowler, 2010; Lind, Bowler, & Raber, 2014; Lind, Williams, Bowler, & Peel, 2014; Terrett et al., 2013). It may be that these memory deficits are in some way related to impaired executive functioning, given the correlations found in other clinical populations between executive functions and episodic memory (Baudic et al., 2006; Greene, Hodges, & Baddeley, 1995) as well as future thinking (de Vito et al., 2012).

Furthermore, it is possible that these executive functions, seen as important to PM, are driven by attentional processes (Garon, Bryson, & Smith, 2008; Posner & Rothbart, 2000), processes which have also been shown as impaired in autism (e.g., problems with disengagement, Landry & Bryson, 2004) visual attention (Mann & Walker, 2003), joint attention (e.g., looking at or listening to people, Klin, Jones, Schultz, & Volkmar, 2003; Schultz, 2005) reduced divided attention (Althaus, deSonneville, Minderaa, Hensen, & Til, 1996; Ciesielski, Knight, Prince, Harris, & Handmaker, 1995) (cf. a review, Allen & Courchesne, 2001). Indeed, problems with attending to relevant sensory information have even been situated as core to autism (Lawson, Rees, & Friis, 2014; Pellicano & Burr, 2012; Van de Cruys et al., 2014; Van de Cruys, Van der Hallen, & Wagemans, 2017). Such problems would thus have a profound impact on PM performance in autism.

In summary, PM represents a ubiquitous daily process, critical to independent living. Successful execution of PM tasks requires the recruitment and coordination of several (socio) cognitive processes, processes that may rely fundamentally on effective attentional and executive control processes. Given the weight of evidence demonstrating autistic impairment in such processes, and the potentially debilitating PM failures this may lead to, it is vital to better understand prospective remembering in autism, its underlying mechanisms and the environmental conditions that best support it.

Therefore, the first section of the current review will summarise all literature directly investigating PM in autism to date, arriving at the conclusion that, relative to the non-autistic population, PM in autism appears to be impaired. Then, in an attempt to better understand why autistic individuals in particular may demonstrate such difficulties, we will consider the complex dynamic nature of PM, the environment in which it is situated, and the demands this puts on individuals to coordinate and act under such an
environment. With this in mind, we will build upon the cognitive explanations of the PM process offered by the multiprocess framework (McDaniel & Einstein, 2000) by considering PM as embedded within a complex dynamic environment, and, as such, apply and further develop an existing account of autism, namely the Bayesian predictive coding account of Van de Cruys, et al. (2014; Van de Cruys et al., 2017). Finally, we will describe how this account, and the multiprocess framework, lead to useful, embodied interventions, many of which are already widely implemented in practice.

2.2 PM IN AUTISM – LITERATURE REVIEW

A literature search was conducted on the Web of Science for all papers including the terms “autism” and “prospective memory”, in the title, published up until December 2016. The search returned 36 studies. After the inclusion of two of the current authors’ unpublished works, and subsequent screening, thirteen studies were available for review (see Fig. 1). The following section will review each of the studies, beginning with three studies demonstrating spared PM ability, followed by five studies demonstrating a PM deficit, and ending with five studies revealing mixed results (e.g. preserved EBPM but diminished TBPM). For brevity, the studies will only be summarised, with key points highlighted. A full description of the methods and results is presented in Table 1, but, for an in-depth description and critique of all studies, including further statistical data (such as effect sizes), we refer to the recently published meta-analysis of Landsiedel, Williams, and Abbot-Smith (2017) on PM in autism. Finally, an overall summary will be presented, describing patterns or commonalities evident between the studies to help elucidate variations in performance, and to discern possible cognitive functions that may contribute to the variation in PM performance.

![Table 1. Overview of all studies on prospective memory in autism.](image-url)
### TABLE 2.2.1: Sample Information

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>Gender</th>
<th>Intellectual Disability Measures</th>
<th>Severity of ASC Symptoms</th>
<th>Diagnostic and Exclusion Criteria</th>
<th>Task Description</th>
<th>Task Delay Length</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Task Description</th>
<th>Number of Trials</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Control Variables</th>
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<td>21 children</td>
<td>Boys</td>
<td>WAIS-IV Full Scale IQ</td>
<td>Mild</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>WAIS-IV Full Scale IQ</td>
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<tr>
<td>21 children</td>
<td>Girls</td>
<td>PPVT</td>
<td>Mild</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>PPVT</td>
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<tr>
<td>22 children</td>
<td>Boys</td>
<td>Raven's Advanced Progressive Matrices</td>
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<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>Raven's Advanced Progressive Matrices</td>
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<td>WISC-III Full Scale IQ</td>
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<td>None</td>
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<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>WISC-III Full Scale IQ</td>
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### TABLE 2.2.2: Control Variables

<table>
<thead>
<tr>
<th>Control Variables</th>
<th>Study</th>
<th>Gender</th>
<th>Age (mean)</th>
<th>Intellectual Disability Measures</th>
<th>Severity of ASC Symptoms</th>
<th>Diagnostic and Exclusion Criteria</th>
<th>Task Description</th>
<th>Task Delay Length</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Task Description</th>
<th>Number of Trials</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Control Variables</th>
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<tbody>
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<td>Boys</td>
<td>6 m, 14 f</td>
<td>WISC-III Full Scale IQ</td>
<td>Mild</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>WISC-III Full Scale IQ</td>
<td></td>
</tr>
<tr>
<td>30 matched controls</td>
<td>Girls</td>
<td>6 m, 14 f</td>
<td>PPVT</td>
<td>Mild</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>PPVT</td>
<td></td>
</tr>
<tr>
<td>30 matched controls</td>
<td>Boys</td>
<td>6 m, 14 f</td>
<td>Raven's Advanced Progressive Matrices</td>
<td>Severe</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
<td>24</td>
<td>No significant</td>
<td>group effect</td>
<td>Raven's Advanced Progressive Matrices</td>
<td></td>
</tr>
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<td>No significant</td>
<td>group effect</td>
<td>WISC-III Full Scale IQ</td>
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### TABLE 2.2.3: Exclusion Criteria

<table>
<thead>
<tr>
<th>Exclusion Criteria</th>
<th>Study</th>
<th>Gender</th>
<th>Age (mean)</th>
<th>Intellectual Disability Measures</th>
<th>Severity of ASC Symptoms</th>
<th>Diagnostic and Exclusion Criteria</th>
<th>Task Description</th>
<th>Task Delay Length</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Task Description</th>
<th>Number of Trials</th>
<th>Mass Effects</th>
<th>Interactions</th>
<th>Control Variables</th>
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<tr>
<td>Age</td>
<td>Boys</td>
<td>6 m, 14 f</td>
<td>WISC-III Full Scale IQ</td>
<td>Mild</td>
<td>None</td>
<td>Delayed Go/NoGo</td>
<td>2 mins</td>
<td>No significant</td>
<td>group effect</td>
<td>ASC &lt; controls;</td>
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<td>group effect</td>
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</table>
2.2.2 Impaired PM in autism

Two of the studies to find impaired PM in autism investigated only TBPM (Altgassen, Sheppard, & Hendriks, 2017; Altgassen et al., 2009). Both studies employed a standard Einstein-McDaniel computer-based TBPM paradigm, the primary difference between versions being that participants press a button at given target times, rather than on presentation of a cue. Participants’ time monitoring behaviour is recorded as the frequency with which they check the clock (via key press), thought to be a measure of strategic, attention switching processes.

Overall, both studies saw TBPM deficits in autistic children and adolescents, compared to non-autistic controls. Furthermore, whilst all participants in both studies increased their time monitoring as the target time approached, the autistic participants in Altgassen et al. (2009) checked the time less frequently overall. Whilst this time monitoring behaviour was spared in the autistic participants in Altgassen et al. (2017) the autistic participants of both studies appeared to check the time less frequently in the critical time interval closest to the target time, although this difference was only close to significance in the study of Altgassen et al. (2009) \( p = .06 \).

Altgassen et al. (2017) went further by investigating the role of motivation, manipulated via the PM instructions. Results revealed that performance was better for all participants of both groups in the “personal motivation” condition (“If you also manage to press this button every minute, you will receive 5 euros”), compared to the social (“It would really help me out if you could remember to press this button every minute” and the low (standard instruction) motivation conditions; the performance within the latter two groups did not differ. Planned comparisons, however, revealed this effect to be driven by the control group only.

Regarding OT performance, controls in the Altgassen et al. (2009) study were more accurate than autistic participants, while groups did not differ in response times. In contrast, there were no group differences in terms of accuracy in the Altgassen et al. (2017) study and autistic participants responded faster to OT stimuli than controls. Moreover, the cost to OT of the additional PM task, seen in both groups in Altgassen et al. (2017) was only evident in the control group in Altgassen et al. (2009).

Taken together, these results demonstrate that when PM tasks rely primarily on strategic retrieval processes (as is the case with TBPM), and comprise OTs with high demands on attentional control resources (visuo-spatial working memory task and 2-back task, respectively), autistic individuals perform less well than non-autistic controls. The lack of any motivation effect on PM in the autistic participants could be a result of a general lower level of motivation for the tasks, possibly linked to a less developed sense of self (discussed in more detail later in the current paper). However, given that OT performance was also impacted, and time monitoring was less frequent and/or less strategic, it may be that attentional resources were at capacity, rendering the ability of the manipulation to influence attention less effective.
However, reduced PM performance is also possible from EBPM paradigms, as demonstrated by the studies of Brandimonte et al. (2011) and Yi et al. (2014). Whilst both studies saw impaired EBPM in the autistic group, they varied considerably in methodology. Brandimonte and colleagues (2011) employed a standard EBPM computer-based paradigm and found the autistic children to respond slower, and with less success, to the black and white PM target pictures than non-autistic controls. Yi and colleagues (2014), on the other hand, applied the same card-naming paradigm as employed in the landmark study of Kvavilashvili, Messer, and Ebdon (2001) in which young children named a stack of cards (OT), passing any cards that had a heart in one corner to the experimenter (PM). Yi and colleagues compared the performance of the autistic children to that of age-matched controls and to ability-matched controls, with the latter group being significantly younger than the two other groups. Results showed that the autistic children remembered to pass significantly less PM target cards to the experimenter than both control groups, an indication that EBPM is difficult for young autistic children, even in the face of a very simple OT.

In contrast to the previously described EBPM studies that saw preserved PM in autistic participants, these studies included PM cues of arguably low salience (line drawings in same format as OT picture trials and a small red heart in the corner of a card, in the Brandimonte et al. (2011) and Yi et al. (2014) studies, respectively. Thus, the task of controlling attention, identifying the relevant cue and retrieving the intention was, according to the multiprocess framework, necessarily more strategic, placing higher demands on attentional control resources, likely compounded by the younger age of the participants (around 8-years-old).

The study described henceforth examined both TBPM and EBPM within one sample by way of the Dresden Breakfast Task (Altgassen et al., 2012), a task designed to assess PM ability under naturalistic conditions. Participants were required to prepare the table for breakfast for their 3 friends' arrival. This was to be completed in a particular way, as per a given set of rules and a photograph, within seven minutes; participants were encouraged to plan their actions beforehand. Four PM tasks were embedded within the main task: 2 EBPM, and 2 TBPM (also see Table 2 for a description of the main assessment techniques).

Analysis of the video-recorded performance of the participants revealed that controls outperformed the autistic participants in every measure of the Dresden Breakfast Task, other than switching. That is to say, controls were better at forming plans and adhering to them, adhering to rules, executing plans fully and effectively, and performing all TBPM and EBPM tasks. Furthermore, controls outperformed autistic participants on a standard laboratory PM task, and scored better at self-report and computer-based executive function measures. This study therefore provides evidence that, under complex and naturalistic conditions, which require participants to coordinate themselves and their execution of several tasks, either sequentially or in parallel, PM performance is severely impaired in autistic individuals, even for EBPM. However, this was the first study to investigate both TBPM and EBPM in the same sample under such conditions, and so it is useful to compare the results with a study with similarly complex and multitask demands, namely with one employing the Virtual Week (Kretschmer et al., 2014).

Kretschmer et al. (2014) employed a computerised version of Virtual Week (also see Table 2 for a description of the main assessment techniques), a board game that imitates daily PM task demands, originally devised by Rendell and Craik (2000). In brief, players roll virtual dice and move their tokens around the board a total of three times (three virtual days). When passing an event square, players must pick up a card and choose an activity from one of three options (e.g. have toast for breakfast), and are only permitted to move on once they roll the number corresponding to their chosen option (OT). EBPM and TBPM tasks are embedded within the game, equally split into either “regular” tasks (e.g. take medication at breakfast - EBPM), or “irregular” tasks (e.g. call plumber at 5pm - TBPM). To perform the task, players press the “perform task” button, which presents the task within a list of (distractor) tasks. The virtual time, which is linked to the movement of the tokens on the board, can be seen on a digital clock produced on-screen via key press.

Half of all participants were assigned to an ‘implementation intention’ condition in which they repeated ‘if-then’ statements on presentation of the PM task, such as “when it is 5pm I will press the ‘perform task’ button and select ‘phone the number.’” Implementation intentions have been posited to strengthen the task-cue association, thereby increasing the probability that the retrieval of the task would be more automatically triggered by presentation of the cue (Gollwitzer, 1999). Indeed, much of the previous work on implementation intentions in populations with reduced planning ability (e.g., older adults; Kliegel, Martin, McDaniel, Einstein, & Moor, 2007) has shown that this particular encoding strategy can be effective in improving PM performance (Chasteen, Park, & Schwarz, 2001), and so the authors hypothesised that this may also be important for their autistic participants.

The autistic participants performed less well than non-autistic controls across all PM tasks, replicating the PM difficulties experienced by autistic participants in multitask conditions, as seen in (Altgassen et al., 2012). Both groups performed better on the regular tasks than the irregular tasks, and a group x regularity interaction revealed the autistic participants to have performed worse than controls on the irregular tasks. Surprisingly, the implementation-intentions did not benefit either group.

2.2.3 PM in autism – mixed results

Thus far, studies reviewed have demonstrated either intact or impaired PM in autism, across both EBPM and TBPM paradigms. Three of the four following studies also included both event- and time-based cues, but, rather than showing a complete deficit, reveal only TBPM, but not EBPM deficits. The final study to be reviewed employed only a EBPM paradigm, but the results were mixed in that differences emerged between participants grouped according to a measure of autism severity. The first study discussed will be that of Henry et al. (2014) as it, like that of Kretschmer et al. (2014), employed the Virtual Week, but with children, rather than adults.
Other than participant age, the methodology employed by Henry et al. (2014) was much the same as Kretschmer et al. (2014), but was adapted to include tasks relevant to children. Also, rather than an implementation condition in this study, the authors included a “low OT absorption” condition, which allowed children to move on from an event card with any dice roll, rather than the standard specific number; furthermore, participants were not required to move the token manually around the board as this was done automatically, further reducing overall cognitive demand.

In contrast to Kretschmer et al. (2014) the main group effect, whereby controls outperformed autistic participants, was qualified by a group by cue-type interaction, revealing that, whilst both groups performed better on EBPM than TBPM tasks, autistic participants only performed worse than controls on the TBPM tasks. This pattern was somewhat mirrored by a cue-type x regularity interaction, in that varying the regularity of the tasks did not result in differences in EBPM performance, but performance in irregular TBPM tasks was worse than that of the regular TBPM tasks.

This pattern again emerged in the studies by Williams et al. (2013) and Williams, Jarrold, Grainger, and Lind (2014) which investigated both EBPM and TBPM in autistic children and autistic adults, respectively. In Williams et al. (2013) the PM of autistic children was investigated by way of an engaging computer game in which the children had to drive a car down a road, taking care to avoid obstacles and other vehicles (OT) whilst collecting gold coins (also see Table 2 for a description of the main assessment techniques). Using a within-subjects design, children's PM was assessed across two separate sessions in which they either had to remember to press a certain key when passing a lorry (EBPM), or to refuel after 80s (TBPM). Performance in the TBPM condition was further supported by the fuel gauge turning red with 20s to go. Upon a fail, the car would stop, the OT score would be reset to zero, and a reminder presented on screen of “Don't forget to refuel!” In a fashion similar to that of previous TBPM studies, participants could press a certain key to check the fuel level.

No differences emerged between groups in OT performance, with both groups performing similarly on the car driving game. The PM results, however, revealed a TBPM deficit, but not an EBPM deficit, in the autistic children, compared to non-autistic children. Furthermore, only the autistic children fared better in their EBPM performance compared to their TBPM performance, although some caution is needed with interpretation as the autistic children were at ceiling in the EBPM task. Fuel monitoring behaviour showed the expected linear increase towards the TBPM target time, for both groups, indicating that strategic monitoring was intact in this autism group. Interestingly, measures of cognitive flexibility and mentalising did show impairments in the autistic group, but only autistic mentalising was associated with TBPM performance. The results of this study again confirmed that EBPM success is possible even for autistic children if PM cues are focal and salient; when external cues are absent, and strategic processes are necessary, as in TBPM tasks, performance may be impaired.

The study by Williams et al. (2014) found very similar results in autistic adults, though this was achieved by using a more common computer-based paradigm. Specifically, participants had to remember to press a different key whenever a musical instrument appeared (EBPM) or every two minutes (TBPM), while judging whether the list presented on-screen was the same as the words previously presented one by one (OT). Again, participants could press a certain key at any moment to bring up a display of a digital clock.

With regards to OT performance, no group or cue differences emerged. With regards to PM accuracy, overall TBPM performance was worse than EBPM. Further, as in the previously described study, EBPM performance between the two groups was similar, whereas autistic TBPM performance was worse than that of controls. Analysis of the response precision of TBPM (i.e. the temporal distance to the target time) and the reaction time of the EBPM revealed no overall differences between TBPM and EBPM performance. However, the analysis did reveal that autistic participants were less precise in the TBPM task, but no slower in the EBPM task. The monitoring of the time did not differ between groups, showing the expected linear increase as the target time approached.

The final study to be summarised is that conducted by Sheppard et al. (2016), which investigated the relationship between autism symptom severity and PM performance. To accomplish this, the study included a group severely autistic children (as categorised by the Childhood Autism Rating Scale – CARS; Schopler, Reichler, DeVellis, & Daly, 1980), and adapted the methods (e.g. participant matching, task design) in novel ways accordingly. Children were engaged in three simple games, played with a hand puppet, which measured their EBPM. Recalling the puppet's name provided a measure of RM.

The inclusion of severely autistic children proved an important aspect, as, overall, only the severe, and not the mild autism group demonstrated poorer PM than the non-autistic controls. A group x task interaction revealed, however, that, remarkably, the severely autistic children performed as well as the non-autistic children on the task that involved picking up a spring toy when leaving the room.

This study, therefore, suggests that variation in autistic symptoms, a common occurrence in a population well known for its heterogeneity (Jeste & Geschwind, 2014), plays an important role in PM performance. Furthermore, EBPM success is possible for severely autistic individuals if they are sufficiently motivated.
Table 2. Description of assessment techniques.

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Task Description</th>
<th>PM cue type</th>
<th>cue delay</th>
<th>psychometric properties</th>
<th>appropriate age range</th>
<th>references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dresden Breakfast</td>
<td>Preparation of breakfast, including planning, setting the table, and cleaning up</td>
<td>PM task (2 each) +</td>
<td>5 min</td>
<td>Inter-rater reliability was high in the Altgassen et al. (2012) study; validity shown by Kliegel &amp; Altgassen (2014); performance r = .95; plan adherence r = .93</td>
<td>7-14 years</td>
<td>Altgassen, Kretschmer &amp; Kliegel (2014); Hering, Cortez, Kliegel &amp; Altgassen (2012)</td>
</tr>
<tr>
<td>Driving game</td>
<td>Computer-based driving game, following certain rules and time restrictions</td>
<td>EBPM tasks (6x) + TBPM tasks (6x)</td>
<td>no delay</td>
<td>good reliability (Cronbach's Alpha) ranging between .57 to .84 for Henry et al. (2014) and .62 and .86 for Henry et al. (2014); virtual version; used in ADHD and older adults: Altgassen, Kretschmer &amp; Kliegel (2014); Altgassen et al., (2015); Rendell, Henry, Phillips, de la Piedad Garcia, Booth, Phillips &amp; McDaniel, &amp; Rendell (2013); Mioni, Rendell, Henry, Cantagallo &amp; Stablum (2013)</td>
<td>7-14 years</td>
<td>Williams et al. (2013)</td>
</tr>
<tr>
<td>Virtual Week</td>
<td>Computer-based game that imitates daily PM task, demands, and pushes the PM task</td>
<td>EBPM &amp; TBPM each day</td>
<td>1-2 days</td>
<td>-Miami University (2014)</td>
<td>7-14 years</td>
<td>Miami University (2014)</td>
</tr>
</tbody>
</table>

Note: EBPM = Event-Based Prospective Memory; PM = Prospective Memory; TBPM = Time-Based Prospective Memory.
results (e.g., Henry et al., 2014; Sheppard et al., 2017) that are generally in line with the multiprocess framework. Intention retention has not been directly investigated, but first evidence points to retrospective memory load affecting PM in autism. Specifically, Kretschmer et al.’s study reported reduced autistic deficits with regular PM tasks that put less demands on retrospective memory as compared to irregular tasks. Similarly, Henry and colleagues (2014) found larger autistic PM deficits for irregular TBPM tasks. However, an important limitation of the reviewed PM studies is that all but one (Sheppard et al., 2016) include only mildly to moderately autistic participants, of average to above average IQ. The PM evidence does not therefore fully represent the autistic population, a population known for its heterogeneity (Masi, DeMayo, Glozier, & Guastella, 2017), which is, indeed, an issue across the autism literature. The study by Sheppard et al. (2017) does highlight the importance of considering symptomatic variation in autism and how it relates to PM performance, revealing a difference in PM performance between ‘severely’ and ‘mildly’ autistic children.

However, in this case, severity classification was made on the basis of a composite CARS score (Schopler et al., 1980), disguising the variation of behaviours that contributed to the total score. Thus, whilst the Sheppard et al. (2017) paper was an important step in the (PM) autism literature, much more needs to be done to more accurately represent the population. Therefore, whilst symptom severity and other aspects of the heterogeneous condition may have contributed to the PM performances seen in the literature, caution is needed when generalising the conclusions to the entire autism population.

