Do importance instructions improve time-based prospective remembering in autism spectrum conditions?

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A B S T R A C T

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 social 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 social importance manipulations, whereas the opposite pattern was predicted for controls. 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, social and personal reward. Participants worked on a 2-back picture-based ongoing task in which a time-based PM task was embedded. A mixed 2 (Group) x 3 (Motivation condition) analysis of covariance with age, verbal and non-verbal abilities as covariates and correct PM responses as dependent variable indicated solely a main effect of group, with controls outperforming the autism group. In contrast to our expectations, there was no main effect of condition, no significant interaction, and none of the covariates had any significant impact. However, further planned analyses revealed that controls only outperformed autistic individuals in the personal reward condition. Controls performed significantly best when a personal reward was promised, whereas there were no significant differences between the motivation conditions for autistic individuals. Findings are discussed in terms of underlying processes.

What this paper adds?

This paper is the first to investigate the potential differential impact of different types of rewards (social, monetary, none) on autistic individuals' prospective memory performance. Surprisingly, neither the Social nor the Personal (monetary) motivation condition positively affected autistic individuals' performance as compared to the Standard (no reward) condition. In contrast, controls performed better when a monetary reward was promised. Future studies should investigate whether autistic individuals may benefit more from tailored, personalized rewards.

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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, 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 and frequent PM failures can lead to negative social, occupational or health-related consequences (Kliegel, Jäger, Altgassen, & Shum, 2008). The critical nature of such PM tasks is, therefore, particularly profound for populations that experience difficulties with safe and independent living, such as those with mild cognitive impairment (Kinsella, Pike, Cavuoto, & Lee, 2018; Pereira, Altgassen, Atchison, de Mendonca, & Ellis, 2018), traumatic brain injury (Raskin & Sohlberg, 2009; Raskin, Williams, & Aiken, 2018; Thöne-Otto & Walther, 2008) and, pertinently for the current paper, autism spectrum conditions (ASC, Sheppard, Bruineberg, Kretschmer-Trendowicz, & Altgassen, 2018). Better understanding of PM ability in such populations could thus lead to the development of more effective interventions and make a positive impact on their everyday life, increase their level of independence and reduce the (potential) burden for caregivers (Kliegel et al., 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, Kretschmer, Knispel, Vollert, & Altgassen, 2015) or by varying task-attractiveness (e.g., having to remember to tell the caretaker to get candy versus the laundry, Causey & Bjorklund, 2014; Somerville, Wellman, & Cultice, 1983) 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, whereas 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 et al. (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 similiar results, see Cicogna & Nigro, 1998). Altgassen, Kliegel et al. (2010), Altgassen, Schmitz-Hubsch, and Kliegel (2010) compared younger and older adults' PM performance in a time-based PM task. Half of the participants were given standard PM instructions, whereas, 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 rewards (at least for some populations).

Conceptually, research differentiates between intrinsic and extrinsic motivation (Deci & Ryan, 1985). Intrinsic motivation means that the performed task itself is inherently motivating, whereas extrinsic motivation refers to performing a task for a means-end. Walter and Meier (2014) postulate that providing a social motive will rather increase intrinsic motivation, in contrast, offering a (monetary) reward will enhance extrinsic motivation. Furthermore, they propose a direct link between the type of motivation and possible changes in attention allocation. Specifically, they suggest that changes in attention allocation, that may be reflected as costs to the ongoing task, will only occur if participants are extrinsically motivated (e.g. studies providing a reward or a relative importance instruction, Kliegel et al., 2004; Smith & Bayen, 2004). Intrinsic motivation, on the other hand, they expect to strengthen the representation of the PM task, to enable automatic retrieval of the delayed intention and to not to lead to any ongoing task costs (Penningroth & Scott, 2007; Slusarczyk & Niedzwienska, 2013).