Taken together, despite the heterogeneous methodology of the conducted studies, and the relative homogeneity of the participants, a pattern emerges that suggests autistic individuals will likely find PM tasks that demand a high level of attentional control and strategic processing, such as those involving multiple sub-tasks and/or cues of low salience, very difficult. These findings are in line with the everyday difficulties of people with autism with planning ahead, and the organization and coordination of (complex) activities.

In terms of improving PM performance and reducing everyday difficulties, reducing the cognitive/strategic demand of PM tasks by increasing the automaticity of retrieval processes, would almost certainly be of benefit to autistic individuals, indeed, to all populations. However, all PM and autism studies conducted so far, with exception of the Dresden Breakfast Task, employed typical laboratory-based tasks that provide high experimental control, but low ecological validity, and which may not be able to reflect the complexity of real life tasks.

2.4 THE DYNAMIC CHARACTERISTICS OF PM

In reality, daily tasks are significantly more complex than the scenarios presented in typical laboratory-based dual-task PM paradigms. For instance, some tasks will only involve a short delay, with few competing tasks and no social interaction, such as remembering to check out with an electronic travel card when alighting the bus after a short journey. In contrast, others will involve long delays and human interaction, in the face of several other tasks and social and cultural expectations, such as passing on a message to a friend at the end of a busy academic conference. Importantly, therefore, PM is a variable, multitask process which demands the fluid and dynamic control of attentional control resources to facilitate the integration and execution of all aforementioned PM-critical cognitive mechanisms, the exact calibration of which depends heavily on context. This between- and within-PM task variability is to some extent recognised by the recent dynamic multiprocess framework proposed by Scullin, McDaniel, and Shelton (2013), which argues for the need for dynamic utilisation of automatic and strategic retrieval processes over time, given the temporal variability of PM demands. Therefore, in practice, whilst investigating discrete cognitive mechanisms, such as executive function (e.g., reducing switching and inhibition demands by increasing cue salience) provides some indication as to the role of that specific mechanism, it ignores the interrelated, systemic and social characteristics of the PM process. One further critical factor in the dynamic PM process is individual difference, that is, how individuals are variably equipped to function in such a complex environment, a factor particularly important to consider for the autistic population who are known for their cognitive and behavioural heterogeneity (Georgiades, Szatmari, & Boyle, 2013; Jeste & Geschwind, 2014).

Thus, to properly understand PM, and so devise the most effective interventions, it is important to consider any processes that may be fundamental to the development of the cognitive and behavioural functions needed for prospective remembering and their dynamic integration and utilisation, whilst also recognising the dynamic and contextual requirements of PM as demanded from an ever changing physical and social environment. With this in mind, the following section will briefly examine the potentially fundamental role of predictive coding in the PM process. Furthermore, via the predictive coding account of account by Van de Cruys et al. (2014), we will show how these predictive coding deficits that may be primary to autism, would result in the cognitive and PM deficits seen in the literature.

In recognition of the dynamic agent-environment interactions inherent to PM, we extend the role of predictive coding in PM, and the account of autism, to not just include perception, but also movement and affect, as is the case in predictive models formulated under active inference (Clark, 2015; Joffily & Coricelli, 2013; Kiverstein & Miller, 2015; Pezzulo, Rigoli, & Friston, 2015). In this way, the notions put forward in the current paper will shed light not only on processes fundamental to PM, but also on the underlying causes of autism. In addition, by better understanding fundamental atypicalities in perception, action and movement, the development of better targeted interventions is supported that not only improve daily PM performance, but also inform clinical practice and help target specific learning to improve autistic individuals’ lives as a whole.

2.5 A UNIFYING PREDICTIVE CODING ACCOUNT OF AUTISM

Simply described, predictive coding is an account of perception in which the main task of the perceptual system is to minimize the prediction-error between predicted and actual sensory input (Clark, 2013; Rao & Ballard, 1999). Under this account, the brain continuously generates predictions about future incoming sensory information
weighting mechanism is essential to successful PM performance. Selectively attending of attentional resources is central to the PM process, then an optimum precision if, as posited by the multiprocess framework (McDaniel & Einstein, 2000) the allocation of attentional resources is central to the PM process, then an optimum precision weighting mechanism is essential to successful PM performance. Selectively attending to relevant information and ignoring the high volume of other information would facilitate time monitoring, or the monitoring for and identification of PM cues (particularly for those of low salience and non-focality), or the switching of attention from one task to another. Furthermore, attenuating the relentless barrage of irrelevant sensory information is important for the development and application of other, higher-level cognitive processes critical to PM, such as planning, retrospective memory, episodic future thinking and critical thinking and reasoning (regarding, say, the context and environment within which the PM is likely to be situated).

Using the previous example of a café, it is easy to see the importance of precision to PM. One would rely on the high-level concept of a café to form a ‘café-prediction’, from which one would expect, and thus assign low precision to, the tumultuous stream of relatively lower-level errors (e.g. sudden bursts of laughter, or cups being dropped to the floor) allowing them to be ignored within (and thus not update) my ‘café-prediction’ model. This would free up attentional resources, which would be particularly important for demanding PM tasks within the café, such as monitoring the time in order to call your boss at a certain time, or to monitor for a cue indicating your coffee is ready, after which you might stop your conversation (OT) and pick up the coffee which has been placed at the end of the counter.

Pertinently for the current review, Van de Cruys et al. (2014), in their unifying account of autism, put forward the selective and contextual weighting of precision, a mechanism essential to attentional control and so to PM, as the core deficit of the condition. Specifically, they situate the core deficit in the High, Inflexible Precision of Prediction Errors in Autism (HIPPEA). This means that impaired precision allocation results in attention often being drawn to what is effectively noise, thus demanding valuable and limited cognitive resources, drawing attention away from real and important learning opportunities, and needlessly updating prediction models. The authors posit that this uniformly high precision, irrespective of context, accounts for the characteristic impairments and difficulties commonly seen in autism, such as atypical sensory processing (Ashburner et al., 2008; Ben-Sasson et al., 2009; Robertson & Baron-Cohen, 2017; Tomchek & Dunn, 2007), social communication difficulties, and insistence on sameness and repetitive behaviours, as efforts to reduce confusing and unpleasant environmental uncertainty (APA, 2013). Specifically, high sensory precision may result in a constant barrage of seemingly unfamiliar, attention grabbing signals, each of which would arguably be at best surprising and distracting; at worst, shocking and frightening. Importantly, prediction itself is not impaired in autism, as is evidenced by superior episodic future thinking and critical thinking and reasoning (regarding, say, the context and environment within which the PM is likely to be situated).

Assuming the validity of the Van de Cruys et al. (2014) account, the deficit of HIPPEA leads directly to the PM impairments seen in the population. It would explain, for example, poor PM performance, relative to non-autistic participants, when PM cues were low in salience (e.g., high precision attributed to each and every error would result in attention being drawn to errors which will always occur and cannot be reduced, thus depleting valuable and limited cognitive processing power, and needlessly updating prediction models. Precision, therefore, is seen as the fundamental mechanism of learning and attention (Van de Cruys et al., 2014) and has a clear and important role in PM.

If, as posited by the multiprocess framework (McDaniel & Einstein, 2000) the allocation of attentional resources is central to the PM process, then an optimum precision weighting mechanism is essential to successful PM performance. Selectively attending...
salience of the PM cue, making it much harder to discern. Thus, the predictive coding account of Van de Cruys arguably contributes much to the understanding of autism, and to PM. An important potential criticism of the account, however, may be that, so far, much of the literature has been mainly theoretical and conceptual in nature, dealing with autism using the tools and concepts derived from predictive coding and provides therefore nothing more than stories (Bowers & Davis, 2012). Although the unification of a disparate range of impairments under one theory is progress in its own right, we agree that much further work is needed. In particular, the development of quantitative computational models that are able to make predictions about updating, learning, and the adjustment of precision on a trial-by-trial basis (Van de Cruys et al., 2017), would greatly advance the field. For example, the aim of the rapidly emerging field of computational psychiatry is to infer the hidden causes (such as the structure of the parameters of an internal model) of measurable quantities (such as actions, reaction times and symptoms; (Friston, Stephan, Montague, & Dolan, 2014; Schwartenbeck & Friston, 2016; Stephan & Mathys, 2014). Furthermore, in their recent paper, Van de Cruys et al. (2017) put forward substantial empirical data in support of their account.

So far, we have only focused on the perceptual aspect of prediction-error minimization. However, PM does not simply involve the perception and processing of external sensory signals. Rather, it is a complex process that depends critically on perception and action. Specifically, it requires the effective coordination of the mind (perception, desires, intentions), the body (bodily sensations, action) and the environment (PM cues and/or target times; social or occupational expectations; competing sensory and social demands for attention) to ensure successful action at the appropriate moment. Consequently, to fully relate predictive coding to PM and to autism, we need to extend HIPPEA to more embodied predictive coding models derived from active inference (Bruineberg, Kiverstein, & Rietveld, 2016; Pezzulo et al., 2015; Seth, 2013).

According to active inference, action, as well as perception, is integral to the predictive coding and error minimisation process. That is, agents do not only try to predict the current state of the environment, but also cause their environment to be in an optimal state (i.e. a state of physical, social and cultural well-being/safety) through action. For example, according to active inference, ‘intending to post an important letter in a post box’ works like ‘determining the need of posting a letter, expecting oneself (with high precision) to post the letter and then selecting an action (reaching into a bag, grasping the letter, then posting it through the slit in the post box) that fulfils that expectation’. Only if an agent has the right predictions (both about what will be an optimal state, and about how it can reach that state), it can cause the environment to confirm to those expectations and consequently lead to an actually optimal state beneficial to the agent (Bruineberg et al., 2016).

Put in more concrete terms, for individuals to flourish in their environment, they must understand their needs in terms of their physical and mental well-being (expected states), and meet them by perceiving and acting upon the environment in an as efficient and beneficial way as possible. This includes among others the congruency of the sensory weighting of prediction-error (precision) with the volatility of the environment and the trade-off between action and perception (Palmer, Lawson, & Hohwy, 2017). Therefore, the role of prediction error minimisation, and the impact of any impairment such as HIPPEA, becomes much more significant, as it mediates all interactions between the brain, the body, and the environment within and between all hierarchical levels (i.e. low-level stimulus to high level concepts/abstractions), facilitating understanding of the self and the world in which it is situated. Active inference and error minimisation is therefore deeply interwoven into everyday processes, not least the PM process.

Given then, the essential role of prediction and error precision in mediating the relationships between the brain, the body and the environment, the adverse consequence of HIPPEA, the precision-weighting deficit put forward as core to autism (Van de Cruys et al., 2014; Van de Cruys et al., 2017) already deemed significant to PM, becomes much more problematic.

It means that autism is not solely a problem of perceptual evidence accumulation, but involves deficits in the interactions between all levels and modalities (e.g. between simple, sensory signals and higher level conceptual/constructed beliefs), between the brain and body, and the ways they coordinate to respond and act upon the environment. Thus, HIPPEA makes a whole range of other autism phenomena intelligible such as their difficulties with understanding internal states, evidenced by a high prevalence of alexithymia (Milosavlejevic et al., 2016), differences with introspection (Shah, Hall, Catmur, & Bird, 2016), differences in rhythm and timing (Isenhower et al., 2012; Sheridan & McAvley, 1997), movement and associated social difficulties (Cook, 2016; Cook, Blakemore, & Press, 2013), and diminished sense of agency (Grynszpan et al., 2012; Sperduti, Pieron, Leboyer, & Zalla, 2014; Zalla, Miele, Leboyer, & Metcalfe, 2015), linked to deficits in episodic memory and episodic future thinking (Lind, 2010). We think that extending the unifying account of autism of Van de Cruys et al. (2014) in such an embodied way, brings the account closer to more embodied unifying accounts of autism such as the one offered by De Jaegher (2015) which places differences in movement, rhythm and coordination, between the self, others and environment as responsible for the emergence of autism. Thus, the embodied HIPPEA and enactive accounts of autism both describe systematic differences in movement and perception that ultimately blend with a different conceptual and social understanding of the environment; indeed, a different way of making sense of the world. We feel that together, both accounts offer a more encompassing account of autism. Furthermore, the difficulties caused by such as account would greatly impact upon PM performance.

PM tasks reflect one aspect of the fundamental real-world demand of navigating a complex physical, social and cultural environment, and so require the efficient coordination of the brain, body and environment to remain in a state of well-being. For example, the environment will create PM demands (work supervisor asks you to pass on important information to a work colleague), generating intentions within the individual (pass message on to colleague). This intention is internalised in terms of relative value (need to please supervisor; consequence for colleague of not receiving message; likely personal emotional state – personal, physical and social consequences of success/failure) which would interact with chances of success (beliefs about own ability to successfully
execute task, given likely future context in which task/cue is situated, and predicted ability to employ appropriate action within it; see Fig. 2). These states are accompanied by physiological responses (increased heart rate, adrenaline/cortisol) and associated affective responses (arousal, worry, stress) that would need to be understood in the context of their situatedness in a socio-cultural setting. In addition, successfully realizing the PM task requires understanding how attentional resources are employed to perceive relevant cues (recalling my supervisor’s request upon seeing my colleague). What is crucial then, is for the agent to be selectively perturbed by aspects of the environment (change your behaviour when seeing your colleague, but try to not get distracted by your phone) in a way that is in line with longer-term plans and goals and the demands of the situation (such as your supervisor’s request). Such selective openness to aspects of the environment (or ‘affordances’) and coordinating with them in an adequate way represents a process fundamental to life and mind (Bruineberg & Rietveld, 2014).

![Diagram](image_url)

**Figure 2.**
Diagram depicting the role of predictive processing in mediating between the brain, body and environment throughout the prospective memory process. Illustrates importance of attending to relevant cues (solid arrows), via effective precision-weighting, against a barrage of competing, often task-irrelevant, information (dashed arrows).

Seeing PM as reflecting this fundamental life processes means that interventions aimed at addressing issues that may be affecting such life processes (e.g., HIPPEA in embodied predictive coding) would also benefit PM performance.

### 2.6 CLINICAL APPLICATION

According to HIPPEA (Van de Cruys et al., 2014; Van de Cruys et al., 2017), autism emerges primarily from an impaired prediction error precision weighting process, resulting in and manifesting as sub-optimal learning and attentional mechanisms. When considered in the context of active inference and the brain-body-environment system, HIPPEA would disrupt the critical continuous and reciprocal learning between all three states of the system, resulting in impaired communication and understanding between the brain and the body, and their perception and action in and with the environment. Given these assumptions, autistic individuals would benefit from holistic and embodied interventions that would support them in attending to and engaging with themselves and the world, which would in turn support their PM performance.

As posited by the above assumptions, autistic people experience difficulty in perceiving and acting in the often irreducibly uncertain world. One obvious way in which to support such a difficulty is to reduce the irreducible uncertainty as much as possible, and provide predictable clear expectations and a safe physical, social and cultural environment. This provision of clear, consistent structure and expectation in the environment is the core principal of the Treatment and Education of Autistic and related Communication-handicapped Children approach (TEACCH; Mesibov, Shea, & Schopler, 2004) which is widely implemented within charities and schools and has good levels of reported effectiveness (Mesibov & Shea, 2010; Panerai, Ferrante, & Zingale, 2002). According to TEACCH, schools/environments should provide autistic individuals with as predictable and ‘low arousal’ physical environments as possible, for example, low sensory input and similar classroom configuration across all classes (e.g. same furniture, consistently arranged and decorated display boards, neutral colours). Reducing the uncertainty in the environment would not only reduce anxiety but would provide a safe, predictable platform from which to learn. These TEACCH principles could also be directly applied to the PM environment: reducing the physical and social uncertainty in the environment parallels the reduction in cognitive load inferred to be beneficial in empirical PM work (e.g., use of salient cues, simple OT). Providing clear PM instructions that are additionally supported by visual cues, could enhance encoding and increase the physical/perceptual salience of the cue, thus decreasing executive control demands by increasing automaticity of intention retrieval.

To increase effectiveness, this approach could easily be incorporated into a person’s existing communication strategy. For instance, an autistic child’s tailored Picture Exchange Communication System (PECS; Bondy & Frost, 1994) could be employed to provide need-appropriate verbal and visual task instructions when supporting them in bringing their sports kit to school the following day. The relevant symbols could be placed on the appropriate day on the child’s daily visual timetable, with copies taken home on the day to act as salient PM cues.

Furthermore, if autism is indeed associated with sub-optimal attentional processes, which may result in difficulties attending to relevant and important cues (internal and external), autistic individuals may benefit from interventions that focus on practicing and training attention. For example, the program Attention Autism (Dawson et al., 2004), originally developed to support the development of joint attention, has been found to improve attention by providing engaging sensory objects. This intervention would thus support the general development of the understanding to engage with relevant cues in the environment, cues which afford personal and social benefits. The benefit to PM of improving attention by way of interventions such as Attention Autism (Dawson et al., 2004) is thus clear: the ability to identify, and allocate attention towards,
appropriate event-based cues in a complex environment would be developed, facilitating more frequent automatic retrieval.

A further method of improving self and internal understanding and the relationship with the environment – or the brain-body-environment system – would be to facilitate impaired learning through interventions that involve the use and coordination of all three of these states. Moving, acting and perceiving to achieve internal (fun, pleasure) and external (social interaction, PM tasks) goals, and post-action perception and reflection on the internal (emotions, feelings, bodily responses) and external (effective communication, understanding others' behaviour, successfully executing a PM task) physical and social results, would support the understanding of one's own function in one's physical and social environment, and improve PM performance at every phase. One would slowly become more attuned to one's own body and its responses and actions within its environment. Examples for such embodied/enactive approaches are movement (for a review, see Lee, Lambert, Wittich, Kehayia, & Park, 2016), drama (Corbett et al., 2011), music (Whipple, 2004), and art therapies (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014) that are currently already employed to support autistic people.

The approaches described above can be incorporated to generate more concrete, PM-specific support and learning strategies. One approach would be to augment the largely non-conscious, impaired embodied predictive coding and error weighting processes that are involved at every PM phase, with explicit, metacognitive processes. Metacognition has been shown to be important in PM, suggesting, for example, that attention-allocation strategies depend somewhat on metacognitive expectations of the PM task demands (Rummel & Meiser, 2013), and an awareness of one's cognitive difficulties may encourage the use of reminders to make sure one does not forget the implementation of the delayed intention (Gilbert, 2015; Phillips, Henry, & Martin, 2008). Although, interestingly, a recent study by Cherkaoui and Gilbert (2017) found that autistic participants gave good metacognitive judgements of their (poorer) PM abilities and predictions of performance, but did not compensate with an increased use of reminders. It may be that the autistic participants differed only in their metacognitive control, but not awareness, in line with the, albeit scarce, literature pointing to difficulties autism in metacognitive control, and to deficits in using monitoring processes to influence cognitive control (for similar results see Grainger, Williams, & Lind, 2016; Wilkinson, Best, Minshew, & Strauss, 2010; but see Wojcik, Allen, Brown, & Souchaj, 2011 for contrasting findings).

Given the benefit of metacognitive strategies to the learning of those who experience learning difficulties (Chevalier, Parrila, Ritchie, & Deacon, 2017) it may be that autistic individuals, indeed any individuals that experience PM difficulties, would benefit from training and support in the use of direct PM metacognitive strategies. Such training could be designed by drawing on the principles of TEACCH (Mesibov et al., 2004) to provide a highly structured, cyclical PM predict-perform-evaluate processes, scaffolded appropriately according to individual cognitive and communication needs (for example, the use of PECS symbols as mentioned above). Figure 3 provides an example of how this could be implemented in, for example, schools, to be completed by children with an appropriate level of adult support. Through this sheet, children would be encouraged to consciously consider a particular PM task, such as remembering their swimming kit, and why it is important to them. Children would also predict the likely environment in which the intention will be executed, how difficult it will be, what reminders or cues they will use and, ultimately, their likely chances of success. The children could then evaluate their predictions and performance, once the task was over, comparing them with what was experienced, informing future strategy and predictions for the same or similar tasks in the future. This cyclical process would augment the predictive processing problems we posit to adversely affect PM in autism, whilst also developing PM-specific, and more general, metacognitive ability. It would also have the added benefit of directly supporting the factors posited by the multiprocess framework (McDaniel & Einstein, 2000) to influence attention allocation and intention retrieval during the PM process (such as intention encoding, cue association, cue salience and task importance).
To summarize, the findings of the PM and autism literature show that making small changes to the PM environment, such as clearly demonstrating the value of completing the task, may improve PM performance. Such a demonstration might increase motivation, offset an impaired understanding of self and may improve PM performance by supporting intention encoding, shielding of the intention from PM-irrelevant stimuli, encouraging monitoring for the PM cue and enabling switching to the intended action. Furthermore, the salience of the cue, both in terms of the sensory distinctiveness as historically described by the PM literature, and in terms of its relevance to the task, may influence the extent to which retrieval of the intention relies on automatic versus strategic, executive control processes.

### 2.7 CONCLUSION

The evidence from studies conducted to date strongly suggest that autistic individuals experience difficulty with PM. However, the few studies in which autistic PM performance was spared, even for severely autistic children, demonstrated that PM success is possible under very structured conditions, with simple OTs, highly salient, focal PM cues and motivating rewards. According to the multiprocess framework, these conditions more automatically encourage the allocation of attention toward PM cues, supporting intention retrieval and execution, and rely less on cognitive functions that are impaired in autism (e.g., executive functions, retrospective memory, episodic future thinking).

According to our proposed account of autism, the commonly found cognitive, social and motor deficits in autism are deeply underpinned by an impaired prediction error weighting ability. This impairment disrupts the development and understanding of the brain-body-environment relationships and interactions, culminating in differences in the way that autistic people perceive, move and make sense of the world. Thus, these differences fundamental to autism may lead to their problems with functioning successfully in the world, a critical aspect of which is successfully performing the frequent and challenging PM tasks. Therefore, whilst treating the ‘symptoms’ of poor PM performance by increasing, for example, cue salience and focality, is easily implemented and almost certain to result in better performance, we propose to directly address problems of prediction and action through embodied autism and PM research paradigms and interventions.

**Footnotes**

1 We have used identity-first, rather than person-first, language throughout the paper in line with the preferences of the autism community (Kenny et al., 2013; Sinclair, 2013).
2 The current paper will focus on the multiprocess framework as it is the theory most used by the reviewed studies.
EVENT-BASED PROSPECTIVE MEMORY IN MILDLY AND SEVERELY AUTISTIC CHILDREN

This chapter is based on:
ABSTRACT

This study is the first to specifically compare event-based Prospective Memory (PM) in children with severe Autistic Spectrum Disorder (ASD) to children with mild ASD and typically developing children. Fifty four children participated: 28 children aged 5 and 13 years with either severe or mild ASD were matched for educational attainment with 26 typically developing children aged 5 to 6 years. Three PM tasks and a retrospective memory task were administered. Results showed that children with severe ASD performed less well than typically developing children on two PM tasks but the children with mild ASD did not differ from either group. The findings suggest naturalistic tasks and motivation are particularly important factors in the success of children with severe ASD.

3.1 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 children 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 & Jarrold, 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 age of 10.6 years were compared to 21 age and IQ matched neurotypical children. The ongoing 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 pattern was also observed in another study by Mackinlay et al. (2009) which used a modified version of 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 observed 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 that 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 Hockstra, 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.

3.2 METHOD
3.2.1 Participants
Twenty-eight autistic children (27 males) participated in the study, ranging in age from 3.2. Correlates with performance on PM tasks in autistic children. 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. (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 assessments and corresponding point scores to facilitate analysis (Port, 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, visual-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 \( Fs < 1.93 \)).
Participant characteristics and national curriculum point scores.

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex</th>
<th>Mean age (SD)</th>
<th>Reading score</th>
<th>Writing score</th>
<th>Number score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>M</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Severe Aut.</td>
<td>1</td>
<td>13</td>
<td>9.30 (1.95)</td>
<td>7.36 (4.50)</td>
<td>4.93 (5.89)</td>
</tr>
<tr>
<td>N = 14</td>
<td></td>
<td></td>
<td>6.0 - 14.5</td>
<td>7.92 (5.67)</td>
<td>4.39 (5.89)</td>
</tr>
<tr>
<td>Mild Aut.</td>
<td>0</td>
<td>14</td>
<td>10.05 (2.55)</td>
<td>9.28 (4.56)</td>
<td>12.50 (7.06)</td>
</tr>
<tr>
<td>N = 14</td>
<td></td>
<td></td>
<td>5.5 - 15.5</td>
<td>11.42 (6.43)</td>
<td>12.50 (7.06)</td>
</tr>
<tr>
<td>Typically</td>
<td>10</td>
<td>16</td>
<td>5.05 (0.27)</td>
<td>9.54 (1.73)</td>
<td>10.12 (1.40)</td>
</tr>
<tr>
<td>Developing</td>
<td></td>
<td></td>
<td>5.10 - 6.5</td>
<td>9.85 (1.78)</td>
<td>10.12 (1.40)</td>
</tr>
<tr>
<td>N = 26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*TD (typically developing children) were at norm.

3.2.2 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.

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.

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.

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, they were then asked if they would like to repeat when 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.

<table>
<thead>
<tr>
<th>Task</th>
<th>Timings (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductions, informed of Wally’s name</td>
<td>60</td>
</tr>
<tr>
<td>Instructions for PM task 1 Clapping</td>
<td>60</td>
</tr>
<tr>
<td>Distractor game (Wac-A-Mole)</td>
<td>60</td>
</tr>
<tr>
<td>Remembering PM Clapping task - trial 1</td>
<td>30</td>
</tr>
<tr>
<td>Retrospective memory task – recalling the name - trial 1</td>
<td>30</td>
</tr>
<tr>
<td>Instructions and practice for PM task 2 Feeding</td>
<td>30</td>
</tr>
<tr>
<td>Distractor game (Wac-A-Mole)</td>
<td>60</td>
</tr>
<tr>
<td>Remembering PM Feeding task - trial 1</td>
<td>180</td>
</tr>
<tr>
<td>Remembering PM Clapping task - trial 2</td>
<td>30</td>
</tr>
<tr>
<td>Retrospective Memory task – recalling the name - trial 2</td>
<td>30</td>
</tr>
<tr>
<td>Distractor game (Wac-A-Mole)</td>
<td>60</td>
</tr>
<tr>
<td>Instructions for PM task 3 Reward</td>
<td>30</td>
</tr>
<tr>
<td>Remembering PM Feeding task - trial 2</td>
<td>180</td>
</tr>
<tr>
<td>Remembering PM Reward task</td>
<td>30</td>
</tr>
</tbody>
</table>
### 3.3 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 $F_1 < 1.58$) nor were there group differences on the composite scores ($F(2, 42) = .68$, $p = .51$, $\eta^2 = .03$). 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.

#### 3.3.1 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 was .50 ($SD = .38$), .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 ($F(2,51) = 6.73, p = .03$, $\eta^2 = .26$). 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 ($p = .31$). To see if this pattern was present in each of the PM tasks completed, the results for each task are reported below.

#### 3.3.2 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, $F(2,53) = 3.90, p = .027$, $\eta^2 = .13$. 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 been prompted in trial 1, significantly improved their performance on trial 2 ($F(26) = 28.00, Z = 2.64, p = .01$), 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.

#### 3.3.3 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, $F(2,51) = 4.28, p = .02$, $\eta^2 = .14$ (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 ($\chi^2 (15, p = .02$) 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.

#### 3.3.4 PM Reward task

This task required the children to complete the handshape task and remember to press a button on the puppet. A one way ANOVA found no overall effect of group, $F(2,51) = 3.12, p = .06$, $\eta^2 = .15$. There were no differences between the groups ($p = .25$). Games Howell post hoc comparisons revealed no differences between the groups in the proportion of unprompted responses ($p = .31$, $\eta^2 = .15$) or the proportion of prompted responses ($p = .31$, $\eta^2 = .15$).
3.3.4 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.

<table>
<thead>
<tr>
<th>Group</th>
<th>Unprompted</th>
<th>Prompted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe Aut. $(N = 14)$</td>
<td>.60</td>
<td>.80</td>
</tr>
<tr>
<td>Mild Aut. $(N=14)$</td>
<td>.86</td>
<td>1.00</td>
</tr>
<tr>
<td>Typically Developing $(N = 26)$</td>
<td>.83</td>
<td>1.00</td>
</tr>
</tbody>
</table>

3.3.5 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 $F(2,51) = .80,\ p = .45, \eta^2_p = .03$ (see Table 6).

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

<table>
<thead>
<tr>
<th>Group</th>
<th>Recall Name Trial 1</th>
<th>Recall Name Trial 2</th>
<th>Proportion correct across both trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe Aut. $(N = 14)$</td>
<td>.79</td>
<td>.86</td>
<td>.82</td>
</tr>
<tr>
<td>Mild Aut. $(N=14)$</td>
<td>.93</td>
<td>.86</td>
<td>.89</td>
</tr>
<tr>
<td>Typically Developing $(N = 26)$</td>
<td>.73</td>
<td>.77</td>
<td>.75</td>
</tr>
</tbody>
</table>

3.3.6 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 ($r(28) = .34,\ p = .07$). 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 ($r(28)$, all $p$’s >.08).

3.4 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 benefited 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 Niedźwięska (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 & Culicte, 1983).

Another important finding was that in the clapping task, the significant improvement of the typically developing children from trial one to trial two (60% 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) (Hoeckstra 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) identified 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 tasks.

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 < .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, η² = .15). Post hoc tests again revealed a significant difference only between the typically developing children and the severely autistic group (p = .005).
CHAPTER

DO IMPORTANCE INSTRUCTIONS IMPROVE TIME-BASED PROSPECTIVE REMEMBERING IN AUTISM SPECTRUM CONDITIONS?

This chapter is based on: Altgassen, M., Sheppard, D. P., Hendriks, M. P. H. (manuscript submitted). Do importance instruction improve time-based prospective remembering in autism spectrum conditions?
ABSTRACT

Background: This study explored the impact of motivation on the memory for delayed intentions (so-called, prospective memory, PM) in autistic individuals. Specifically, we were interested in the effects of personal (i.e., receiving a reward) as compared to prosocial motivation (i.e., performing a favour for someone). Given the well-established theory of mind deficits in autism, we expected autistic individuals to benefit more strongly from personal than prosocial importance manipulations, while the opposite pattern was predicted for controls.

Method: Sixty-one adolescents with autism and 61 typically developing adolescents participated, with each group distributed equally to one of the three motivation conditions of standard, prosocial and personal import. Participants worked on a 2-back picture-based ongoing task in which a time-based PM task was embedded.

Results: A mixed 2 (Group) x 3 (Motivation condition) analysis of variance indicated a main effect of group, with controls outperforming the autism group, and a main effect of condition, with overall better performance in the personal than the prosocial and standard motivation condition. There was no significant interaction.

Conclusions: In line with previous evidence, autistic individuals showed reduced PM performance. Controls performed significantly best when a personal reward was promised, while there were no significant differences between the motivation conditions for autistic individuals. Findings are discussed in terms of underlying processes.

4.1 INTRODUCTION

For most people, successful daily life depends critically on remembering to complete a large number of tasks at the right moment in the future, such as remembering to finalize your daughter’s costume for her carnival party at school the next day, or filing your tax report on time, or taking out the garbage on Monday evening. Such tasks are common examples of so-called prospective memory (PM) tasks. PM refers to the execution of delayed intentions at a certain point in time (time-based PM tasks), upon appearance of an external cue (event-based PM tasks) or right after having completed an activity (activity-based PM tasks, Brandimonte, Einstein, & McDaniel, 1996). PM tasks are ubiquitous in everyday life. Frequent failures in prospective remembering can lead to negative social, occupational or health-related consequences (Kliegel, Jäger, Altgassen, & Shum, 2008). PM tasks are dual tasks, thus, while the individual is busily engaged in an ongoing activity, he/she has to remember to perform the delayed intention at the appropriate moment (Ellis, 1996). This means that both tasks compete for individuals’ limited cognitive resources which is especially relevant for populations with reduced cognitive resources (McDaniel & Einstein, 2000). Prospective remembering comprises multiple phases: intention formation (e.g., planning of the intended action); storing the intention in memory during intention retention, and; initiating and executing the intention at the appropriate moment. In terms of underlying processes, PM performance is mainly supported by executive functions (e.g., planning, monitoring for the target cue that indicates the appropriate moment for intention initiation, inhibition of ongoing activities to switch to the PM task) and retrospective memory (remembering when and what one intends to do, Kliegel, Martin, McDaniel, & Einstein, 2002).

As postulated by the influential multiprocess framework (McDaniel & Einstein, 2000), the extent to which strategic, executive control resources are involved in the retrieval of delayed intentions depends on the task itself (e.g., type of PM cue, difficulty of the ongoing task, importance of the PM task) and on characteristics of the individual (e.g., cognitive resources, personality traits). For example, cues that are more salient may rather automatically attract attention and prompt retrieval of the intended action, whereas less salient cues may require more monitoring to be detected and more inhibitory resources to interrupt the ongoing task and switch to the PM task. On the other hand, ongoing tasks that are rather difficult may absorb more cognitive resources than easier tasks, thus leaving less resources available to support the PM task and, for instance, to monitor for the PM target cue. Recently, Kliegel, Altgassen, Hering, and Rose (2011) postulated that (potential) deficits in PM in clinical or developing populations with reduced cognitive resources are mediated by a mismatch between PM task-specific requirements of cognitive resources (e.g., a PM task may require more or less switching during intention initiation and execution) and condition-specific impairments in those resources (e.g., a condition such as autism may lead to less available switching resources). It is only when the available resources are insufficient for the specific PM task at hand, that an impairment is expected (i.e., even though individuals may have reduced switching resources, these may still be sufficient for a low switching-intensive PM task).
Importantly, non-cognitive factors, such as motivation, may also affect individual’s employment of cognitive resources. Motivational biases (e.g., being more motivated by important intentions) may lead to individuals strategically focusing their available cognitive resources on task relevant aspects. For example, if I do not want to be late for a job interview, I may monitor the time more frequently than when meeting a friend in a café. So far, PM research on the role of motivation or importance of the PM task has typically been investigated by promising a reward for correct PM responses (Meacham & Singer, 1977; Sheppard, Kreutzschmer, Knispel, Vollert, & Altgassen, 2015) or by varying task-attractiveness (e.g., having to remember to tell the caretaker to get candy versus the laundry, Somerville, Wellman, & Curtice, 1983; Causey & Bjorklund, 2014) as well as by manipulating importance of the PM task as compared to the ongoing task (e.g., Kliegel, Martin, McDaniel, & Einstein, 2001; Kliegel, Martin, McDaniel, & Einstein, 2004) or providing social reasons to do well in the PM task (e.g., Altgassen, Kliegel, Brandimonte, & Filippello, 2010; Brandimonte & Ferrante, 2008; Brandimonte, Ferrante, Bianco, & Villani, 2010). These studies have largely shown that increasing participants’ motivation for the task improves their PM performance. From a conceptual perspective, it has been argued that importance effects should only occur when PM tasks rely on strategic, attention-demanding processes, but not when automatic processes suffices (McDaniel & Einstein, 2000). In effortful PM tasks, additional monitoring should benefit PM performance, while ongoing task performance should decrease (so-called costs to the ongoing task) due to the then fewer available monitoring resources (Kliegel et al., 2001, 2004). Consistently, Kliegel and colleagues (2001) found a positive effect of task importance in younger adults in a time-based PM task, where strategic processing is necessary and in contrast, no importance effect in an event-based task which supported automatic processing. Similarly, importance positively affected performance in an event-based task, if this task required the strategic allocation of attentional resources, but not if it encouraged automatic processing (Kliegel et al., 2004). These results imply that stressing the importance of a PM task during intention formation may indeed enhance participants’ performance. It could be then, that importance instructions would compensate for reduced PM functioning by re-directing attentional resources during the retrieval phase, something which would particularly benefit individuals with reduced executive control abilities. In line with these predictions, Altgassen, Zöllig, Kopp, Mackinlay, and Kliegel (2007) reported spared time-based PM performance in individuals with Parkinson’s disease, who suffer from reduced executive functioning (Uekermann et al., 2004; Weintraub et al., 2005), when they were told to focus on the PM task. In contrast, they showed reduced performance as compared to healthy controls in the same task when asked to concentrate on the ongoing task.

As indicated above, individuals not only show better PM performance when promised a reward or asked to prioritize the PM task, but also when social motives for doing well are provided. For example, participants in a study by Kvavilashvili (1987) were more likely to remember to hang up a telephone receiver when told the experimenter was waiting for an important phone call, then when not told (for similar results, see Cicogna & Nigro, 1998). Altgassen et al. (2010) compared younger and older adults’ PM performance in a time-based PM task. Half of the participants were given standard PM instructions, while to the other half the PM task was introduced as doing a favour for the experimenter. Overall, younger adults outperformed older adults. However, an age group by importance manipulation interaction indicated that older adults’ PM performance improved when a social motive was provided, whereas younger adults’ performance was unaffected by the importance manipulation. Following a similar approach, Brandimonte and Ferrante (2008) manipulated importance of an activity-based PM task (i.e., remembering to sign a form after having completed a verb verification task) by either providing a social motive (i.e., if you do not remember to sign the form, important information will be missed and the experiment will be invalid), a personal reward (i.e., course credit for performing the PM task) or by giving standard instructions. Participants showed more correct PM responses in the social motive condition than the other two conditions. In 2010, Brandimonte, Ferrante, Bianco, and Villani replicated their findings of best PM performance in a social importance condition (as opposed to a standard condition, reward condition or a combination of social importance with reward; in the latter participants performed poorest) using a comparable ongoing and PM task (social importance condition: if they will remember to sign the form, the experimenter will collect important data for her thesis; reward condition: gain course credit). Taken together, these studies indicate that social motives may improve PM performance as compared to standard or even personal importance (at least of some populations). Notably, social importance manipulations will only be effective if the recipient is able to decipher the social motive and to perceive it as relevant. Populations that experience difficulties in taking the perspective of other people and in understanding their beliefs or emotions (i.e. reduced theory of mind or empathy), may perceive social motives as less important and be more motivated by the prospect of a personal reward for good performance. Thus, to accurately predict individuals’ PM performance it may not be sufficient to consider their potential mismatch of task demands and cognitive resources, but to also take individuals’ social-cognitive skills into account when exploring social importance effects. To test this assumption, the present study set out to compare the effects of different types of motivation manipulations in a population with reduced theory of mind, namely individuals with autism spectrum condition (ASC), with those of neurotypical controls.

ASCs are associated with impairments in social interaction, communication and imagination as well as restricted interests and activities and atypical reactivity to sensory input (APA, 2013). In addition, they show reduced organization abilities such as difficulties with prioritizing, coordinating and sequencing activities (Mackinlay, Charman, & KarmiloF-Smith, 2006; Ozonoff et al., 2004), which have been related to deficits in PM (Mackinlay et al., 2006). So far, eleven studies on PM in ASC have been published. Deficits in prospective remembering have not only been observed in standard lab-based tasks, but also in more naturalistic tasks that mimic everyday PM requirements (e.g., Dresden Breakfast task, Altgassen, Kohan, & Kliegel, 2012; Virtual Week, Henry et al., 2014; Kreutzschner, Altgassen, Rendell, & Bölte, 2014). In line with the well-documented deficits in executive control functions in autistic individuals (Hill, 2004;
IMPORTANCE INSTRUCTIONS AND PM IN AUTISM

4.2 METHOD

4.2.1 Participants

Sixty-one autistic adolescents and 61 non-autistic adolescents participated in the study, with each group distributed randomly, stratified only to control for age and ability, to one of the three motivation conditions of standard, social and personal motivation. The full factorial design can be taken from Table 1. Groups were parallel for gender, age and verbal IQ, but not for verbal IQ (here, the autistic group scored higher than controls). Conditions were parallel for gender and verbal ability. Therefore, this study set out to explore the impact of motivation on time-based PM performance in autistic children. Specifically, we were interested in the effects of personal (i.e., receiving a reward) as compared to social motivation (i.e., performing a favours for someone). To maximise importance effects, we not only used a time-based PM task that, in general, puts high demands on self-initiated processing and executive functions, but also employed an ongoing task that is cognitively highly demanding (a 2-back working memory task). Given the well-established theory of mind deficits in autism (e.g., Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Frith & Happé, 1994), we expected autistic individuals to benefit more strongly from personal than social importance manipulations, as they might be less responsive towards social cues and perceive such tasks as less important. In contrast, we predicted the opposite pattern for controls in line with Brandimonte and colleagues' studies (2008; 2010). In terms of group effects, we expected autistic individuals to show less correct PM responses than controls (e.g., Altgassen et al., 2009; Williams et al., 2013). Moreover, based on the previously found beneficial effects of rewards or social motives on the PM of neurotypical children or adults (Altgassen, Kliegel et al., 2010; Brandimonte & Ferrante, 2008; Sheppard et al., 2015), and autistic children (Sheppard et al., 2011; Yi et al., 2014). Overall, time-based tasks put higher demands on executive control processes than event-based tasks, as there is no external cue that can prompt retrieval of the intention; instead the individual has to keep track of the elapsed time in order not to miss the target time. Given that autistic individuals have difficulties with prioritizing tasks or activities (which may underlie or contribute to their organization difficulties and their PM deficits) and show reduced executive control resources, importance instructions that highlight the value of the PM task may support the strategic employment of their cognitive resources, and in turn, support their PM performance. In fact, there is first evidence by Sheppard, Kvavilashvili, and Ryder (2016) for the potential importance of intrinsic motivation in autism. Comparing severely autistic, mildly autistic and non-autistic control children, the severely autistic group performed worse than the non-autistic controls in two standard PM tasks, but showed spared performance when the PM task involved a reward for success (i.e., remembering to collect a toy spring when leaving the classroom); mildly autistic children did not differ from either group in any of the PM measures.

Therefore, this study set out to explore the impact of motivation on time-based PM performance in autistic individuals. Specifically, we were interested in the effects of personal (i.e., receiving a reward) as compared to social motivation (i.e., performing a favour for someone). To maximise importance effects, we not only used a time-based PM task that, in general, puts high demands on self-initiated processing and executive functions, but also employed an ongoing task that is cognitively highly demanding (a 2-back working memory task). Given the well-established theory of mind deficits in autism (e.g., Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Frith & Happé, 1994), we expected autistic individuals to benefit more strongly from personal than social importance manipulations, as they might be less responsive towards social cues and perceive such tasks as less important. In contrast, we predicted the opposite pattern for controls in line with Brandimonte and colleagues' studies (2008; 2010). In terms of group effects, we expected autistic individuals to show less correct PM responses than controls (e.g., Altgassen et al., 2009; Williams et al., 2013). Moreover, based on the previously found beneficial effects of rewards or social motives on the PM of neurotypical children or adults (Altgassen, Kliegel et al., 2010; Brandimonte & Ferrante, 2008; Sheppard et al., 2015), and autistic children (Sheppard et al., 2016), posited to arise by influencing the allocation of attentional resources, we expected to see an overall positive effect of highlighting the importance of the PM task.
4.2.2 Materials and procedure

4.2.2.1 PM task
For the ongoing task participants worked on a picture-based 2-back working memory task, using coloured versions of Snodgrass and Vanderwart’s (1980) picture set (Rossion & Poutho, 2004). Participants were required to indicate, via key press as quickly and as accurately as possible, whether the coloured picture on screen was the same as that presented two pictures previously (green key “Z” for “yes”; orange key “B” for “no”). Each picture was presented for 1500ms, with a 500ms interstimulus interval. Participants first demonstrated their understanding of the task by way of a paper version, followed by a 10-trial practice block on the computer. All participants demonstrated sufficient understanding at this stage, and so no participants repeated the practice. The practice was then followed by a 20-trial block (single-task block). Upon completion of the single-task block, participants were told they would soon be taking a short break, after which they would complete the task again, only this time there would be an additional task to consider (PM task). Specifically, they were asked to press a pink key (“P”) whenever one minute had passed. To see how much time had already elapsed, they could press a white key (“spacebar”) upon which a digital clock was displayed for 1500ms. Depending on to which motivation condition participants were allocated, the rationale of task instructions varied. Participants were only assigned to one motivation condition to prevent carry-over effects from one condition to the other, and to reduce the likelihood of practice effects.