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 an 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, & Karmiloff-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 (see Sheppard et al., 2018 for a review). 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, Koban, & Kliegel, 2012; Virtual Week, Henry et al., 2014; Kretschmer, Altgassen, Rendell, & Bölte, 2014). In line with the well-documented deficits in executive control functions in autistic individuals[2] (Hill, 2004; Sanders, Johnson, Garavan, Gill, & Gallagher, 2008), reduced PM performance has been most consistently found in time-based tasks (Altgassen, Williams, Bölte, & Kliegel, 2009, 2012; Kretschmer et al., 2014; Williams, Boucher, Lind, & Jarrold, 2013), whereas results for event-based tasks are somewhat mixed and seem to depend on the specific task characteristics and demands (Altgassen, Schmitz-Hubsch et al., 2010; Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Yi et al., 2014; see Smith-Spark, 2018; Talbot, Muller, & Kerns, 2018, for reviews showing similar patterns of performance in other developmental disorders, such as dyslexia or Attention Deficit Hyperactivity Disorder). 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 elapsing 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 extrinsic 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

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[2] We have used identity-first, rather than person-first, language throughout the paper in line with the preferences of the autism community (Gernsbacher, 2017; Kenny et al., 2016).

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 Ferrante's studies (2008), Brandimonte et al.'s studies (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.

2. Method

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 cognitive 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 non-verbal IQ, but not for verbal IQ (here, the autistic group scored higher than controls). Conditions were parallel for gender and verbal ability, but not for age and non-verbal ability; on average, participants of the Personal motivation condition were older and showed a higher non-verbal ability than those of the other two conditions. As expected, autistic participants showed significantly higher levels of autistic traits than controls on the Dutch version of the Social Responsiveness Scale (SRS, Roeyers & Thys, 2010).

Autistic participants were recruited from a Dutch school for special education and from Dutch clinics for autistic children and their families. All autistic participants had received a formal diagnosis of Autistic Disorder (20), Asperger syndrome (18) or PDD-NOS (23) by local health service professionals following DSM-IV-TR criteria (APA, 2000). All autistic participants were high-functioning (IQ > 85). Non-autistic participants were recruited from Dutch mainstream schools. Verbal ability was assessed with the Vocabulary subtest of the Dutch version of the Wechsler Intelligence Scale for Children (WISC-III, Kort et al., 2005), or for those over the age of 16, the vocabulary subtest of the Wechsler Adult Intelligence Scale (WAIS-IV-NL, Wechsler, 2012). Results are reported in age-normed scaled scores ($M = 10$, $SD = 3$; range 1–19; Table 1). As a measurement of non-verbal ability, the Matrices subtest of the Wechsler Non-Verbal Scale of Ability (WNV, Wechsler & Naglieri, 2008) was conducted. Results are reported in age-normed T-Scores ($M = 50$, $SD = 10$; range 20–80; Table 1). All adolescents, and their parents, provided written informed consent. The study was approved by the Ethics Committee Faculty of Social Sciences, Radboud University, Nijmegen, and the study was conducted in line with the Helsinki declaration.

2.2. Materials and procedure

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 & Pourtois, 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 1500 ms, with a 1000 ms interstimulus interval. The task was first explained via a paper version, in which participants demonstrated understanding by correctly indicating whether the last picture in the list occurred two pictures ago, or not. This was followed by a 10-trial practice block on the computer during which the experimenter checked the correctness of responses. All participants demonstrated sufficient understanding at this stage (maximum of 2 mistakes), 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 1500 ms. 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, Kliegel et al.'s study (2010), Altgassen, Schmitz-Hubsch 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 min, and so it would help the experimenter greatly if the

Table 1
Individual differences across groups' and motivation conditions.

	Standard Condition		Social motivation		Personal Reward		group F(df)	condition F(df)	interaction F(df)
	ASD N = 21 M (SD)	Controls N = 19 M (SD)	ASD N = 19 M (SD)	Controls N = 21 M (SD)	ASD N = 21 M (SD)	Controls N = 21 M (SD)			
age	15.7 (1.0) range 14-18	15.7 (1.1) range 14-17	15.9 (1.1) range 14-18	15.9 (1.0) range 14-17	16.9 (1.7) range 14-19	16.0 (1.1) range 14-18	2.33(1,116)	4.2 (2,116)*	1.8(2,116)
gender	21m	19m	16 m, 3f	21m	20 m, 1f	21m			
SRS	64.95 (11.9) N = 20	43.8 (7.1) N = 16	58.6 (13.6) N = 17	42.18 (3.9) N = 11	69.5 (14.6) N = 16	45.29 (7.5) N = 17	84.67 (1,91)***	3.1 (2,91)	< 1
verbal ability	12.2 (2.2)	10.7 (2.4)	14.2 (2.0)	10.9 (2.0)	12.9 (2.6)	11.6 (2.0)	24.5 (1,116)***	2.3(2,116)	2.8(2,116)
non-verbal ability	57.8 (6.8)	56.4 (9.1)	56.5 (9.3)	58.5 (8.9)	62.4 (6.6)	60.5 (7.6)	< 1	3.7(2,116)*	< 1