For the neutral (standard) condition, participants were simply told the additional task involved pressing the pink key as closely as possible to each minute, from the 1st to the 6th minute. To encourage an adequate encoding of the task, the experimenter, followed by the participant, read out the rule, “The rule is: I will press the pink key after every minute” (for a similar approach, see Altgassen et al., 2009). Following Altgassen et al.’s study (2010), for the social motivation condition the PM task was introduced as the participant performing a favour for the experimenter. Specifically, participants were told that, for another research project, the experimenter wanted to know how many ongoing task trials could be completed in 1 minute, and so it would help the experimenter greatly if the participant could press the pink key every minute. For the personal reward motivation condition, participants were promised a reward for doing well on the PM task. Specifically, they were told that if they remembered to press the pink key at least 4 out of the 6 times, they would receive €5. The PM instructions were followed by an approximate 10 minute filled delay, during which participants completed the vocabulary sub-test (Kort et al., 2005; Wechsler, 2012). Subsequently, participants were engaged in the dual-task block comprising 80 ongoing task trials (25% 2-back working memory hits, 75% non-targets), without any reminder of the additional PM task. PM dependent measures were number of successful PM responses (max 6; ± 2s around the target times: 1, 2, 3, 4, 5, 6 minutes). Time monitoring (number of white button presses) was also measured (total number; mean monitoring behavior collapsed across the four 15s-intervals preceding the six targeted times). Unfortunately, due to experimenter error the responses to the n-back hits of the control group were not recorded. Therefore, dependent variables for the ongoing task were proportion of correct (non-target) responses and reaction times. Once the dual-task block was completed, participants were asked if there was anything else, other than the ongoing task, they were meant to do. All participants remembered that they had to press the pink key every minute. Thereafter, participants completed the rest of the vocabulary test (if they had not finished it before) and worked on the matrices substest of the WNV (Wechsler & Naglieri, 2008). All received €5 for taking part in the study, regardless of condition or actual performance.

4.3 RESULTS

4.3.1 Correct PM responses
A 2 (group) x 3 (motivation condition) analysis of variance (ANOVA) was conducted to compare correct PM responses across groups and conditions (Table 2). There were significant main effects of group, and condition, whereas, the interaction was not significant. Overall, the ASC group (M = 3.85, SD = 1.97) performed less well than controls (M = 4.70, SD = 1.71). Furthermore, participants in the Personal motivation condition (M = 4.90, SD = 1.56) outperformed those in the Standard (M = 3.79, SD = 1.96) and Social conditions (M = 4.08, SD = 1.98), although the performance of the latter two conditions was different. Planned comparisons revealed that controls only outperformed the ASC group in the Personal condition (p = .004), which drove the group effect (standard p = .12; social motivation p = .92). Furthermore, whilst the performance of the ASC group did not differ between conditions (all p > .20), the performance of the controls reflected that of the main effect of condition; namely, significantly better performance in the Personal condition, compared to both the Standard (p = .013) and Social conditions (p = .003), whilst performance in the latter two conditions was the same (p = .69).

Table 2.
Prospective memory and ongoing task performance.

<table>
<thead>
<tr>
<th></th>
<th>Standard Condition</th>
<th>Social motivation</th>
<th>Personal Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASC M (SD)</td>
<td>Controls M (SD)</td>
<td>ASC M (SD)</td>
</tr>
<tr>
<td>correct PM responses</td>
<td>3.4 (2.1)</td>
<td>4.3 (1.7)</td>
<td>4.1 (1.9)</td>
</tr>
<tr>
<td>single-task OT accuracy</td>
<td>92.6 (7.7)</td>
<td>90.6 (14.7)</td>
<td>94.0 (15.5)</td>
</tr>
<tr>
<td>dual-task OT accuracy</td>
<td>92.8 (5.5)</td>
<td>90.4 (7.5)</td>
<td>94.0 (4.1)</td>
</tr>
<tr>
<td>response times</td>
<td>727 (153)</td>
<td>807 (108)</td>
<td>727 (152)</td>
</tr>
<tr>
<td>response times</td>
<td>819 (95)</td>
<td>821 (98)</td>
<td>771 (107)</td>
</tr>
</tbody>
</table>

Note. OT refers to ongoing task.
4.3.2 Time monitoring

A mixed 2 (group) x 3 (motivation condition) x 4 (interval) ANOVA, with repeated measures on the last factor, was carried out with time monitoring as dependent variable. There was a main effect of interval \( F(3,345) = 105.17, p < .001 \), but not of group \( F(1,115) = .796, p = .374 \), or condition \( F(2,115) = 1.71, p = .314 \). There was, however, a significant interval by group interaction, \( F(3,345) = 5.27, p = .001 \), and a significant interval by condition interaction \( F(3,345) = 2.44, p = .025 \). All other interactions were not significant (all Fs < 1.2). Overall, participants increased the average number of clock checks each 15s interval as the target time approached (see Figure 1); with clocks checks in each interval being significantly higher than the previous interval (all \( p < .001 \)). Further analysis of the significant interactions revealed that, whilst clock checks in the first three intervals was the same for both groups (all \( p > .57 \)), controls (\( M = 2.47, SD = 2.10 \)) checked the clock more frequently than the autistic participants (\( M = 1.82, SD = 1.51 \)) in the 4th interval, with the mean difference approaching significance (\( p = .068 \)). Furthermore, clock checks only differed significantly between the Standard (\( M = 1.71, SD = 1.45 \)) and Personal condition (\( M = 2.54, SD = 1.50 \)) in the 4th interval (\( p < .04 \)); while across all other intervals clock checks were the same for all motivation conditions (\( p > .16 \)).

4.3.3 Ongoing task

A mixed 2 (group) x 3 (motivation condition) x 2 (task block) ANOVA, with repeated measures on the last factor and proportion of correct ongoing task responses as dependent variable was conducted (Table 2). There were no main effects of group, condition, or task block, and no significant interactions. Thus, both groups performed similarly, achieving a similar proportion of correct non-N-back responses (ASC: \( M = 92.80, SD = 6.68 \); controls: \( M = 91.91, SD = 6.66 \)). Moreover, no significant differences were found between any of the three motivation conditions (Standard: \( M = 90.63, SD = 7.49 \); Social: \( M = 93.64, SD = 6.58 \); Personal: \( M = 92.79, SD = 4.58 \)) or between the single (\( M = 92.87, SD = 9.58 \)) and the dual-task block (\( M = 92.05, SD = 6.72 \)).

In terms of ongoing task response times, a mixed 2 (group) x 3 (motivation condition) x 2 (task block) ANOVA indicated a significant main effect of group and task block, but no effect of condition, and no interactions. Thus, the ASC group responded faster to the 2-back non-target stimuli than the control group, and overall, participants’ speed of response in the single task block (\( M = 766, SD = 157 \)) was significantly quicker than that of the dual-task block (\( M = 797, SD = 98 \)). Performance did not vary across the motivation conditions.

3.3.4 Correlations

Separately for groups and motivation conditions (Table 3), correlational analyses were conducted between correct PM responses and clock checks during the fourth interval, single and dual ongoing task performance (accuracy, response times), age as well as verbal and non-verbal ability. For autistic individuals and all three motivation conditions, PM performance positively correlated with clock checks during the last interval before the target time. Thus, more correct PM responses were associated with more clock checks. In the Standard condition, age negatively correlated with PM performance, thus younger age was associated with more correct PM responses. There were no other significant correlations for the ASC group. In contrast, for controls no significant correlation between PM performance and clock checks was observed in the Personal condition, while the other two conditions showed positive correlations indicating a link between better PM performance with more clock checks. Similarly, only in the Personal condition (dual-task) ongoing task performance correlated positively, and ongoing task response times correlated negatively with PM performance. Thus, more correct and faster ongoing task responses were associated with better PM performance. There were no other significant correlations for controls.

Table 3.
Correlations of correct prospective memory responses.

<table>
<thead>
<tr>
<th></th>
<th>Standard Condition</th>
<th>Social motivation</th>
<th>Personal Reward</th>
</tr>
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<tbody>
<tr>
<td>clock checks interval 4</td>
<td>ASC .71***</td>
<td>.59***</td>
<td>.48*</td>
</tr>
<tr>
<td></td>
<td>Controls .73***</td>
<td>.46*</td>
<td>.27</td>
</tr>
<tr>
<td>single-task OT accuracy</td>
<td>ASC .17</td>
<td>-.39</td>
<td>-.09</td>
</tr>
<tr>
<td></td>
<td>Controls .05</td>
<td>-.14</td>
<td>-.01</td>
</tr>
<tr>
<td>single-task OT RT</td>
<td>ASC .41</td>
<td>.11</td>
<td>.12</td>
</tr>
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<td></td>
<td>Controls -.20</td>
<td>.24</td>
<td>-.34</td>
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<tr>
<td>dual-task OT accuracy</td>
<td>ASC .09</td>
<td>.05</td>
<td>.03</td>
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<td></td>
<td>Controls .04</td>
<td>-.09</td>
<td>.62**</td>
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<tr>
<td>dual-task OT RT</td>
<td>ASC -.05</td>
<td>.21</td>
<td>.22</td>
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<td></td>
<td>Controls .00</td>
<td>.11</td>
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<td>age</td>
<td>ASC -.51*</td>
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<td></td>
<td>Controls .36</td>
<td>.31</td>
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<tr>
<td>verbal ability</td>
<td>ASC -.04</td>
<td>.20</td>
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<td></td>
<td>Controls -.02</td>
<td>.05</td>
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<tr>
<td>non-verbal ability</td>
<td>ASC -.18</td>
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<td>.15</td>
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<td></td>
<td>Controls .14</td>
<td>.36</td>
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Note. * \( p < .05 \); ** \( p < .01 \); *** \( p < .001 \);
\( ASC = \) Autism Spectrum Condition; OT = ongoing task; RT = response times

4.4 DISCUSSION

This study set out to explore the impact of motivation on time-based PM performance in autistic individuals. Specifically, we were interested in the effects of personal (i.e., receiving a reward) as compared to social motivation (i.e., performing a favour for someone). With this, we aimed to test the assumption that to accurately predict
individuals’ PM performance under varying motivation conditions, it may not be sufficient to consider their potential mismatch of task demands and cognitive resources, but to also take their social-cognitive skills into account; given that they are needed to adequately perceive and assess social motives when exploring social importance effects.

As expected, controls outperformed autistic individuals in the time-based PM task (Altgassen et al., 2012; Altgassen et al., 2009; Henry et al., 2014) and achieved, overall, more correct PM responses. However, planned comparisons revealed that controls only performed better than autistic individuals in the Personal condition (in which controls performed best), while group effects tended towards significance in the standard condition and were non-existent in the social motivation condition. Moreover, based on the previously found beneficial effects of rewards or social motives on the PM of neurotypical children or adults (Altgassen, Kliegel, et al., 2010; Brandimonte et al., 2010; Sheppard et al., 2015), and severely autistic children (Sheppard et al., 2016) we expected to see an overall positive effect of highlighting the importance of the PM task.

However, while there was indeed a significant main effect of condition, this effect was (again mainly) driven by the increased performance of (control) participants in the Personal motivation condition as compared to both the standard and the social motivation condition. This finding contrasts with Brandimonte and colleagues’ (2008; 2010) studies who reported improved performance in a prosocial, but not in a personal reward condition as compared to a standard condition (for more evidence on the beneficial effects of prosocial goals on PM performance, see D’Angelo, Bosco, Bianco, & Brandimonte, 2012).

In terms of differential effects of motivation manipulations across groups, given the known theory of mind deficits in autism, which may make them less responsive towards social cues and lead to them perceiving such social tasks as less important, we expected autistic individuals to benefit more strongly from personal than social importance manipulations. For controls, we predicted the opposite pattern in line with Brandimonte and Ferrante’s (2008) study. In contrast to our predictions, the ASC group performed comparably across all three motivation conditions, while controls performed significantly best in the Personal condition, compared to both the Standard and Social conditions. It is somewhat surprising that autistic individuals seem to not be affected by importance manipulations. Possibly, the importance manipulation was too subtle or indirect for the autistic individuals. For both the Social and the Personal condition, the higher importance of the PM task, relative to the ongoing task, had to be inferred (e.g., help the experimenter or receive 5EUR) as there was no explicit statement highlighting that the PM task was more important and that they should focus on it. Autistic individuals have difficulties with understanding nonliteral or figurative speech (e.g., sarcasm, joking, and metaphors) which has been linked to reduced theory of mind (Happe, 1995; Happé, 1993; Tager-Flusberg, 1996) and a local processing bias (Baron-Cohen, 1997; Jolliffe & Baron-Cohen, 1999).

These difficulties may have prevented the autistic participants from fully understanding the implications of the importance instructions and, therefore, the personal and social value of succeeding in the PM task. Future studies should test whether explicitly instructing autistic participants on which task is important, and on which they should focus, improves their PM performance.

While our findings on controls’ performance contrast with Brandimonte and colleagues’ (2008) studies that reported better performance of younger adults in socially important tasks than those associated with a personal reward, they are consistent with one of our previous studies that found beneficial effects of social importance in older adults, but not in younger adults (Altgassen, Kliegel, et al., 2010). Possibly, adolescents (the age group of the present study), similarly to younger adults, are less responsive to social motives and thus perceive social tasks as less important.

Another possibility is that importance manipulations are sensitive to methodological differences, such as differences in the phrasing of the social importance condition and the promised reward. While the current study (similarly to Altgassen, Kliegel, et al., 2010) introduced the PM task in the social importance condition as the participant performing a favour for the experimenter, Brandimonte and colleagues (2008) emphasized the prospect of failing to implement the delayed intention (i.e., if you do not remember to sign the form, important information will be lost) which may have made the (negative) social consequences of forgetting to perform the task more salient and the PM task more important.

On the other hand, in their 2010 study Brandimonte and colleagues applied a similar phrasing of the social importance manipulation as the present study, and still observed the best performance in this condition. Possibly, Brandimonte and colleagues’ PM task may have also been more meaningful than the one used in the current study (i.e., signing a form to ensure data is not lost has clear and critical relevance to the experiment in which the person is participating). In contrast, the relevance of pressing a specific key to indicate how many ongoing task trials could be completed in 1 minute, and potential consequences of failure, may have been less clear. Differences in the pattern of results between the present and Brandimonte and colleagues’ studies may also result from the different populations included. Brandimonte’s studies only tested psychology students that may be well aware of the importance of storing data, while this may have been less clear for the adolescents of the present study that all still attended school.

Similarly, the prospect of getting €5 may have been very appealing and thus highly motivating for adolescents, while getting course credit (the reward in both Brandimonte studies) may have been less attractive or not even convincing in the sense that psychology students may not believe that they could not get course credit for poorly performing in an experiment. It is also possible that pleasing an adult (i.e., the experimenter in the Social motivation condition) was a prospect that held little intrinsic value for the adolescent participants of the present study. It may be that manipulating social issues more directly relevant to teenage life, such as peer group membership (Albert, Chein, & Steinberg, 2013) would have a greater effect. Future research could thus investigate, for example, whether performing a PM task to help one’s ‘team’ (e.g., one’s class/school) win a competition against another team would result in better PM performance, as compared to control conditions.
Unfortunately, we did not assess participants' subjective perception of the relative importance of the PM and ongoing task, or their motivation to do well across the different motivation conditions. Future studies should include measures of subjective importance assessments. A further explanation for the different findings across studies may be the differences in the characteristics of the applied PM and ongoing tasks. Overall, the methodology of the present study resembles Altgassen et al.'s (2010) more closely than Brandimonte’s study. The first two applied a similar manipulation of social motivation, both employed a rather (executive control resources) demanding ongoing task and used a time-based PM task, whereas Brandimonte and colleagues used activity-based PM tasks that are supposed to require less executive functions given that no activity has to be interrupted and no monitoring for the PM cue is needed.

One potential limitation of the present study is that age, verbal and non-verbal ability were not fully parallel across groups and conditions. The finding of superior verbal ability of the ASC group as compared to controls was rather surprising, given that verbal ability is sometimes considered a weakness in ASC (Akbar, Loonis, & Paul, 2013; Frith, 1989); possibly, then, the present sample comprised a highly selective group. However, differences in these variables did not explain PM performance. Neither verbal nor non-verbal ability were significantly related to PM performance. Age was only significantly (negatively) associated with PM performance for the ASC group in the Standard condition, with younger participants showing better PM performance. Nevertheless, future studies need to make sure to better match groups in terms of age, verbal and non-verbal ability. Another potential limitation is the fact that we did not screen for additional psychiatric disorders using a standardized screening test such as the Structured Clinical Interview for DSM Disorders (First, Williams, Karg, & Spitzer, 2016) or the Composite International Diagnostic Interview (Kessler et al., 2004). Additional psychiatric disorders may have also affected individuals' performance and their response to the experimental manipulation.

Overall, the ongoing task was equally difficult for both groups, and participants performed comparably well across all task conditions; both in the single- and dual-task block. Surprisingly, autistic individuals responded faster to ongoing task items than controls. Overall, participants showed lower response times in the single than the dual-task block which is likely due to practice effects given that the single task was always performed before the dual-task. Importantly, this also implies that there were no costs to the ongoing task of monitoring for the PM target time, once the PM task was added. Similarly, the different motivation conditions did not differ in terms of participants' response times to ongoing task items. Moreover, the only significant correlations to emerge between PM and (dual) ongoing task performance was observed for controls in the Personal condition – the condition in which they performed best. In contrast to previous studies (Loft & Yeo, 2007; Smith & Hunt, 2014) that reported increased costs to the ongoing task when the PM task was emphasized, in this study, better PM performance was associated with better ongoing task performance and faster response times. However, this is not the first study to find no ongoing task costs despite improved time-based PM performance (Altgassen, Kliesel, et al., 2010; Altgassen et al., 2007).

With regards to time monitoring behaviour, overall, participants increased the average number of clock checks each 15s interval as the target time approached. Whilst clock checks in the first three intervals was comparable for both groups, controls checked the time more frequently than the autistic participants in the 4th interval. This may indicate less strategic monitoring behaviour in the ASC group which is consistent with previous findings (e.g., Altgassen et al., 2009). Interestingly, clock checks during the last interval correlated with correct PM responses (separately) for both groups and all conditions, except for controls in the Personal condition. The latter result was somewhat surprising given that this was the condition that controls performed best in and typically time monitoring in the last interval before the target time is strongly associated with individuals’ PM performance (Einstein & McDaniel, 1996). However, this observation is in line with previous research (Altgassen, Kliesel, et al., 2010; Altgassen et al., 2007) that also did not report more frequent clock checks or a steeper increase of time monitoring in the presence of improved PM performance when highlighting the PM task. Given that increased PM performance of controls in the Personal condition came at no cost to the ongoing task and no increased monitoring behaviour, our findings support assumptions that intentions are encoded with higher activation than other to be remembered information (so-called intention superiority effect, Goschke & Kuhl, 1993; see also, Cohen & Gollwitzer, 2008, Gollwitzer & Cohen, 2008).

In this conceptual framework, beneficial effects of importance manipulations could be explained by importance instructions leading to especially high activation of the prospective cues at the time of encoding. This would facilitate retrieval of intended action in the performance phase through increased mental accessibility of the intention without needing to affect ongoing task performance or monitoring behaviour. Similarly, Walter and Meier (2014) suggest that stressing the importance of the PM task may affect participants’ performance similarly to meta-cognitive strategies (e.g., implementation intentions, Gollwitzer, 1999) by increasing associations between the PM task and the context in which it is later performed which may strengthen memory traces, decrease the need for strategic monitoring, and facilitate rather automatic retrieval of the intention (see Altgassen, Kretschmer, & Schnitzspahn, 2017, for a similar discussion of the effects of episodic future thinking).

This does not imply that importance manipulations may never work due to changes in resource allocation as suggested by the multiprocess framework (e.g., increased monitoring for more important tasks), but that increased PM performance can also follow rather automatic retrieval and execution of the intended action. So far, most research on PM has focussed on the phases of intention initiation and execution and has investigated how differences in task characteristics and cognitive resources may affect individuals’ performance, and has rather neglected the phases of intention formation and retention. In light of the present findings that do not support assumptions of the multiprocess framework in terms of increased monitoring or a focus on the PM task at the expense of the ongoing task as mechanisms underlying beneficial effects of importance, further research is clearly needed to investigate the impact of task importance on intention formation (e.g., by people spontaneously imagining performing
the intended action in the future, thus engaging in episodic future thinking) or intention retention (e.g., by rehearsing the intention and its target time).

Taken together, in line with all published evidence on time-based PM in ASC, at first glance this study replicated reduced PM performance in autistic individuals. However, further analyses indicated that groups actually only differed in their number of correct PM responses in the Personal condition, which was driven by controls’ increased performance. In terms of significant motivation effects, only controls benefitted from (Personal) importance instructions. Critically, controls’ improvement in the Personal Condition led neither to costs in the ongoing task nor to increased time monitoring behaviour, implying that beneficial effects of importance manipulations may not only work via changes in resource allocation but may also be the result of increased mental accessibility of intentions and enhanced automaticity of retrieval processes. Both groups demonstrated strategic time monitoring behaviour, with the number of clock checks increasing in each of the four 15 second intervals leading up to the target time. However, control participants did check the time in the final interval more often than the autistic participants, thereby possibly demonstrating greater strategic behaviour.
ABSTRACT
The current study examined, for the first time, the effect of cue-intention association, as well as the effects of promised extrinsic rewards, on prospective memory in young children, aged 5-years-old (n=39) and 7-years-old (n=40). Children were asked to name pictures for a toy mole, whilst also having to remember to respond differently to certain target pictures (prospective memory task). The level to which the target picture was associated with the intention was manipulated across two conditions (low- or high-association) for all participants, whilst half of the participants were promised a reward for good prospective memory performance. Results showed a main effect of age, with the 7-year-olds outperforming the 5-year-olds. Furthermore, there was a main effect of reward, with those promised a reward performing better than those who were not. No effect was found for cue-association, with the participants of both age groups performing equally well in both association conditions. No significant interactions were found between any of the variables. The potentially important role of reward in young children’s everyday prospective memory tasks, and possible reasons for the lack of a reflexive-associative effect, are discussed.

5.1 INTRODUCTION
Prospective memory (PM) tasks are tasks in which planned intentions must be executed in the future (Einstein & McDaniel, 1990) either upon the occurrence of an event (event-based PM) or at a certain time (time-based PM). These tasks are critical to everyday life, with failure possibly resulting in serious personal and social consequences (e.g., missing medication or forgetting to pass on an important message to a supervisor) and for children this is no different (e.g., forgetting to bring homework and/or equipment to school, missing a school trip). Indeed, for young children starting school, there is arguably a sudden increase in PM demands, and an expectation by adults to behave increasingly independently (Suddendorf & Moore, 2011). As it has been shown that children who develop poor PM abilities are likely to experience difficulties in interacting with parents, teachers, and peers (McCauley & Levin, 2004; Meacham & Leiman, 1982) it is clear that those starting school are at a critical stage in their development, and it is thus important to investigate PM in this age group. The purpose of the current study, therefore, was to further elucidate upon the development of PM in young children and the possible underlying cognitive mechanisms. This could lead to a better understanding of the conditions under which successful PM can be achieved, even at a young age.

That PM ability develops and improves with age is now well-established (Ford, Driscoll, Shum, & Macaulay, 2012; Klieweg & Jäger, 2007; Kliegel et al., 2013; Kvävlishvili, Messer, & Ebdon, 2001; Mahy & Moses, 2011; Sommerville, 1983; Walsh, Martin, & Courage, 2014). However, the mechanisms driving this development, and the conditions under which the age effects are most pronounced, are still unclear. In their recent review, Mahy, Moses, and Kliegel (2014) put forward their executive model of PM development, positing that executive functions (EF) are the most important mechanisms underlying PM development. EF comprises abilities such as set-shifting, inhibition, and working memory. The authors argue that the well-established and protracted development of EF abilities, which improve from early childhood (Carlson, 2005; Lee, Bull, & Ho, 2013; Munakata, Snyder, & Chatham, 2012) through to adulthood (see (Best & Miller, 2010) for a review), are instrumental in the developing ability to execute an intention at the appropriate time/event in the face of a distracting ongoing task (OT). This view is complimented by the influential Multiprocess Framework (McDaniel & Einstein, 2000) which states that PM tasks vary in the type of retrieval processes required and can rely either on rather automatic (low EF demand) or strategic (high EF demand) processes. For instance, some tasks will automatically 'pop into mind' on presentation of a PM cue (e.g., if the cue is distinctive/salient, or if it is strongly associated with the intention, such as a red letter box prompting memory of the intention to post a letter) whilst others will necessitate a strategic monitoring of the environment for the PM cue (e.g., if the cue is not presented in the immediate environment, such as looking out for a pharmacy whilst driving home). Furthermore, those tasks which demand a higher degree of strategic monitoring will leave less available resources for the OT, resulting in costs to OT performance (Scullin, McDaniel, & Einstein, 2010). This Multiprocess Framework is supported by evidence from studies with young children employing dual-task paradigms (i.e., participants completing an OT with an embedded PM task) which
attempt to directly manipulate the need for automatic or strategic processes, and better understand the role of executive functioning at this age (Ford et al., 2012; Kliegel, Mackinlay, & Jäger, 2008; Kliegel et al., 2013; Kvavilashvili et al., 2001; Mahy, Moses, & Kliegel, 2014; Mahy & Moses, 2011). For instance, in a series of computer-based experiments, Kliegel et al. (2013) found that, when the need for strategic and executive processes was reduced by increasing the PM cue saliency (or distinctiveness), cue centrality (i.e. cue inside, rather than outside the centre of attention) and reducing OT absorption, PM performance was improved in 6- to 10-year-olds. Furthermore, they found that when cue centrality was increased, the younger children performed as well as the older children, a result which implies the age difference in performance was due to the additional strategic requirements of monitoring when the cue was outside the focus of attention. Mahy et al. (2014) also found that 5-year-olds outperformed 4-year-olds, and that performance for both age groups was worse when cues were less salient and the OT more difficult. Further, the authors reported that the EF ability, inhibition, measured via performance on the Simon Says task (Carlson, 2005) accounted for a significant level of variance for non-salient cues, and individual differences in inhibition fully mediated the effect of age on PM performance. In another study, Kvavilashvili et al. (2001) found that increasing inhibition demands adversely affected PM performance. Specifically, the authors found that requiring the children to interrupt the OT, in order to execute the PM task, resulted in worse performance than when the PM task was at the end of the OT. This result was further supported by similar findings from Kliegel et al. (2008) who found the effects of interrupting the task to be greater for children of an average age of 7- and 10-years, and for older adults of around 67-years-old, than for younger adults 25-years of age, indicative of less developed EF in children, and reduced EF in older adults. Further supporting evidence for the role of EF for PM performance stems from studies using a correlational approach (Kerns, 2000; Mahy & Moses, 2011; Ward, Shum, Mackinlay, Baker-Tweney, & Wallace, 2005). For instance, Mahy and Moses (2011) showed that working memory significantly predicted PM (even after controlling for age and inhibition) in 4 to 6-year-old children.

In sum, according to the Multiprocess Framework (McDaniel & Einstein, 2000) and Mahy et al.’s Executive Framework (Mahy et al., 2014) and supporting evidence, younger children, whose EF resources are less developed, will find PM tasks that are high in EF demand more difficult. However, they can perform well on tasks which depend more on automatic, reflexive processes and hence are lower in EF demand or if the task encourages the allocation of their limited EF resources. It is important, then, to further investigate the role of EF in PM in children to better understand the conditions under which automatic processes, or resource allocation, can be encouraged and thus better support children in everyday life.

Two factors that have been put forward by the Multiprocess Framework to impact on PM performance are motivation and cue-intention association. To date only one study has investigated the effect of extrinsic incentives in PM in young children (Gaujardo & Best, 2000) and none have examined cue-intention association (McDaniel, Guynn, Einstein, & Brenizer, 2004) in a younger age group, two factors which will be discussed, respectively, henceforth.

The benefit of motivation in PM in young children, particularly with regard to the use of incentives, is an area that has received very little attention in the literature. However, despite young children’s limited EF resources (Gathercole, Pickering, Ambridge, & Wearing, 2004; Schneider & Bjorklund, 1992; Zelazo, Carlson, & Kescel, 2008; Zelazo et al., 2003) some studies suggest that successful PM performance is possible for very young children if they are highly motivated (Causey & Bjorklund, 2014; Kliegel, Brandenberger, & Aberle, 2010; Ślusarczyk & Niedźwińska, 2013; Somerville, Wellman, & Cullice, 1983). Ślusarczyk and Niedźwińska (2013) for example, found that tasks which they considered to contain a high level of intrinsic motivation, such as reminding the experimenter to give them a candy at the end of session, as opposed to remembering to put pencils on the shelf, resulted in higher PM performance for all participating young children, ranging in age from 2- to 6-years-old. Causey and Bjorklund (2014) also found that 2- to 4-year-olds were more successful in collecting a sticker at the end of the session, than they were at turning over a sign. Arguably, these results are in line with the Multiprocess Framework (McDaniel & Einstein, 2000) and the Executive Framework (Mahy et al., 2014) as highly motivating tasks demand less in terms of inhibition, and encourage the allocation of limited resources to the PM task. This notion is further supported by the goal-based motivational model posited by Penningroth and Scott (2007) which suggests that PM performance will be improved when the intention has high personal relevance. It seems plausible then, that if motivation was achieved via more extrinsic motivators, such as incentives, then the same positive motivation effects could be expected. Indeed, positive effects of monetary incentives have recently been found in healthy adults (Cook, Rummel, & Dummel, 2015) and adolescents with traumatic brain injury (McCauley, McDaniel, Pedroza, Chapman, & Levin, 2009; McCauley et al., 2011). However, only one study to date has investigated the effect of incentives, rather than the use of more intrinsically motivating tasks, on PM performance in young children (Gaujardo & Best, 2000) and they did not find a positive effect.

However, in Gaujardo and Best’s (Gaujardo & Best, 2000) computer-based task, 3- and 5-year-olds were shown a series of 6 blocks of 10 pictures, with each picture shown individually for 5s, and a 1s between-picture interval, and were told they would be asked to recall as many pictures as possible after each block (OT). For the additional PM task, they were told to press the space bar every time they saw a target picture (one in each block). It could be argued that this is a difficult task for such young children as it loads heavily on working memory and demands prolonged attention, which could have had a negative impact on PM performance and the effect of the reward manipulation. Furthermore, children were provided with common food and toy items (e.g. pennies, fruit chews) each time they correctly pressed a key on presentation of a PM target picture, which may not have been very motivating. Therefore, it is the intention of the present study to reduce the executive demands of the OT and to provide a more motivating incentive.
A further factor yet to be studied in young children is that of the strength of cue-intention association. It is, however, a manipulation that McDaniel et al. (2004) found to be effective in healthy adults, informing their ‘reflective-associative hypothesis’, with the pertinent result being that PM was better when PM cues were highly associated with the intention (e.g. writing the word thread on presentation of the word needle) than when there was a low cue-intention association (e.g. spaghetti-thread). The authors argue that this finding is in line with the Multiprocess Framework (McDaniel & Einstein, 2000), in that the low-association condition required strategic monitoring processes, whilst performance in the high cue-intention association condition reflected automatic, reflexive-associative retrieval. The positive effect of high cue-intention association has also been found in other studies, for example, in older adults (McDaniel et al., 2004; Pereira, Ellis, & Freeman, 2012; Pereira, Ellis, & Freeman, 2012) and clinical populations (Woods, Dawson, Weber, Grant, & Group, 2010). Woods et al. (2010) for instance, found that the PM performance of HIV patients, a clinical group found to be particularly susceptible to age-related executive functioning and attentional impairment (Cherner et al., 2004; Sacktor et al., 2007), was better when cues and intentions were semantically related (e.g., “When I hand you a postcard, self-address it”) than when they were unrelated (e.g., “When I show you a picture of a cow, snap your fingers”). Following this line of reasoning, it could be expected that cue-intention association might play an important role in children’s PM performance; however, no study to date has examined this aspect in children, and is thus of interest to the current study.

The primary aim of the current study, therefore, was to investigate the role of cue-intention association and motivation in the PM ability of 5- and 7-year-old children, hence examining PM in age-groups at, or around, the age of starting school, who are thus experiencing increasing everyday PM demands. Children performed a simple card-naming OT, with the embedded PM task including both a high- and low-association condition. Further, half of the children were provided the incentive of a promised surprise gift for good PM performance. Based on the literature, main effects of age in PM performance of HIV patients, a clinical group found to be particularly susceptible to age-related executive functioning and attentional impairment (Cherner et al., 2004; Sacktor et al., 2007), was better when cues and intentions were semantically related (e.g., “When I hand you a postcard, self-address it”) than when they were unrelated (e.g., “When I show you a picture of a cow, snap your fingers”). Following this line of reasoning, it could be expected that cue-intention association might play an important role in children’s PM performance; however, no study to date has examined this aspect in children, and is thus of interest to the current study.

The procedure of the session was similar to that of Kvavilashvili et al. (2001) in that children were asked to name picture cards (derived from the Snodgrass and Vanderwart (1980) picture set) for a hand puppet named Morris the Mole but asked to respond differently to given target pictures. Children were first introduced to the experimenter and asked if they would like to stay and play some games. Upon confirmation, children were then engaged in a short conversation to ensure they felt at ease. They were then provided the incentive of a promised surprise gift for good PM performance. Based on the literature, main effects of age in PM performance of HIV patients, a clinical group found to be particularly susceptible to age-related executive functioning and attentional impairment (Cherner et al., 2004; Sacktor et al., 2007), was better when cues and intentions were semantically related (e.g., “When I hand you a postcard, self-address it”) than when they were unrelated (e.g., “When I show you a picture of a cow, snap your fingers”). Following this line of reasoning, it could be expected that cue-intention association might play an important role in children’s PM performance; however, no study to date has examined this aspect in children, and is thus of interest to the current study.
card as usual, but then to also say ‘juice’. There were a total of 6 PM target pictures per condition (fruits: apple, banana, lemon, orange, pear and grapes; animals: dog, cat, giraffe, horse, rabbit and elephant). To ensure that all children knew the target pictures were indeed part of the relevant category, before instructing the PM task a short conversation ensued whereby children were asked to name different fruits or animals. If not all of the target pictures had been named, the experimenter prompted with questions, such as “how about a strawberry, is that a fruit?” Once the children had shown they knew the target pictures to be part of the relevant category, a practice block was conducted, whereby children named three cards, with the third being a target item. All children demonstrated understanding by successfully first naming the card, and then saying ‘juice’ on presentation of the target item.

Around half of the children (reward condition: 19 5-year-olds, 19 7-year-olds) were then told that, if they did very well in remembering to say ‘juice’ at the right moment then, before they went back to their friends, they would get to choose a prize from the exciting ‘surprise box’ in which there were many exciting items. To introduce a delay between PM task instruction and execution (Ellis & Kravilashvili, 2000) the children were told they would first play another game in which they would explain the meaning of different words to Morris (HAWIVA-III and HAWIK-IV). After approximately three minutes the children were told they had done very well but it was now time to play the game they discussed earlier, and the experimental dual-task block commenced (the children were not reminded of the PM task at this point). This procedure was then repeated for the second block. Presentation of the Lo-Assn and Hi-Assn task blocks was counterbalanced. Once both blocks were completed, any remaining ability tasks were finished, after which all children were congratulated on an excellent performance and told that Morris was very grateful for their help, and that they could choose something from the surprise box (irrespective of reward condition).

Children’s PM performance was measured as the number of correct responses (max. 6 for each association condition) that they remembered to say ‘juice’ after presentation of the correct picture cue. Dependent variables for OT performance were percentages of correctly named picture cards (for the baseline and dual task blocks, respectively).

5.3 RESULTS

5.3.1 PM performance

Table 1 shows the mean percentage of successful PM hits by age, reward and cue-intention association. A 2 (age: 5- vs. 7-year-olds) by 2 (reward: no reward vs. reward) by 3 (block: baseline vs. Lo-Assn vs. Hi-Assn) ANOVA, with repeated measures on the last factor, revealed significant main effects of age $F(1, 75) = 134.699, p < .001, \eta^2 = .642$, block $F(1.65, 124.01) = 615.960, p < .001, \eta^2 = .89$ and reward $F(1, 75) = 8.555, p < .01, \eta^2 = .102$. No significant interaction was found between all three factors, but a significant interaction was found between age and block, $F(1.65, 124.01) = 17.458, p < .001, \eta^2 = .189$; pairwise comparisons showed that both 5yr- and 7yr-olds achieved a higher percentage of correctly named cards in baseline block than both other blocks (all $p < .001$) but only 5yr-olds performed better in the Hi-Assn block than the Lo-Assn block ($p < .05$). A further interaction was found between age and reward, $F(1, 75) = 6.55, p < .05, \eta^2 = .08$. Pairwise comparisons revealed 5yr-olds, but not 7yr-olds ($p > .05$), achieved a higher percentage of correctly named cards in the reward condition, compared to the no reward condition ($p < .001$). Finally, a significant interaction was found between block and reward, $F(1.65, 124.01) = 3.696, p < .05, \eta^2 = .047$. Pairwise comparisons revealed that, whilst both the reward group and the no reward group performed better in baseline performance than in both subsequent assn-trial blocks (all $p < .05$) those in the reward condition named a higher percentage of cards in the baseline block than those in the no reward condition ($p < .01$, mean difference = 3.34%). However, both groups performed equally well in the subsequent Assn-trial blocks (all $p > .05$).
mean percentage (and standard deviation) of successful OT naming trials by task block and condition of reward.

<table>
<thead>
<tr>
<th>Task Block</th>
<th>Condition</th>
<th>No Reward</th>
<th>Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Lo-Assn</td>
<td>73.17 (5.24)</td>
<td>75.33 (3.65)</td>
</tr>
<tr>
<td></td>
<td>Hi-Assn</td>
<td>93.50 (6.71)</td>
<td>99.47 (5.24)</td>
</tr>
<tr>
<td>5-year-olds</td>
<td>Baseline</td>
<td>76.14 (3.73)</td>
<td>98.42 (5.02)</td>
</tr>
<tr>
<td></td>
<td>Lo-Assn</td>
<td>84.29 (1.16)</td>
<td>76.67 (3.14)</td>
</tr>
<tr>
<td></td>
<td>Hi-Assn</td>
<td>83.42 (1.90)</td>
<td>83.55 (1.92)</td>
</tr>
<tr>
<td>7-year-olds</td>
<td>Baseline</td>
<td>76.78 (4.70)</td>
<td>98.95 (3.98)</td>
</tr>
<tr>
<td></td>
<td>Lo-Assn</td>
<td>76.67 (3.14)</td>
<td>80.11 (4.33)</td>
</tr>
<tr>
<td></td>
<td>Hi-Assn</td>
<td>79.78 (4.33)</td>
<td>80.11 (4.33)</td>
</tr>
<tr>
<td>Total</td>
<td>Baseline</td>
<td>79.92 (5.25)</td>
<td>98.95 (3.88)</td>
</tr>
<tr>
<td></td>
<td>Lo-Assn</td>
<td>79.78 (4.70)</td>
<td>80.11 (4.33)</td>
</tr>
<tr>
<td></td>
<td>Hi-Assn</td>
<td>80.11 (4.33)</td>
<td>80.11 (4.33)</td>
</tr>
</tbody>
</table>

5.4 DISCUSSION

The current study is the first to examine the effects of age and cue-intention association on PM in 5- and 7-year-old children, whilst being only the second to investigate the effects of providing an extrinsic incentive in this age group. Based on the literature, primarily the Executive Framework (Mahy et al., 2014) and Multiprocess Framework (McDaniel & Einstein, 2000), it was expected that 7-year-old children would outperform 5-year-old children in the PM task, across both conditions. Further, it was anticipated that both the promise of reward, in the form of a gift incentive, and high cue-intention association would positively affect PM performance, and that these effects would possibly more benefit the younger children, as reward would encourage the allocation of EF resources to the task, and high cue-intention association would promote reflexive-associative (i.e., more automatic) processes, reducing EF demand.

Firstly, as expected, significant age effects were found, with the 7-year-olds outperforming 5-year-olds in the PM task, across both conditions. Also in line with predictions and previous evidence of positive effects of motivation on PM in children (Causey & Bjorklund, 2014; Kliegel et al., 2010; Somerville et al., 1983) those who were promised a reward performed better than those who were not, an effect found across age groups. This result is in contrast to the only other study to specifically investigate the effects of extrinsic incentives on PM in young children (Guajardo & Best, 2000). It seems possible that by reducing the working memory demands of the OT in the current study, compared to those of Guajardo and Best’s study (Guajardo & Best, 2000) (naming, rather than remembering, cards) potentially confounding EF factors were reduced; and by providing a more motivating incentive (a ‘surprise box’ rather than common food and toy items) increased motivation was achieved. It is therefore argued that the current results extend literature on the positive effects of motivation on PM found in tasks that were more intrinsically motivating (Causey & Bjorklund, 2014; Kliegel et al., 2010; Somerville et al., 1983), demonstrating that extrinsic rewards may also be beneficial to PM performance.

At first glance, these results may indicate that children focused more on the PM task when offered a reward. However, the apparent lack of additional OT costs in the reward condition does not support this notion. In fact, for 5-year-olds, OT performance was actually better in the reward condition. This is perhaps surprising as the Multiprocess Framework (McDaniel & Einstein, 2000) posits that perceived task importance influences the allocation of attentional resources between the OT and PM task, thus benefiting the ‘more important’ task at a cost to the other task, an effect which has been shown in previous studies (Hering, Phillips, & Kliegel, 2014; Kliegel, Martin, McDaniel, & Einstein, 2004; Kliegel, Martin, & Moor, 2003; Woods et al., 2014). Therefore, if the reward increased motivation due to the perceived importance of the PM task, one might have expected to see an increased cost to the OT. However, we contend that, even if attention was drawn to the more important PM task, it is unlikely that the deliberately simple card-naming nature of the OT would be adversely affected. Indeed, most OT errors were simple misnaming errors, for example, calling an orange an apple. It is possible, however, that the children were slower to name the cards, and so future studies should employ more sensitive measures (e.g., reaction times) which may reveal an OT cost. This is an important future direction, which could elucidate upon the effect of additional PM tasks and their importance relative to the OT, and the impact they may have on the different phases of the PM process (e.g. Mahy et al., 2014). For example, other recent studies which also did not find a cost to OT, despite a positive ‘importance’ effect on the PM task in Parkinson’s patients, or positive effects of monetary incentives in healthy populations (Aldassion, Zöllig, Kopp, Mackinlay, & Kliegel, 2007 respectively; Cook et al., 2015) posited it is possible that increased personal importance of the intention resulted in a stronger encoding of the PM cues at the time of instruction, thus facilitating PM cue retrieval without requiring further attentional resources, a notion further supported by the motivational-cognitive model of Penningroth and Scott (2007). It would be interesting to investigate this further by increasing the demand/difficulty of the OT, and observe how this interacts with rewards.

This finding has important implications for the home and school environment of young children, where incentives (and motivation) could be employed as a strategy for remembering important everyday prospective tasks, such as remembering to give a letter to a parent, or bringing a swimming kit in on the appropriate day. This could also apply to remembering to execute appropriate social behaviours at the right time, such as saying ‘please’ and ‘thank-you’, or putting a hand up before giving an answer; in fact, encouraging good social behaviour through proactive strategies (e.g., increasing motivation through rewards such as praise and stickers) have been argued to be the most common, and effective, good-behaviour strategies in schools (Arthur-Kelly, Gordon, & Butterfield, 2003; Clunies-Ross, Little, & Kienhuis, 2008). However, with such paucity of PM research in this area, it is important for future research to further investigate...
motivation and incentives. Indeed, this may be particularly important for populations with social impairments, such as those with autism spectrum disorder (APA, 2013) who may be less socially motivated to successfully perform a PM task (e.g. to remember to perform an action in the future in such a way as to consider the well-being of others, such as closing a door quietly if a classmate has a headache) and thus benefit more from an incentive conferring motivation on a personal level.