Note.
* $p < .05$.
*** $p < .001$.

participant could press the pink key every minute. For the *personal 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 min filled delay, during which participants completed the vocabulary sub-test (Kort et al., 2005; Wechsler, 2012). Previous research (Brandimonte et al., 1996; Ellis & Kvavilashvili, 2000) has shown that a delay between giving the PM instructions and the actual PM task as well as a ratio of relatively few prospective items to ongoing task items are necessary to make sure that the prospective intention is not continually maintained in working memory and to induce sufficient prospective of forgetting. 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,. ± 2 s around the target times: 1, 2, 3, 4, 5, 6 min, cf. a similar approach Kliegel et al., 2005; Zinke et al., 2010) and mean distance to target PM times (temporal PM accuracy). Time monitoring (number of white button presses) was also measured (total number; mean monitoring behavior collapsed across the four 15 s-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 subtest of the WNV (Wechsler & Naglieri, 2008). All received €5 for taking part in the study, regardless of condition or actual performance.

3. Results

3.1. Correct PM responses

A 2 (group) x 3 (motivation condition) analysis of covariance (ANCOVA) with age, verbal and non-verbal abilities as covariates was conducted to compare correct PM responses across groups and conditions (Table 2). There was a significant main effect of group ($F(1,112) = 6.1$, $p = .015$, $\eta_p^2 = .05$), whereas, the main effect of condition ($F(2,112) = 2.5$, $p = .09$, $\eta_p^2 = .04$), and the interaction were not significant ($F(2,112) = 2.37$, $p = .09$, $\eta_p^2 = .04$). All three covariates had no significant impact (all Fs < 1.3). Overall, the autism 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 motivation conditions ($M = 4.08$, $SD = 1.98$), although the performance of the latter two conditions was no different. Planned comparisons revealed that controls only outperformed the autism group in the Personal condition ($F(1,112) = 9.3$, $p = .003$, eta = .08), which drove the group effect (standard $F(1,112) = 2.78$, $p = .10$, eta = .02; social motivation $F < .01$, $p = .96$, eta = .000). Furthermore, whilst the performance of the autism group did not differ between conditions (all $p > .23$), controls performed significantly better in the Personal condition, compared to both the Standard ($p = .03$) and Social conditions ($p = .005$), whilst performance in the latter two conditions was the same ($p = .59$) (Fig. 1).

We then conducted a 2 (group) x 3 (motivation condition) ANCOVA with PM temporal accuracy (i.e. mean distance to target times) as dependent variable and with age, verbal and non-verbal abilities as covariates (Table 2). There was a significant main effect for condition with overall participants showing more timely responses in the Personal condition, followed by the Social and then the Standard condition ($F(2,102) = 3.81$, $p = .03$, $\eta_p^2 = .07$). No significant effects emerged for group or for the group by condition interaction (both $Fs < 1.3$). All three covariates had no significant impact (all $Fs < .84$).

3.2. Time monitoring

A mixed 2 (group) x 3 (motivation condition) x 4 (interval) ANCOVA, with repeated measures on the last factor, was carried out with time monitoring as dependent variable and with age, verbal and non-verbal abilities as covariates (Table 3). There were no significant main effects (interval $F < 1$, group $F < .06$, condition $F(2,112) = 2.54$, $p = .11$, $\eta_p^2 = .02$. There was, however, a significant interval by group interaction, $F(3,336) = 3.56$, $p = .01$, $\eta_p^2 = .03$. All other interactions were not significant (all $Fs < 1.2$;

Table 2
Prospective memory and ongoing task performance.