Perhaps the most surprising result was found in the cue-intention association condition, where participants of both ages did not, as predicted, perform significantly better in the high-association condition, compared to the low-association condition. This prediction was derived from the previous positive cue-intention association effects found in both healthy adults (McDaniel et al., 2004; Pereira et al., 2012; Pereira et al., 2012) and clinical groups (Woods et al., 2010) which suggested that high-association enables more reflexive/automatic processes (McDaniel & Einstein, 2000), reduces EF demands and thus improves the PM performance, particularly for those with less-developed EF resources, e.g. younger children (Mahy et al., 2014). However, the present finding of no effects of association on PM performance is in line with other previous evidence (Bartsch, 2013). Another possibility is that the current result could be explained by the ‘delay–execute’ effect (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Rendell, Vella, Kliegel, & Terrett, 2009); previous research has found that requiring participants to delay executing an intention once it is retrieved negates the effects of incentives on PM performance (Einstein et al., 2000; Rendell et al., 2009). This effect is theorized to arise due to increased demands on working memory, task switching and inhibition when prospective intentions cannot be performed immediately upon appearance of the target cue (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003; Klügel & Jaeger, 2006; McDaniel, Einstein, Graham, & Rall, 2004; McDaniel, Einstein, Stout, & Morgan, 2005). Children in the current study were instructed, on presentation of the target item, to first continue with the OT of naming the card, and then to execute the PM task of saying ‘juice’. However, it is possible that including this in the design of the study inadvertently introduced a delay–execute effect, which neutralized the positive effect of high-cue–intention association. In other words, increasing the cue–intention association in the high association condition may have induced a stronger reflexive retrieval response, but requiring its initial inhibition upon cue presentation may have placed a proportionately higher demand on inhibition and working memory as compared to the low association condition. More specifically, the strong reflexive response of saying juice when seeing the strongly associated cue of a fruit, may have been neutralized by the ‘delay–execute’ effect of inhibiting the intention and holding it in mind whilst first naming the card. This notion has important everyday implications, as young children arguably must often wait to execute an intention once it has been retrieved e.g., waiting for adult to finish talking/teaching before passing on a message (Rendell et al., 2009). Inhibiting an intention in this way could, for example, put a strain on working memory and induce a fear of failing the intention, which could, in turn cause anxiety, as well as significant cost to the ongoing activity, such as sitting in lesson. This example should be considered cautiously as it is highly speculative at this point but, given the potentially important implications, future research should further examine the delay–execute effect in young children, and the ways in which it may interact with factors thought to facilitate automatic retrieval.

Finally, both age groups saw a decrease in OT performance during both the dual-task blocks (Lo-Assn and Hi-Assn) compared to the Baseline-block; furthermore, the costs to the OT were greater in the Lo-Assn block, but only for the younger children. These results are thus in line with Mahy’s Executive Framework (Mahy et al., 2014) in that developing attentional resources/EF are important underlying mechanisms for the PM process in children, with those with less resources more adversely affected in their ongoing activity by the addition of an extra task. These results are also consistent with Scullin et al. (2010) which saw greater OT costs when strategic processes were needed to monitor for the PM cue, and less cost when automatic processes were sufficient. These data contribute further evidence for the development of PM (Kliegel et al., 2013; Kvavilashvili et al., 2001; Mahy & Moses, 2011) and are in line with both the Executive Framework (Mahy et al., 2014) and the Multiprocess Framework (McDaniel & Einstein, 2000) in that developing attentional resources/EF are important underlying mechanisms for PM in children, with those with less resources more adversely affected by the addition of an extra task.

In conclusion, the current study is the first to provide evidence for the benefits of incentives on PM in 5- and 7-year-old children, whilst also contributing further evidence in support of the important role that executive functioning plays in the PM process, as posited by the Executive Framework and the Multiprocess Framework (McDaniel & Einstein, 2000). Furthermore, the results regarding the lack of cue-intention association introduced the possibility that ‘delay–execute’ effects can neutralize the benefits of automatic processes, which would have important implications for children’s everyday PM functioning, opening up important future directions for research.
DID YOU HEAR? AUTISTIC CHILDREN BENEFIT MORE FROM AUDITORY PROSPECTIVE MEMORY CUES THAN NON-AUTISTIC CHILDREN.

This chapter is based on:
ABSTRACT

The transition from primary to secondary school is particularly difficult for autistic children, a transition underpinned by an increase in prospective memory (PM) demands. To better understand PM in autistic children of the relevant age, and the factors which may be employed to support it, the current study investigated the impact of cue salience (distinctiveness) on prospective memory (PM) in autistic and non-autistic children of around 11 years-old. The study was also unique in manipulating the visual and auditory salience of PM cues. Results revealed both groups benefitted from an increase in visual and auditory salience, but only autistic participants were faster to react to auditory cues. Thus, whilst the PM performance of all children may benefit from increased visual cue salience, autistic children, many of whom experience atypical auditory sensitivity, may be particularly able to take advantage of increased auditory salience. The ways in which cue salience may be used to support children, particularly autistic children, in their transition to secondary school are discussed.

6.1 INTRODUCTION

Autism spectrum conditions (ASC; henceforth, autism) are characterised by social communication difficulties, repetitive behaviours and atypical sensory reactivity (APA, 2013). It is perhaps unsurprising, then, that transitioning from primary school to the new social, academic and physical environment of secondary school is particularly difficult for autistic children (Makin, Hill, & Pellicano, 2017). It is of major concern that difficulties adapting to the transition to secondary school can result in anxiety, depression and poor self-esteem, as well as poorer academic performance (Ashton, 2008; West, Sweeting, & Young, 2010; Zeedyk et al., 2003), difficulties that may well be contributing to the high prevalence of mental health problems in autism (Salazar et al., 2015; Simonoff et al., 2013; Simonoff et al., 2012). The identification of the issues potentially underlying the transition problems are thus important for ensuring the well-being of autistic children, and in supporting them in realising their academic potential. One issue likely important to the transition is prospective memory (PM) ability. The PM process involves the formation of intentions and executing them at the appropriate moment in the future, either at a certain time (time-based PM; TBPM), or when cued by a particular event (event-based PM; EBPM) (Einstein & McDaniel, 1996). Examples of PM tasks in relation to the primary-to-secondary transition would include remembering to bring in the appropriate books and equipment for different lessons, and to complete homework and bring it in on time. Critically, it is the increased number of such PM tasks in secondary school that autistic children and their parents have reported as particularly difficult (Makin et al., 2017), suggestive of impaired PM ability. Whilst research on PM in autism is still relatively scarce, the well-known problems in autism with executive function and memory, such as switching flexibly between tasks or foci of attention (Corbett & Constantine, 2006; Leung & Zakanzis, 2014), and impairments in free recall tasks (Bowler, Gardiner, Grice, & Saavalainen, 2000), processes upon which PM is posited to rely (Mahy, Moses, & Kliegel, 2014; Smith & Bayen, 2004; West, Scolaro, & Bailey, 2011), also point to a PM deficit. Indeed, of the few studies conducted so far, all experiments have revealed a TBPM deficit (Altgassen, Koban, & Kliegel, 2012; Altgassen, Williams, Bölte, & Kliegel, 2009; Henry et al., 2014; Kretschmer, Altgassen, Rendell, & Bölte, 2014; Williams, Boucher, Lind, & Jarrold, 2013; Williams, Jarrold, Grainger, & Lind, 2014), although the results of EBPM experiments are mixed, with an almost equal number of the studies reporting either intact EBPM (Altgassen & Koch, 2014; Altgassen, Schmitz-Hubsch, & Kliegel, 2010; Henry et al., 2014; Sheppard, Kvavilashvili, & Ryder, 2016; Williams et al., 2013; Williams et al., 2014), or impaired EBPM (Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Kretschmer et al., 2014; Sheppard et al., 2016; Yi et al., 2014). Importantly, most TBPM tasks can be converted into EBPM tasks by, for example, setting reminders on an iPad or a smartwatch; that is, the cognitive demand can be ‘offloaded’ (Gilbert, 2015). Better understanding EBPM in autism, and the potential this has for intervention, is, therefore, the focus of the current paper. All studies that have investigated event-based PM in autism will be discussed henceforth, followed by a closer examination of the sensory characteristic of EBPM cues pertinent to the current study, namely, cue salience, and how it may interact with the sensory processing differences in autism.
In the first study demonstrating undiminished PM ability in autism, Altgassen and colleagues (2010) required participants to complete a computerised working memory task, but to respond differently when cued by the background colour turning a distinctive yellow (PM task). Results revealed that autistic participants were as accurate and quick to respond to the visual PM cues as matched controls. In contrast, Brandimonte et al. (2011), found autistic participants to perform less well than comparison groups when asked to respond to a picture cue, embedded within a picture categorisation task. However, the PM cues of both studies clearly differed in their distinctiveness, or salience: the picture cue employed by Brandimonte et al. (2011) did not differ visually to the items of the ongoing task, whereas the cue employed by Altgassen et al. (2010) was a distinctive bright yellow, covering much of the screen. The cues of the other studies demonstrating intact EBPM of autistic participants were also arguably of relatively high salience, such as distinctive blue words (Altgassen & Koch, 2014), and large, distinctive lorries in a computer game (Williams et al., 2013), whereas the small heart in the corner of a card (Yi et al., 2014) and the kettle changing colour (Altgassen et al., 2012), cues within studies that found impaired EBPM, were arguably less contextually distinctive. Differences in cue salience could therefore, according to the Multiprocess Framework (McDaniel & Einstein, 2000), contribute to the contrasting results of the EBPM and autism literature.

This framework posits that the perceptual and semantic characteristics of the PM cue, such as its salience relative to the ongoing task, can influence the intention retrieval process by placing differential demands on cognitive resources; that is, cues low in salience require strategic monitoring processes (high executive demand), and cues high in salience allow for more automatic processes (low executive demand). Thus, a highly salient cue, such as that employed by Altgassen et al. (2010), may rather automatically prompt retrieval of the intention and demand less of executive function processes, supporting PM performance even in populations with reduced executive functioning.

Evidence in support of this hypothesis can be found in studies reporting positive effects of increased cue salience in, for example, the very young (Kliegel et al., 2013; Mahy, Moses, & Kliegel, 2014) and old (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010). Kliegel et al. (2015) found that by increasing the number of PM cues on-screen, the performance of 5 year-olds, compared to 7 year-olds, was improved. Similarly, Mahy et al. (2014) found that surrounding targets with a red border improved the EBPM of pre-schoolers (for similar results in adults with Korsakoff’s syndrome, and, respectively, undergraduate students, see Altgassen, Ariese, Wester, & Kessels, 2015; Hicks, Cook, & Marsh, 2005).

Further support for the multiprocess framework McDaniel and Einstein, (2000) can be found in the executive framework set out by Mahy et al. (2014) to explain prospective memory development in children. According to this framework, increased cue salience improves PM performance by reducing the need for the cognitively demanding executive processes required at the point of PM intention retrieval and execution, such as switching from the ongoing task to the PM task. Such evidence adds weight to the notion that increasing cue salience in a PM task will be particularly beneficial for autistic participants, who have consistently demonstrated an impairment in executive functions such as inhibition and task-switching (Hughes, 2001; Hughes, Russell, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991).

In addition to executive function, it is also important to consider the way in which cue salience is related to sensory processing. Reported levels of atypical sensory reactivity in autism are as high as 80% (Ben-Sasson et al., 2009), most commonly in the tactile and auditory modalities (Ashburner, Ziviani, & Rodger, 2008; Robertson & Baron-Cohen, 2017; Tomchek & Dunn, 2007) and atypical sensory processing is now a core diagnostic criteria of autism (APA, 2013). Clearly, the way in which the PM cue is processed perceptually is critically important when considering the degree of its salience. Those with increased sensory sensitivity may, for example, perceive a greater level of salience in the PM cue, and may therefore show a greater benefit in terms of their subsequent PM performance compared to those with lower sensory sensitivity. In this way, sensory hypersensitivity, which is often seen as an autistic impairment, would confer an advantage in relation to PM performance.

To date, however, all studies of PM that have manipulated PM cue salience have not included autistic participants. Moreover, whilst some studies have included auditory cues (e.g. Altgassen et al., 2012; Altgassen, Kretschmer, & Kliegel, 2012; Sheppard et al., 2016) none have explicitly manipulated auditory cue salience; instead, all previous cue salience manipulations have been visual in nature (e.g. red border around target cue (Mahy et al., 2014); increased number of flowers on-screen (Kliegel et al., 2013); letter strings in red rather than the white letter strings of the ongoing task (Smith, Hunt, McVay, & McConnell, 2007)). This is perhaps surprising, given that many of the PM cues in everyday life are of an auditory nature, such as timer alarms, or a combination of both auditory and visual, e.g. appointment notifications via a calendar application. Therefore, the consideration of auditory cues is critical to further the ecological validity of the current PM literature. Arguably, this is particularly important for understanding everyday PM in autism, given the high prevalence of atypical auditory processing in the population (Ashburner et al., 2008; Tomchek & Dunn, 2007).

The overall aim of better understanding EBPM in autistic children, of primary-to-secondary school age (≤11-years-old), was divided into two sub-aims: 1) to ascertain whether increased visual cue salience is as beneficial to PM performance in autism as has been found in other populations, and; 2) to further the understanding and everyday relevance of cue salience in PM for all populations by investigating the as yet ignored role of auditory cues. This was achieved by exploring whether increased auditory cue salience confers benefits comparable to those of visual cues, and whether this pattern is the same for autistic and non-autistic individuals. Children were engaged in a classic dual task PM paradigm in which a PM task was embedded within a simple ongoing categorisation task. Thus, whilst children were indicating, via key press, whether the two on-screen pictures belonged to the same category or not, they had to remember to press a different key, as quickly and as accurately as possible, upon presentation of a PM target cue. The salience of the PM target cue was manipulated across three conditions: a low
salience condition, with the target picture presented in the same format as the ongoing task pictures: a high visual salience condition, whereby salience was increased by way of a red border surrounding the target; and a high auditory salience condition, whereby salience was increased by way of an auditory beep in a third condition.

Based on the inconsistent findings in the literature, we had no clear expectations regarding a possible group effect, or lack thereof. We did expect a main effect of salience, as participants were predicted to achieve more correct PM responses in both high salience conditions than in the low salience condition. As previously found EBPM deficits in autism were potentially due to the low salience of the cues used (e.g., Brandimonte et al., 2011), and spared performance due to highly salient cues (e.g., Altgassen et al., 2010), we expected a significant group x salience interaction, with controls performing better than autistic children in the low salience, but not the high salience conditions. Furthermore, given that increased cue salience should facilitate inhibition and task-switching at the critical PM execution phase (Mahy et al., 2014), and that improvements in such abilities are often seen by shorter response times (Draheim, Hicks, & Engle, 2016; Kiesel et al., 2010), we expected a similar pattern of results for reaction time data of correct PM responses; namely, that increased salience would result in faster overall response times. A lack of previous research again yielded the possibility of a main effect of group uncertain; however, given the robust findings of task-switching impairment in autistic individuals (Hughes, 2001; Hughes et al., 1994; Ozonoff et al., 1991), we predicted a group x salience interaction, with controls responding faster than autistic children in the more demanding, low-salience condition, but not in the high salience conditions.

6.2 METHOD
6.2.1 Participants
Twenty-four autistic children and 23 non-autistic children participated in the study. Groups were parallel for age and verbal IQ, but not for non-verbal IQ, or for gender (see Table 1). However, as non-verbal IQ did not correlate significantly with any PM measures, it was not included as a covariate (all ps > .09). Autistic participants were recruited from a Dutch school for autistic children and from Dutch clinics for autistic children and their families. All autistic children had received a formal diagnosis of autism, or Asperger’s syndrome (APA, 2000). In addition, 22 and 19 parents or teachers (of autistic and control participants, respectively) completed the Dutch version of the Social Responsiveness Scale (SRS; Roeyers & Thys, 2010) as well as the ‘auditory filtering’ and ‘visual/auditory sensitivity’ sub-scales of the Social Responsiveness Scale (SRS; Roeyers & Thys, 2010) to ensure they were comfortable and happy to participate. The order of the session was described in detail below.

1) Ongoing task, practice block and baseline block
Children were introduced to the categorization ongoing task (similar to that of Altgassen et al., 2015) in which they were required to indicate, as quickly and as accurately as possible via keypress, whether the two coloured pictures on the computer screen were of the same category (green key) or not (orange key). Pictures were presented for a maximum of 4 seconds, or until a response had been made, with a 1-second inter-stimulus interval. Participants were not able to make a response within 500ms in order to prevent continual pressing. The pictures were coloured versions of Snodgrass and Vanderwart’s (1980) picture set (Rossion & Pourtois, 2004), and included the following six categories: body parts; toys; instruments; food items; furniture, clothes. Children first performed a practice block of 10 trials, and then a baseline block of 20 trials.

2) Salience condition PM instructions and picture encoding
It was then explained to the children that they would be performing the task again in about 10 minutes, only next time it would be more difficult; they would be deciding on

Table 1: Means (S.D.) and group differences in participant characteristics and symptoms.

<table>
<thead>
<tr>
<th></th>
<th>ASC (N = 24)</th>
<th>Controls (N = 23)</th>
<th>t</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>11.25 (1.26)</td>
<td>11.09 (1.26)</td>
<td>0.57</td>
<td>.576</td>
<td>0.15</td>
</tr>
<tr>
<td>Gender M (F)</td>
<td>24 (0)</td>
<td>7 (16)</td>
<td>(25.31)</td>
<td>&lt;.001</td>
<td>-</td>
</tr>
<tr>
<td>Verbal IQa</td>
<td>11.67 (2.93)</td>
<td>10.35 (2.08)</td>
<td>1.77</td>
<td>.083</td>
<td>0.53</td>
</tr>
<tr>
<td>Non Verbal IQa</td>
<td>61.58 (10.31)</td>
<td>53.78 (9.82)</td>
<td>2.66</td>
<td>.011</td>
<td>0.79</td>
</tr>
<tr>
<td>SRS total T-scorea</td>
<td>72.86 (13.00)</td>
<td>43.95 (5.29)</td>
<td>9.03</td>
<td>&lt;.001</td>
<td>2.93</td>
</tr>
<tr>
<td>SSP – Auditory filteringa</td>
<td>14.29 (4.03)</td>
<td>25.35 (3.96)</td>
<td>11.06</td>
<td>&lt;.001</td>
<td>2.84</td>
</tr>
<tr>
<td>SSP Visual/Auditory sensitivitya</td>
<td>18.19 (9.33)</td>
<td>23.85 (1.84)</td>
<td>5.66</td>
<td>&lt;.001</td>
<td>1.88</td>
</tr>
</tbody>
</table>

* normed vocabulary score on sub-test of WISC-III-NL (10 is norm)
* T-score on matrices sub-test of WNV-NL (50 is norm)
* SRS: social responsiveness scale; high scores indicative of atypical/autistic social responsiveness
* SSP: short sensory profile; low scores indicative of atypical sensory responsiveness
* Cohen’s d effect sizes of 0.2 as small, 0.5 as medium, and 0.8 as large (Cohen 1988)
more pictures (70 trials) and performing an extra task (PM task). They were then shown a screen with 4 pictures on it, and told, next time they did the categorisation task and they saw any of these four pictures they had to press the pink key (rather than the green or orange key), as accurately and quickly as possible. The children named the pictures on the screen, and upon learning them they were asked to say them out loud and then write down names of the depicted objects to further ensure the pictures were well memorised. The salience of the target pictures varied by condition: 1) low salience condition - 4 target pictures were presented in an identical format to the ongoing task pictures; 2) high visual salience condition – 4 target pictures were surrounded by a red border; and 3) high auditory salience condition – 4 target pictures were accompanied by an auditory tone. However, piloting revealed that simultaneous presentation of an auditory beep and the PM cue was confusing for the children, and resulted in very poor performance. The auditory beep was thus presented 500ms prior to presentation of the PM cue. The order of conditions was counter-balanced. Dependent variables were number of correct PM responses (max 4 per condition), correct ongoing task responses (percentage), and reaction time of correct responses (ms).

3) Filled delay
To ensure the PM instructions were not held in working memory (Ellis & Kvatilashvili, 2000), children were engaged in a short activity prior to the dual-ongoing task/PM task. The first activity was the verbal sub-test of the Dutch version of the Wechsler Intelligence Scale for Children-III (WISC -III-NL; Kort et al., 2005), the second, the matrices task from the Wechsler Nonverbal Scale of Ability(WNV; Wechsler & Naglieri, 2008), and the third, the digit-span, also from the WISC-III-NL.

4) Dual-task block
After approximately 8 minutes, the filled delay activity was paused (if not finished) and, without further reminder of the PM instructions, the children began the dual-task block. When they had finished, they received the instructions for the next salience condition, and then experienced a filled delay before completing the task, i.e. steps (2 to (4), which were repeated once more until all three conditions had been completed.

5) Post-task PM task confirmation and picture recall
Once all three conditions had been completed, participants were asked if there was anything else they were meant to do, other than the categorization task. All participants answered correctly. To further assess retrospective memory, participants were then asked to recall as many of the 12 target pictures as they could. If not all PM pictures were recalled, this was then followed by a PM target picture recognition task, whereby the 12 target pictures were presented, in the low salience format, with 12 non-target pictures and the children were asked to identify as many targets as possible. Thereafter, the children finished any sub-tests still uncompleted.

Figure 1. Illustration of paradigm, showing sequence of steps: 1 – Single ongoing task; 2 – High visual salience instruction screen; 3 – OT (70 trials) in dual-task block; 4 – PM (4 trials) target screen.
CHAPTER 6

6.3 RESULTS

6.3.1. PM performance

To assess PM performance, a 3 x 2 mixed analysis of variance (ANOVA), with the within-group factor salience (Low-salience, Hi-visual salience, Hi-auditory salience) and the between-group factor group (ASC and controls) was conducted. Mauchly’s test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 15.72, \ p < .001$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .78$). There was a significant main effect of salience, $F(2, 90) = 55.32, \ p < .001, \ \eta^2_p = .55$, but no main effect of group, $F(1, 45) = 1.35, \ p = .25, \ \eta^2_p = .03$, and no significant interaction $F(2, 90) = 1.93, \ p = .162, \ \eta^2_p = .04$ (see Fig. 2). Participants overall achieved a greater number of correct PM responses in both the Hi-visual ($M = 3.85, SD = .42$) and the Hi-auditory ($M = 3.68, SD = .66$) salience conditions, compared to the low salience condition ($M = 2.34, SD = 1.17$), but performed equally well on the two high-salience conditions. There was no difference between the number of correct PM responses made by control participants ($M = 3.20, SD = 1.22$) and autistic participants ($M = 3.38, SD = .86$).

Reaction time, (in milliseconds), for correct PM responses was then analysed. Given that participants who scored zero correct responses were not included, participant numbers were therefore reduced for the control group ($n = 18$). A 3 x 2 mixed ANOVA, with the within-group factor salience (Low-salience, Hi-visual salience, Hi-auditory salience) and the between-group factor group (ASC and controls) was then carried out. There was a significant main effect of salience, $F(2, 80) = 17.82, \ p < .001, \ \eta^2_p = .308$, but no main effect of group, $F(1, 40) = .173, \ p = .68, \ = .004$. However, there was a significant salience by group interaction, $F(2, 80) = 3.14, \ p = .049, \ = .073$ (see Fig. 3). Correct responses in both the Hi-visual ($M = 1332.64, SD = 387.38$) and Hi-auditory ($M = 1450.45 SD = 457.77$) salience conditions were quicker than correct responses in the low salience condition ($M = 1842.61, SD = 622.72$). Overall, correct PM response times of the control participants ($M = 1513.43, SD = 496.29$) were no different to the autistic participants ($M = 1563.25, SD = 575.33$). Subsequent pairwise comparisons revealed that, whilst both groups were quicker in the high-visual salience condition compared to the low-salience condition, (ASC: $p < .001$, Cohen’s $d = 1.16$; controls: $p = .005$, Cohen’s $d = 0.78$), only the autistic group benefitted from the high-auditory salience condition as compared to the low salience condition (ASC: $p < .001$, Cohen’s $d =1.08$; controls: $p = .30$). There were no significant differences between the two high salience conditions for both groups (all ps > .13). There were no significant group effects for any of the salience conditions (all ps > .14).

Figure 2. Mean number of correct prospective memory responses (max 4) by group. Error bars represent standard error of means.

Figure 3. Mean response time of correct prospective responses by group. Error bars represent standard error of means.
### 6.3.2 PM cue recall and recognition

To compare performance of the groups on the retrospective component of the PM task, i.e. memory for the PM cues, a 3 x 2 mixed ANOVA was conducted on post-test, free recall of PM cues with the within-group factor cue salience (Low-salience cues, High-visual salience cues, High-auditory salience cues), and the between-group factor of group (ASC and controls; see Table 2). There was no main effect for either factor (both ps > .37), and no interaction (p=.57) indicating that all cues were encoded, and subsequently recalled, equally well by both groups.

Following the recall, participants were asked to identify as many of the 12 PM cues from a set of 24 pictures (see Table 2). A subsequent-independent-samples t-test revealed that there was a significant between-group cue-recognition difference, t(45) = 1.26, p = .041; however, as both groups’ means were greater than 11.5 (of a maximum 12) scores were at ceiling, a clear indication that cue recognition did not confound PM performance.

### Table 2. Means (S.D.) of post-test probe and ongoing task performance across groups.

<table>
<thead>
<tr>
<th></th>
<th>ASC</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post-test PM probes (max 12)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM cue recall</td>
<td>7.08 (2.36)</td>
<td>7.83 (1.61)</td>
</tr>
<tr>
<td>PM cue recognition</td>
<td>11.83 (.38)</td>
<td>11.48 (.73)</td>
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<tr>
<td><strong>Ongoing task</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Accuracy (percent)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>88.13 (10.61)</td>
<td>89.57 (9.03)</td>
</tr>
<tr>
<td>Low salience</td>
<td>86.87 (8.58)</td>
<td>86.36 (8.74)</td>
</tr>
<tr>
<td>High visual salience</td>
<td>85.72 (9.76)</td>
<td>89.29 (5.80)</td>
</tr>
<tr>
<td>High auditory salience</td>
<td>88.01 (6.48)</td>
<td>86.72 (6.22)</td>
</tr>
<tr>
<td><strong>Response times (ms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>1284.09 (270.61)</td>
<td>1280.19 (226.46)</td>
</tr>
<tr>
<td>Low salience</td>
<td>1610.00 (298.93)</td>
<td>1513.18 (238.22)</td>
</tr>
<tr>
<td>High visual salience</td>
<td>1436.84 (262.94)</td>
<td>1387.52 (234.43)</td>
</tr>
<tr>
<td>High auditory salience</td>
<td>1422.62 (273.09)</td>
<td>1357.40 (290.80)</td>
</tr>
</tbody>
</table>

### 6.3.3 Ongoing task performance

To investigate performance of the two groups on the ongoing task (see Table 2), a 4 x 2 mixed ANOVA, with the within-group factor task block (Baseline, Low-salience, High-visual salience, High-auditory salience) and the between-group factor group (ASC and controls) was conducted. Mauchly’s test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 20.49, p = .001$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .75$). There was no main effect of task block, $F(2.24, 135) = 1.305, p = .277, \eta^2 = .028$, or group, $F(1, 45) = .163, p = .688, \eta^2 = .004$ and no significant interaction $F(2, 135) = 1.79, p = .169, \eta^2 = .038$. Both groups achieved the same level of accuracy across all four task blocks.

To analyse the reaction time for accurate ongoing task responses (see Table 1), a 4 x 2 mixed ANOVA, with the within-group factor task block (Baseline, Low-salience, High-visual salience, High-auditory salience) and the between-group factor group (ASC and controls) was carried out. There was a significant effect of task block, $F(3, 135) = 27.73, p < .001, \eta^2 = .381$, but no main effect of group, $F(1, 45) = .640, p = .428, \eta^2 = .014$, and no significant interaction $F(3, 135) = .784, p = .505, \eta^2 = .017$. Pairwise comparisons revealed that both groups were slower to respond in the Low-salience and High-visual salience blocks, compared to Baseline (both ps < .001). Moreover, participants overall responded slower in the the Low-salience block than both high salience blocks (all ps < .001). Response times did not differ between the high salience blocks (ps > .44).

### 6.4 DISCUSSION

The current study set out to examine EBPM in autistic children of around 11-years-old, with a view to better understanding the reported EBPM difficulties experienced by this population when transitioning to secondary school. This was achieved by examining the role that cue salience plays in the EBPM of autistic children. The study also investigated the role of auditory cue salience in the EBPM of both autistic and non-autistic children, an important first, with regards to ecological validity, in the PM literature. No predictions were made regarding main group differences, with regards to either PM accuracy or response times, due to the mixed findings in the literature, with roughly half of studies showing intact EBPM (Altgassen & Koch, 2014; Altgassen et al., 2010; Henry et al., 2014; Sheppard et al., 2016; Williams et al., 2013; Williams et al., 2014) and half showing impaired EBPM (Brandimonte et al., 2011; Kretschmer et al., 2014; Sheppard et al., 2016; Yi et al., 2014). However, main effects of salience were expected for both PM accuracy and correct PM response times. Specifically, that performance in the high salience conditions would yield more accurate, and faster, responses than the low salience condition. Furthermore, given the potentially beneficial role increased cue salience plays in studies finding intact autism PM performance (e.g., distinctive blue words and bright yellow screen, Altgassen & Koch, 2014; Altgassen et al., 2010, respectively), we expected a group x salience interaction, again, for both PM performance measures; that is, autistic participants were expected to perform less accurately, and slower, in the low salience condition, but as accurate and as fast in the high salience conditions, as non-autistic children.
No main effect of group, but an expected main effect of salience, revealed the increase in the visual and auditory salience of cues to be beneficial to both groups across both PM performance measures; that is, overall, participants were quicker and more successful in the visual and auditory salience conditions, compared to the low salience condition, though performance in both high salience conditions was similar. Further analysis revealed that both groups performed comparably, again, across both PM performance measures, in each of the salience conditions. Consequently, the expected group x salience interaction, whereby the autistic group were predicted to perform worse in the low salience condition but not the high salience conditions, did not emerge.

However, there was an interesting and unexpected group x salience interaction in the response time data (but not the accuracy data), which represented an unpredicted difference in the way each group’s performance was affected by each of the high salience conditions. Specifically, whilst both groups were significantly faster to respond when the visual salience of the cues was increased, only the autistic group was also faster when cues were auditorily salient. Indeed, autistic participants were, on average, over 25 percent faster in both high salience conditions, compared to the low salience condition, accompanied by large effect sizes (both ds > 1), whereas the non-autistic group were just over a 10 percent faster in the visual condition (d > .7) but no faster in the auditory condition.

The main effect of salience (driven by participants’ superior performance in both PM measures across both high salience conditions, compared to the low salience condition) provides important evidence in support of the positive influence of increased cue salience in PM as predicted by the multiprocess framework (Einstein & McDaniel, 1996) and is in line with those studies demonstrating benefits of increased visual cue salience (Altgassen et al., 2010; Kliegel et al., 2013; Mahy et al., 2014). Furthermore, these results suggest that, not only are auditorily salient cues as beneficial for PM as has been found for visually salient cues, but that this is also true for autistic populations. As there was no main group effect, nor the predicted group x salience interactions (i.e., between-group differences in the low salience condition but not the high salience conditions) for either PM measure (accuracy nor response time), these results are suggestive of preserved event-based PM in autistic children, even with cues low in salience, and are thus in line with all literature reporting intact event-based PM in autism (Altgassen et al., 2010; Henry et al., 2014; Sheppard et al., 2016; Williams et al., 2013; Williams et al., 2014). However, it is important to note a limitation of the accuracy results; namely that both groups’ PM accuracy scores were at ceiling in the high salience conditions, which may have contributed to the lack of between-group differences (following a restricted capacity for variation, given the maximum score was 4). Indeed, ceiling effects have potentially confounded results of some of the previous studies that have also reported intact event-based PM in autism (Williams et al., 2013; Williams et al., 2014). Further scrutiny of the response time data, therefore, with the greater capacity for variation, may help discern more subtle group differences, and help to further elucidate the nature of the retrieval processes underlying the salience effect. The significantly faster response by both groups to highly visual cues, and by the autistic group to auditory cues, compared to the response time for the low salience cues, is arguably indicative of faster, more automatic retrieval processes; that is, the more salient cues resulted in the intention more automatically ‘popping into mind’ thus reducing demand for the slower, more strategic and cognitively effortful processes of monitoring for the cue, retrieving the intention and inhibiting/switching from the ongoing task to execute the intention (McDaniel & Einstein, 2000). This notion is supported by the ongoing task results, as ongoing task response times were also significantly slower for both groups in the low salience condition compared to both of the high salience conditions.

This cost to ongoing task performance has been suggested to reflect an increase in cognitively demanding strategic processes (Leigh & Marcovitch, 2014; McDaniel & Einstein, 2000; Smith et al., 2007) associated with the additional PM task. It is also worth emphasising that the dominant measure for the relevant executive functioning tasks, such as task switching, when examined in the laboratory, is response time (Draheim et al., 2016; Kiesel et al., 2010). It may be, therefore, that the large decrease in response times, particularly for the autistic group, reflects an amelioration of inhibition and task-switching costs—normally incurred at the point of intention retrieval and execution, brought about by salience-induced automatic processes. This can only be speculated at this point, but a systematic investigation of the effects of salience on the underlying executive processes involved in PM for clinical and non-clinical populations, may prove a fruitful endeavour of future research.

It is of significant interest here that the autistic participants, a group of children who were reported to almost exclusively react to visual and auditory information in an atypical, hyper-sensitive manner (see SSP scores, Table 2), reacted quicker to the auditory cues compared to the low salience cues. This was not true of the non-autistic group, resulting in the unexpected interaction. It is possible then, that the hypersensitive sensory responsiveness of the autistic participants resulted in a subjective amplification of the salience of these cues, thus causing them to be even more distinctive, thereby lending auditory cues a similarly beneficial effect as the visual cues. This implies, therefore, that an often-thought of impairment in autism, such as sensory hypersensitivity, could actually confer an advantage in everyday life. This notion is in line with the neurodiversity movement, advocating that the many characteristics of autism do not represent a ‘disorder’, but rather differences that can actually be a strength given the right context/environment (Baron-Cohen, 2017).

With regard to PM in daily life, the current results contribute evidence in support of intact EBPM in autism. Given the consistently found deficit in TBPM (e.g., Kretschmer et al., 2014; Williams et al., 2013; Williams et al., 2014) it is important to, where possible, convert TBPM tasks to EBPM tasks by setting reminders (cues). This cognitive ‘offloading’ should be supported and encouraged by caregivers, as autistic children have been shown not to always set reminders to offset their perceived difficulty of a task (Cherkasou & Gilbert, 2017). In light of the current evidence, the reminders/cues should be as visually and auditorily salient as possible. Salient visual cues are already a core feature of effective visual communication systems commonly employed for autistic
children, such as the Pictorial Exchange Communication System (PECS; Bondy & Frost, 1994) and others within the ‘Treatment and Education of Autistic and Related Communication-Handicapped Children’ (TEACCH; Mesibov, Shea, & Schopler, 2004). Such cues/systems could therefore be incorporated into the planning and execution of EBPM tasks for children in secondary school. Auditory cues could include, for example, smartwatch reminders, or iPad or Google Calendar alerts. The benefits of auditory cues in everyday life can be seen in the success of assistive technology currently used to support everyday tasks (many of which are of a prospective nature) in populations known to have difficulty with such activities (e.g., older adults, individuals with MCI, those with intellectual and neurodevelopmental disabilities), that employ tones or beeps to remind clients of the intended action (for a review of such technologies, actions and populations, see Gillespie, Best, & O’Neill, 2012).

However, it is important to note that this study is only the first step in understanding the effect of cue salience in PM in autism, and further investigation is required. The auditory cues in the current study, for example, were isolated beeps, presented within a quiet, controlled and relatively predictable environment, and thus not analogous to the noisy, multi-sensory environment of, say, a classroom. Performance in a controlled versus a naturalistic environment would also explain the discrepancy between the intact EBPM performance of the current study and the reported EBPM difficulties at school (Makin et al., 2017). Future studies should therefore investigate EBPM in autism as situated in, for example, a naturalistic school setting, whereby children perform several different PM tasks within a complex auditory, visual and even social environment, such as a classroom.

In sum, the current study provides evidence that increasing the salience of cues supports event-based PM performance in children of primary-to-secondary school age, which has important implications for supporting the tasks they find difficult during the transition (e.g., use of reminders for homework and extra-curricular activities). Importantly, these cue salience benefits were also seen in the PM of autistic children, a population known to experience particular difficulty during the transition to secondary school (Makin et al., 2017). Furthermore, the current study critically extended the common PM computer paradigm by including an auditory cue condition, providing important evidence for the benefit of auditory cues for all children. The evidence was especially interesting for autistic children, who, in contrast to the non-autistic children, were also faster in their response to auditory cues, an indication that sensory hypersensitivity, so prevalent in autism, can in fact be beneficial under certain conditions.
CHAPTER 7

7.1 THESIS AIM

The overarching aim of the current thesis was to better understand PM in autism, with a view to developing effective strategies to facilitate optimal PM performance. Given the importance of PM to successful daily functioning, improving PM may go some way to improving the currently low levels independent living (Anderson, Shattuck, Cooper, Roux, & Wagner, 2014; Newman et al., 2011) and employment (Howlin, Goode, Hutton, & Rutter, 2004) seen currently across the autistic population. This may then help to improve low levels of independent living, even compared to other disability groups) (Anderson, Shattuck, Cooper, Roux, & Wagner, 2014; Newman et al., 2011) and employment (Howlin, Goode, Hutton, & Rutter, 2004) currently seen in the population.

Factors deemed key to the PM process by the multiprocess framework (McDaniel & Einstein, 2000) were investigated, leading to important findings regarding the relevance of autism symptom severity, cue salience and task importance/motivation to PM performance in autism. These results were included in a systematic review of all PM in autism studies. The importance of considering factors such as cue salience and motivation was emphasised, describing the way in which they could be optimised within the PM process to provide an optimal PM environment and maximise the chances of PM success in autism. The review chapter also emphasised the real-life, multifactorial and embodied nature of PM, the importance of considering the process as a whole, and the dynamic interaction within and between individual and environmental factors.

7.2 CHAPTER SUMMARY

Four of the five chapters investigated specific factors of the PM process, and demonstrated their relevance for PM in autism, and the way in which they may, under certain conditions, influence PM performance. The empirical papers presented in Chapters 3 to 6 are described and critiqued in detail in the review of Chapter 2, and so, to avoid repetition, will be only briefly summarised here.

The systematic review of all PM and autism literature presented in Chapter 2, including papers of the current thesis, revealed that, despite considerable methodological heterogeneity amongst the studies, autism PM performance was generally in line with what would be predicted, given the known problems with PM-relevant cognitive functions, such as attention (Landry & Bryson, 2004), executive function (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009) memory and future thinking (Lind, Williams, Bowler, & Peel, 2016) and ToM (Baron-Cohen, 2000) and the varying cognitive demand of PM (Einstei n & McDaniel, 1996; McDaniel & Einstein, 2000); that is, that tasks demanding a high level of executive control and strategic processing, such as TBPM tasks, or EBPM tasks involving, for example, cues of low salience or focality and/or difficult OTs, would prove very difficult for autistic individuals.

Thus, of the experiments reviewed, all TBPM experiments saw impaired performance in autistic, compared to non-autistic, participants. The findings with regards to EBPM performance were more mixed, with tasks involving cues of low salience or focality, or difficult, attention-demanding OTs, seeing poorer performance; when these conditions were reversed (i.e., high cue salience/focality or easy OTs) autism performance paralleled non-autistic controls. These findings were in line with a recent meta-analysis of the same studies (Landsiedel, Williams, & Abbot-Smith, 2017).

Chapter 3 investigated autism severity by comparing PM performance of severely with mildly autistic children, and non-autistic children. The unprecedented inclusion of a group of severely autistic children was facilitated by running the task under more naturalistic conditions (fun and engaging games with a hand puppet and an adult, in a classroom) and ability matching in an atypical way (teacher educational progress ratings, rather than, say, IQ tests, which are neurotypically biased and exclusive). The three headline results of the study were thus: the severely and mildly autistic children differed in that only the severely autistic group performed less well than the non-autistic group, pointing to overall symptom severity as an important to consider with regards to PM ability in autism; the group difference emerged from the second round of two PM tasks, revealing that only the non-autistic children improved/learnt from experience; for one of the three PM tasks, in which they had to remember to pick up a desirable toy when leaving the class, the severely autistic children performed as well as even the non-autistic children, suggesting that high motivation is important in the PM process.

Chapter 4 also demonstrated the importance of motivation in PM performance by revealing the benefit of external incentives to the PM performance of young non-autistic children. That is, children in two age groups (5-year-olds and 7-year-olds) performed better when promised a surprise toy gift for good performance. The group difference in performance also supported the notion that age-related factors, such as executive function, are an important factor to consider.

Chapter 5 then investigated motivation in autistic and non-autistic adolescents in a TBPM task. A main group effect was consistent with TBPM difficulties found in all previous PM and autism studies. Furthermore, autistic groups did not differ despite receiving different instructions designed to elicit either social or personal motivation. The non-autistic group did, however, improve when personally motivated (by a promised cash reward).

Chapter 6 investigated a factor highly relevant to autism and the well-known sensory processing differences in the population, namely, the visual and auditory sensory characteristics of the EBPM cues. The study found that the EBPM success of all children improved (of the primary-to-secondary school transition age of around 11-years-old) when the visual and auditory salience of the cues was increased. Interestingly, while both groups also became faster when the visual salience was increased, only the autistic children, who were nearly all rated to exhibit atypical sensory reactivity by way of the SSP, were also faster when the auditory salience of the cues was increased.

At a glance, the findings from these studies are in line with Figure 2 of the thesis (p8) in that they imply autistic PM performance is best for tasks that are highly motivating, and which are supported by focal, salient cues. Much of the cognitive effort of TBPM tasks is thus reduced by setting external prompts, or ‘intention offloading’ (Gilbert, 2015a), a practice inherent to EBPM tasks. Cognitive effort can then be further reduced...
by increasing cue salience and focality to invoke more automatic, rather than strategic, intention retrieval processes. The application of this reduced cognitive effort is then more reliably directed to the PM task by increasing the perceived PM ‘task importance’, relative to the OT, resulting in increased motivation for the PM task.

7.3 PROVIDING AN OPTIMAL PM ENVIRONMENT

When considering ways in which PM tasks can be devised/supported, the understanding that certain tasks, their particular constituents and contexts within which they are embedded can be difficult for autistic individuals, provides a good starting point. This knowledge can be used, as with current best practice for autism, to initially provide the most supportive environment to account for all possible difficulties, and then progressively tailor the support to realise individual potential.

In practical terms, practitioners can immediately begin to support PM in autistic individuals in a holistic, individual way, by offloading cognitive demand to reminders (cues) where possible, and optimising the effect of such cues by maximising salience (loud, incongruous beeps) and focality (processed with ongoing task, e.g. swimming bag by the door). The value, and instructions, of PM tasks should be conveyed, via person-appropriate communication systems, maximising motivation (and so resource allocation). Individual abilities and preferences should always be considered, perhaps best achieved by involving the individual in the process (choice of incentive, self-setting targets/rewards, choice of salient cue).

7.4 DYNAMIC SYSTEM CHARACTERISTICS OF PM

The evidence described in the thesis thus far provides useful insights into the factors important in the PM process, and the ways in which they might be optimised so as to provide an environment offering the best chances of PM success. These factors, and developed supporting strategies, were based on the way in which, according to the MPF (McDaniel & Einstein, 2000) they influence the allocation of attentional resources. However, many questions remain. Why, for instance, do autistic individuals struggle with tasks that depend more on self-initiated strategic monitoring processes? Is it simply reduced executive function capacity? Or perhaps executive function is itself intact, but the control of such attentional resources is impaired by atypical sensory processing, being, for example, continuously distracted by auditory information due to hypersensitivity? Why, and how, does symptom severity influence PM performance? What is the optimal level of salience in relation to a person’s sensory processing profile? And in what way does the subjective, perceived value of the task interact with the control and implementation of such cognitive, perceptual and action processes?

When considering such questions, one must consider the broad variation in the nature of PM tasks and the demand they put on cognitive resources (TPBM task, involving long delay and social interaction vs EBPM task involving short delay, salient focal cues and no social interaction), whilst also considering the broad variation in the individual difference of such resources, differences exemplified well by the heterogeneity of the autistic population. Prospective memory, therefore, is a complex process better seen as a network of dynamically interacting cognitive, behavioural, environmental and context specific factors. The relationships between factors will shift dynamically over time and through context changes, constrained by dynamically interacting individual differences. Figure 1a presented in the introduction can thus be developed to more accurately represent the dynamic structure of the PM process, as illustrated by Figure 1b, below.

![Dynamic System Characteristics of PM](image-url)

Such a complex, dynamic system makes PM performance very difficult to predict for any given person and/or environment, particularly with the pronounced individual difference often present in autism, thus limiting the ecological validity of the highly controlled, laboratory-based PM paradigms. The breakfast study by Altgassen, Koban, and Kliegel (2012) which involved planning and performing many tasks under social and time pressure, is perhaps the only study thus far to capture the dynamic multi-task, multi-factor nature of real-life PM processes (a process which proved very difficult for the
autistic participants). Given that the overall aim of the thesis is to provide understanding to inform the provision of optimal PM environments, and the most effective intervention strategies, it is important to look to processes that may underpin the development and application of the functions so relevant to PM. In light of this, the final section of the review considered embodied predictive coding models as fundamental to PM and autism, and examined how impairments in predictive might account for autism and the PM difficulties found in the population.

7.5 EMBODIED PREDICTIVE PROCESSING

Predictive coding is described in great detail from page 24 of Chapter 2 but, very simply, it describes the process of perception by which organisms progressively make sense of the world by continuously making predictions (top-down) about incoming (bottom-up) sensory information; prediction-errors then update and improve predictions, minimising future error. However, there is a limit to what can be predicted; some events are inherently and irredutably unpredictable (the sudden, unseen laughter of a fellow classmate, or the unseen scraping sound of a chair, for example). It is therefore important to learn to flexibly and context-sensitively vary the confidence (precision) that a prediction-error can be minimised, and thus attention worthy and should update prediction models. Thus, through optimal precision, within a developed model of a classroom, the unseen scraping sound of a moved chair would be surprising, not unexpected, would demand minimal attention and would not update the prediction model of a classroom. In this way, precision is the mechanism fundamental to learning and the development and control of executive and attentional resources (Van de Cruys et al., 2014), resources deemed by as critical to the PM process (McDaniel & Einstein, 2000).

Van de Cruys et al. (2014) situate the precision weighting mechanism as core to the development of autism. Specifically, they contend that autistic individuals uniformly and inflexibly assign high precision to prediction errors, an impairment they term High Inflexible Precision of Prediction Errors in Autism (HIPPEA). This would result in difficulty attending to relevant information, and would disrupt the progressive learning about the world, from sensory input to higher level context/conception. The authors argue that it is this process that leads to the social and communication difficulties, and the atypical sensory processing so characteristic of autism, and would indeed underpin the existing accounts of autism, such as executive dysfunction (Hill, 2004) WCC (Friston & Happé, 1994; Happé & Frith, 2006) and ToM (Baron-Cohen, 2000). We contend in Chapter 2 that this would also lead directly to the problems with PM seen in the population. Difficulties with the control of attention would make strategic monitoring of the time for TBPM tasks much more difficult; difficulty in selecting relevant cues in the environment would render EBPM cues as much less ‘salient’ relative to all other attention demanding sensory information.

Importantly, however, PM is inherently an embodied process; PM success is made possible through the effective understanding and coordination of one’s body in the service of navigating one’s environment, as it is perceived given one’s situation. The predictive coding account of PM and autism was thus extended accordingly, to include not just perception, but also movement and affect, as do predictive models formulated under active inference (Bruijne, Kiverstein, & Rietveld, 2016; Pezzulo, Rigoli, & Friston, 2015; Seth, 2013). Under such a model, perception and action work to resolve prediction-error. Thus, agents do not only try to improve predictions, but they also act on the environment to cause it to conform to predictions. Therefore, the role of prediction error minimisation, and the impact of any impairment such as HIPPEA, becomes much more significant, as it mediates all interactions between the brain, the body and the environment within and between all hierarchical levels (i.e. low-level stimulus to high level concepts/abstractions), facilitating understanding of the self and the world in which it is situated. Such an impairment would therefore explain many of the other, more embodied difficulties seen in autism, such as a high prevalence of alexithymia (Milosavljevic et al., 2016), difficulties with introspection (Shah, Hall, Catmur, & Bird, 2016), differences in rhythm and timing (Isenhower et al., 2012; Sheridan & McAuley, 1997), movement and associated social difficulties (J. Cook, 2016; J. L. Cook, Blakemore, & Press, 2013), and diminished sense of agency (Grynszpan et al., 2012; Sperduti, Pieron, Leboyer, & Zalla, 2014; Zalla, Miele, Leboyer, & Metcalfe, 2015), linked to deficits in episodic memory and episodic future thinking (Lind, 2010).

The roles that active inference and error-minimisation play in determining and attending to important and PM task-relevant, internal and environmental cues, at each level of the PM process was described as follows (and illustrated by Figure 2 below): the environment will create PM demands (work supervisor asks you to pass on important information to a work colleague), generating intentions within the individual (pass message on to colleague). This intention is internalised in terms of relative value (need to please supervisor; consequence for colleague of not receiving message; likely personal emotional state – personal, physical and social consequences of success/failure) which would interact with chances of success (beliefs about own ability to successfully execute task, given likely future context in which task/cue is situated, and predicted ability to employ appropriate action within it). These states are accompanied by physiological responses (increased heart rate, adrenaline/cortisol) and associated affective responses (arousal, worry, stress) that would need to be understood in the context of their situatedness in a socio-cultural setting. In addition, successfully realizing the PM task requires understanding how attentional resources are employed to perceive relevant cues (recalling my supervisor’s request upon seeing my colleague). Crucially then, a person performing a PM task must be selectively perturbed, via effective error-minimisation, by aspects of the environment and the self (change your behaviour when seeing your colleague, but try to not get distracted by your phone) in a way that is in line with longer-term plans and goals and the demands of the situation (such as your supervisor’s request). If one was perturbed by each and every aspect of the self and environment, as is hypothesised by HIPPEA, then selecting those aspects relevant to your PM goals would be extremely difficult, suffused as they would be in a barrage of other, non-relevant sensory information.
7.6 INTERVENTIONS/SUPPORTING STRATEGIES

Critical to supporting complex, dynamic (PM) behaviour, underpinned by embodied predictive processes impaired by HIPPEA, is the employment of holistic, embodied interventions, employed to maximally reduce uncertainty, both in the self and in the environment. Indeed, striving to reduce increase environmental predictability is a basic tenet of established and successful approaches to supporting autism, such as TEACHH (Mesibov, Shea, & Schopler, 2004) and PECS (Bondy & Frost, 1994). These approaches deem consistent, clear and visually-supported structure and communication as essential to the understanding, learning and well-being of autistic individuals. Any PM intervention should thus incorporate any and all existing systems developed under these approaches, including, for example, PM instructions supported by person-appropriate visual cues, cues which could also be used as the PM cue. Other established autism interventions involving the development of attention, such as Attention Autism (Dawson et al., 2004), would also support the attentional difficulties implied by HIPPEA, and so also related PM difficulties.

General mind-body interventions would support mind-body interactions and understanding, improving, for example, coordination, which may then support the effort of physically switching between OT and PM tasks. Support for this notion can be found in the relative success of embodied interventions in autism, such as movement (for a review, see Lee, Lambert, Wittich, Kehayia, & Park, 2016), drama (Corbett et al., 2011), music (Whipple, 2004), and art therapies (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014).

A further approach described in Chapter 2, one more specifically addressing PM, is the use of metacognitive strategies. Metacognitive strategies have been shown to benefit the learning of individuals with learning difficulties (Chevalier, Parrila, Ritchie, & Deacon, 2017) and have been found to play a role in PM; for example, metacognitive expectations of PM task demands have been shown to influence attention allocation strategies (Rummel & Meiser, 2013); and awareness of one’s cognitive capacities may encourage one’s use of reminders (Gilbert, 2015b; Phillips, Henry, & Martin, 2008). Interestingly, however, autistic participants did not set reminders to compensate for accurate judgements of their own PM abilities (Cherkaoui & Gilbert, 2017). The authors posited this was suggestive of intact meta-awareness, but impaired meta-control, in line with research pointing to difficulties with metacognitive control in autism, and to deficits in using monitoring processes to influence cognitive control (for similar results see Grainger, Williams, & Lind, 2016; Wilkinson, Best, Minshew, & Strauss, 2010; but see Wojcik, Allen, Brown, & Souchay, 2011 for contrasting findings).

Metacognitive strategies, therefore, could be employed to explicitly direct attention towards relevant information, both internal and external, important to every phase of the PM process, thus compensating for the attentional deficits implied by an embodied HIPPEA. Drawing on the principles of TEACCH (Mesibov et al., 2004), namely, to provide a highly structured, visual and predictable environment, we suggested engaging autistic individuals in a cyclical PM predict-perform-evaluate processes (see Figure 3), directing individual’s attention to important information, such as the importance of the task, likely chances of success, and the cues they predict would be most effective and salient for them.

![Figure 3](image-url)

_Schematic representation of a predict-perform-evaluate process through which individuals would be encouraged to think deeply about all self and environmentally-related aspects of a PM task, with each evaluation informing the subsequent prediction, engendering a cyclical process of continuous improvement._
Post-task evaluations would allow individuals to consider their performance, and how it matched up to predictions and cue choice, information that could be used to inform future predictions. In this way, individuals would be explicitly augmenting the largely unconscious error minimisation process (see Figure 4 for an example of how this could be implemented in a school setting).

![PM metacognition worksheet to support individuals with specific PM tasks. Metacognitive awareness and control would be developed by encouraging individuals to regularly predict and evaluate their PM performance, based on their understanding of self, PM ability, task importance, past performance, self-chosen reminders/cues, and the likely environment in which it will occur. Levels of support, formatting, could be adapted to an individual need-appropriate level, e.g., full adult support, the use of symbols in place of words.](image)

### 7.8 FUTURE RESEARCH

The examination of such metacognitive processes, examined when implemented within, say, school-based intervention studies, would provide important insights into both the practical and theoretical value of metacognition in PM, understanding that is as yet lacking with regards to autism. The currently suggested “predict-perform-evaluate” process could also provide a basis for future research in, for example, cognition training and possible transfer effects. For example, would such meta-cognitive PM training only improve PM performance on the specific task, or would it transfer to other PM tasks, or event to other meta-cognitive tasks? Indeed, could such real training improve ability in other related domains, such as executive function? Whilst there is currently a lack of research investigating the potential transfer of benefits of real-life, embodied training to closely/distantly related naturalistic and/or computer-based abilities, there is some promising evidence that training working memory in the playground, for example, can transfer to computer-based working memory tasks (Zhao, Chen, Fu, & Maes, 2015).

### 7.9 CONCLUSION

The findings from the empirical papers and systematic review presented within the current thesis suggest that autistic individuals would find the majority of PM tasks difficult. As such tasks pervade daily life, these difficulties likely contribute to the problems with independent living and employment, and associated mental health problems, so common to the population. However, the current thesis also provides evidence that good PM performance is possible, and highlights factors, such as cue salience and motivation, as key to success, providing quick and practical methods of supporting autistic individuals in achieving optimal PM performance. After viewing the PM process as a complex, dynamic interaction between individual and environmental factors, we put forward embodied predictive coding processes as fundamental to PM. As such, the disparate and primarily cognitive mechanisms (e.g., executive function and memory) commonly considered to underlie the PM process, and the understanding of self, critical to interpreting bodily signals and coordinating the body in acting to execute PM intentions, were seen as fundamentally underpinned by prediction and error-minimising processes. Our embodied predictive coding account of autism, based on that by Van de Cruys et al (Van de Cruys et al., 2014), suggests that the cognitive, motor and social differences so characteristic of autism, are in fact due to differences in prediction error weighting ability, as are, consequently, difficulties with PM. To best support PM in autism, therefore, it is best to support and understand the fundamental problems of perception and action by way of embodied, metacognitive interventions and research paradigms.
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ACKNOWLEDGEMENTS

Moving out to the Netherlands to complete a PhD has been a rewarding experience. Whilst enjoyable in many ways, it has not been easy and there is no way it could have been achieved without the help of the many patient, supportive, patient, funny, caring, intelligent, enthusiastic, generous and very patient people around me.

I would first like to thank my supervisors, Roy Kessels, Jos Egger and Mareike Altgassen. Roy, your advice has always been extremely valuable, and I have often felt motivated and enthusiastic following our discussions. Jos, I was particularly motivated by our discussion during an NRP dinner, and really appreciate you volunteering your children for participation in the research! Mareike, I feel we have achieved a lot together and you have been there as I have progressed from complete novice to published researcher.

There would never have been a chapter 3, let alone a PhD thesis, if it wasn’t for the supervision and encouragement during my Master’s thesis by Nuala Ryder and Lia Kavilashvili. I still remember, with equal measures of fondness and fear, presenting the study at my first ever conference talk at the PM conference in Naples. Hard to believe that was 4 years ago!

Saskia van Uum, I greatly valued our chats throughout my PhD, as well as (despite my well-known excellent organisational skills) your reminders and gentle prompts!

The social life at the Donders has also be important in making PhD life an enjoyable and fun place to be. So, to name but a few, thank you Xiaochen Zheng, Sybrine Bultena, Arushi Garg, Johanna de Vos, Sanne Schoenmakers, Simon Jan Hazenberg, Lukas Spieß, Thomas Wolfers, Ricarda Braukmann, Remco Bastiaannet, Natalia Shiota, Matthias Ekman.

Lisa Helena, the support of my family has been important, offering in various ways respite from academic angst, whether it was via your gracious and somewhat lively hospitality, Jamie Turner, Luke, Melissa and Henry Sheehan, Jo Davenport, Nick, Ellie, Florry and Austin Bell, Richard El Gooooooodo Gordon, Darren Jefferson.

Fenny Zwart, I feel so lucky to have had you as an office mate. There are not many others who would be able to put up with my incessant talking, my determined untidiness and, in particular, the frustration of me always being right. I’m looking forward to many more years of friendship with you and Roemer van de Meij, and much much more talking.

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Paul, Wozza, Woz Neck, WB. Thanks for your patience, encouragement, reassurance, ‘amusing’ lies, your often-uncontrollable laughter at any of my social embarrassments, trips and/or physical pain and, most of all, your friendship. Very simply, I could not have done this without you. Much love.

Ellie Townsend, we have become increasingly good friends ever since we watched the 6 Nations in the imaginatively named Irish pub, The Shamrock. I look forward to this continuing and remember, if you ever need to mine my extensive knowledge regarding physics, chemistry, salt or anything else therein, I’m always here for you.

Ruud Berkers, so many good times over the years, from hazily remembered nights in Dollars to not-quite running up a mountain in Ireland, twice. I’m honoured to have you as my paronym, and look forward to many more years of friendship, perhaps even chatting about our clinical careers together…

To my oldest and closest friends; thank you for always being there for me, whether it was to listen, laugh, or staunchly refuse to listen to anything about my work. It was important to know you were all always there when things were difficult, to help me get perspective, remember the important things in life and just how lucky I was. So, thank you Adam, Michelle, Rosie and Freya Ryan, Lester Bood Gale and Laura Heywood, Mark “T” Turner, Luke, Melissa and Henry Sheehan, Jo Davenport, Nick, Ellie, Florry and Austin Bell, Richard El Gooooooodo Gordon, Darren Jefferson.

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Sam Sheppard, thank you for keeping me grounded with your humbling, if a little caustic, sarcasm (offset by your kind enthusiasm Gabbi Thompson Menanteux). Sin, I’m so proud of you and of what you have achieved. Your strength has never ceased be a source of amazement and inspiration to me, nor will it ever. Izzy Sheppard, you are already following in your Mum's footsteps, growing bewilderingly quickly into a thoughtful and kind person. Love you all.

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And finally, I’d like to acknowledge Mum, who made me the person I am and able to achieve what I have. Wish you were still here to see me get my PhD, although this does mean I avoid the experience of you permanently changing my name to “Dan, my son who is a doctor”. Silver linings x.

To my closest and dearest friends: thank you for always being there for me, whether it was to listen, laugh, or staunchly refuse to listen to anything about my work. It was important to know you were all always there when things were difficult, to help me get perspective, remember the important things in life and just how lucky I was. So, thank you Adam, Michelle, Rosie and Freya Ryan, Lester Booc Gale and Laura Heywood, Mark “T” Turner, Luke, Melissa and Henry Sheehan, Jo Davenport, Nick, Ellie, Florry and Austin Bell, Richard El Gooooooodo Gordon, Darren Jeff.

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**Hoofdstuk 2**  
Het overkoepelende doel van het huidige proefschrift is daarom om een bijdrage te leveren aan de beperkte en inconsistentte literatuur over PG en autisme. Een beter begrip van PG in deze conditie kan tot tastbare strategieën leiden om een optimale en veilige, onafhankelijk leven te hebben. De visuele saillantie werd vergroot, alleen de autistische kinderen, die bijna allemaal sneller werden wanneer de visuele en auditieve saillantie van de cues was versterkt. Interessant genoeg bleek dat terwijl beide groepen sneller werden wanneer de visuele saillantie werd vergroot, alleen de autistische kinderen, di bahia almal scores van atypische sensorische reactiviteit behaalde op de Short Sensory Profile (SSP), ook sneller waren wanneer de auditieve saillantie van de cues was verhoogd. Bovendien wordt verondersteld dat veel van deze cognitieve en sociale functies ten gronde liggen aan PG, en daarmee wijzen op een PG probleem in autisme, wat weer overkoepelend doel van het huidige proefschrift is daarom om een bijdrage te leveren aan de beperkte en inconsistentte literatuur over PG en autisme. Een beter begrip van PG in deze conditie kan tot tastbare strategieën leiden om een optimale en veilige, onafhankelijk leven.
De systematische review van alle PG-en autismeliteratuur, inclusief de artikelen uit het huidige proefschrift, gepresenteerd in Hoofdstuk 2 toonde aan dat, ondanks aanzienlijke methodologische heterogeniteit tussen studies, de PG-prestatie bij autisme over het algemeen in lijn was met wat zou worden voorspeld, gegeven de bekende problemen met PG-relevante cognitieve functies, zoals aandacht, EF, geheugen en toekomst denken en ToM en de variërende cognitieve eis van PG; dat wil zeggen, de taken die een hoge mate van executieve controle en strategische verwerking vereisen, zoals TBPG-taken, of GBPG-taken die bijvoorbeeld laag saillante cues of moeilijke aandacht vraagende OTs hadden, slechter prestatie lieten zien; wanneer deze condities werden veranderd met hoog saillante cues en makkelijke OTs, bleek de autisme-prestatie vergelijkbaar aan niet-autistische controles. Deze bevindingen zijn in lijn met een recente meta-analyse van dezelfde studies.

De bevindingen verkregen uit de artikelen van het huidige proefschrift laten zien onder welke condities PG waarschijnlijk moeilijk is voor autistische individuen en bieden suggesties om taken aan te passen en succes te faciliteren. Echter, in de zoektocht naar een meer fundamenteel proces, beschreef het huidige proefschrift PG en autisme door de lens van 'predictive coding'. Het PG proces en de cognitieve functies waarvan wordt verondersteld dat deze hieraan ten grondslag liggen, werd beschreven als ontstaan vanuit een effectief predictive coding mechanisme, een mechanisme waarvan wordt gedacht dat het aangetast is in autisme. Deze predictive coding benadering van autisme werd vervolgens uitgebreid onder ingebedde predictive coding modellen om de gedragsmatige, cognitieve en bewegingskenmerken van autisme verder te begrijpen.
CURRICULUM VITAE

Daniel Patrick Sheppard was born in Clapham, London, on August 2nd 1979. In 2003, having graduated with honours with a Bachelor of Arts (BA) in Business Administration at Brighton University, he secured a position as a sales analyst at a multinational organisation. In 2005, following his drive to try and contribute in a more meaningful way to society, and to have a positive influence on young people’s lives, he switched careers and began teacher training. He gained qualified teacher status in 2006, and that year began teaching his first class of 32 9- and 10-year-olds. In 2009, Daniel secured a position in a school for children with severe learning difficulties.

After two years, his desire to understand, and thus better support, behaviour at a deeper, more psychological level led to his desire to become a clinical psychologist. Accordingly, he completed a Master of Science in Psychology (MSc) from the University of Hertfordshire, graduating with Distinction. After an unsuccessful attempt at joining the Doctorate of Clinical Psychology in 2013, Daniel gained a split-position of teacher/assistant psychologist at a school for severely autistic children. Then, in 2014, he was fortunate to be presented with an opportunity to begin a PhD at the Donders Institute for Brain, Cognition and Behaviour at Radboud University Nijmegen, during which he could continue the work he began with his Master’s thesis on prospective memory in autism. The next step is to continue with the clinical aspirations, and train as a clinical psychologist, ultimately by gaining a place on the Doctorate of Clinical Psychology in the UK.
PUBLICATIONS


CONFERENCE PRESENTATIONS


DONDERS GRADUATE SCHOOL FOR COGNITIVE NEUROSCIENCE

For a successful research Institute, it is vital to train the next generation of young scientists. To achieve this goal, the Donders Institute for Brain, Cognition and Behaviour established the Donders Graduate School for Cognitive Neuroscience (DGCN), which was officially recognised as a national graduate school in 2009. The Graduate School covers training at both Master’s and PhD level and provides an excellent educational context fully aligned with the research programme of the Donders Institute.

The school successfully attracts highly talented national and international students in biology, physics, psycholinguistics, psychology, behavioral science, medicine and related disciplines. Selective admission and assessment centers guarantee the enrolment of the best and most motivated students.

The DGCN tracks the career of PhD graduates carefully. More than 50% of PhD alumni show a continuation in academia with postdoc positions at top institutes worldwide, e.g. Stanford University, University of Oxford, University of Cambridge, UCL London, MPI Leipzig, Hanyang University in South Korea, NTNU Norway, University of Illinois, North Western University, Northeastern University in Boston, ETH Zürich, University of Vienna etc.. Positions outside academia spread among the following sectors: specialists in a medical environment, mainly in genetics, geriatrics, psychiatry and neurology. Specialists in a psychological environment, e.g. as specialist in neuropsychology, psychological diagnostics or therapy. Positions in higher education as coordinators or lecturers. A smaller percentage enters business as research consultants, analysts or head of research and development. Fewer graduates stay in a research environment as lab coordinators, technical support or policy advisors. Upcoming possibilities are positions in the IT sector and management position in pharmaceutical industry. In general, the PhDs graduates almost invariably continue with high-quality positions that play an important role in our knowledge economy.

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