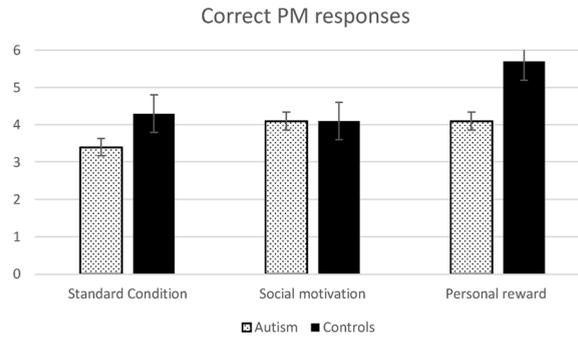|	Standard Condition		Social motivation		Personal Reward	
	ASD	Controls	ASD	Controls	ASD	Controls
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
correct PM responses	3.4 (2.1)	4.3 (1.7)	4.1 (1.9)	4.1 (2.0)	4.1 (1.8)	5.7 (.6)
PM temporal accuracy	672 (297)	741 (.516)	739 (357)	558 (372)	50 (.215)	436 (199)
single-task OT accuracy	92.6 (7.7)	86.7 (14.7)	94.0 (5.8)	94.6 (6.2)	91.6 (12.5)	96.5 (6.2)
dual-task OT accuracy	92.8 (5.5)	90.4 (7.5)	94.0 (4.1)	91.9 (5.8)	91.7 (8.2)	91.4 (8.4)
single-task OT response times	727 (153)	807 (168)	727 (132)	812 (157)	753 (178)	770 (162)
dual-task OT response times	819 (95)	821 (90)	771 (107)	823 (93)	737 (88)	811 (94)

Note. OT refers to ongoing task.

Fig. 1. Prospective Memory Performance.

Table 3
Correlations of correct PM responses.

		Standard Condition	Social motivation	Personal Reward
clock checks interval 4	ASD	.71***	.79***	.48*
	Controls	.73***	.46*	.27
single-task OT accuracy	ASD	.17	−.39	−.09
	Controls	.05	−.14	−.01
single-task OT RT	ASD	.41	.11	.12
	Controls	−.20	.24	−.34
dual-task OT accuracy	ASD	.09	.05	.03
	Controls	.04	−.09	.62**
dual-task OT RT	ASD	−.05	.21	.22
	Controls	.00	.11	−.51*
age	ASD	−.51*	.36	−.16
	Controls	.36	.31	.32
verbal ability	ASD	−.04	.20	.04
	Controls	.02	.05	−.10
non-verbal ability	ASD	−.18	.09	.15
	Controls	.14	.36	.03

Note.
 * $p < .05$.
 ** $p < .01$.
 *** $p < .001$; OT refers to ongoing task.

except for the interval by condition interaction $F(6,336) = 1.86$, $p = .09$, $\eta_p^2 = .03$). All three covariates had no significant impact (verbal ability $F(1,112) = 2.54$, $p = .11$, $\eta_p^2 = .02$; non-verbal ability $F(1,112) = 2.38$, $p = .13$, $\eta_p^2 = .02$; age $F < .06$) (Fig. 2).

Further analysis of the significant group by interval interaction revealed that, overall, both groups increased the average number of clock checks each 15 s interval as the target time approached; with clocks checks in each interval being significantly higher than the previous interval (autism group $F(3,110) = 17.73$, $p < .001$, $\eta_p^2 = .33$; controls $F(3, 110) = 46.25$, $p < .001$, $\eta_p^2 = 56$). Moreover, whilst clock checks in the first two intervals were the same for both groups (both $Fs < .85$), controls tended to check the time more frequently in the third interval ($F(1, 112) = 2.74$, $p > .10$, $\eta_p^2 = .024$) and did so significantly more often than the autism group in the 4th interval ($F(1, 112) = 4.01$, $p = .048$, $\eta_p^2 = .04$).

3.3. Ongoing task

A mixed 2 (group) x 3 (motivation condition) x 2 (task block) ANCOVA, with repeated measures on the last factor and proportion of correct ongoing task responses as dependent variable and age, verbal and non-verbal abilities as covariates was conducted (Table 2). There were no main effects of group ($F < .51$), condition ($F(2,107) = 2.15$, $p = .12$, $\eta_p^2 = .039$) or task block ($F < 1.64$), and no significant interactions (block by group $F < .25$; block by condition $F(2,107) = 2.53$, $p = .08$, $\eta_p^2 = .05$; group by condition F $(2,107) = 2.63$, $p = .08$, $\eta_p^2 = .05$; block by group by condition $F(2,107) = 1.74$, $p = .18$, $\eta_p^2 = .031$). All three covariates had no significant impact (all $Fs < 1.39$, all $ps > .24$, all $\eta_p^2 < .01$). Thus, both groups performed similarly, achieving a similar proportion of correct non-N-back responses (autism: $M = 92.80$, $SD = 6.68$; 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: $M = 93.64$, $SD = 4.58$; personal: $M = 92.79$, $SD = 7.40$) 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) ANCOVA with age, verbal
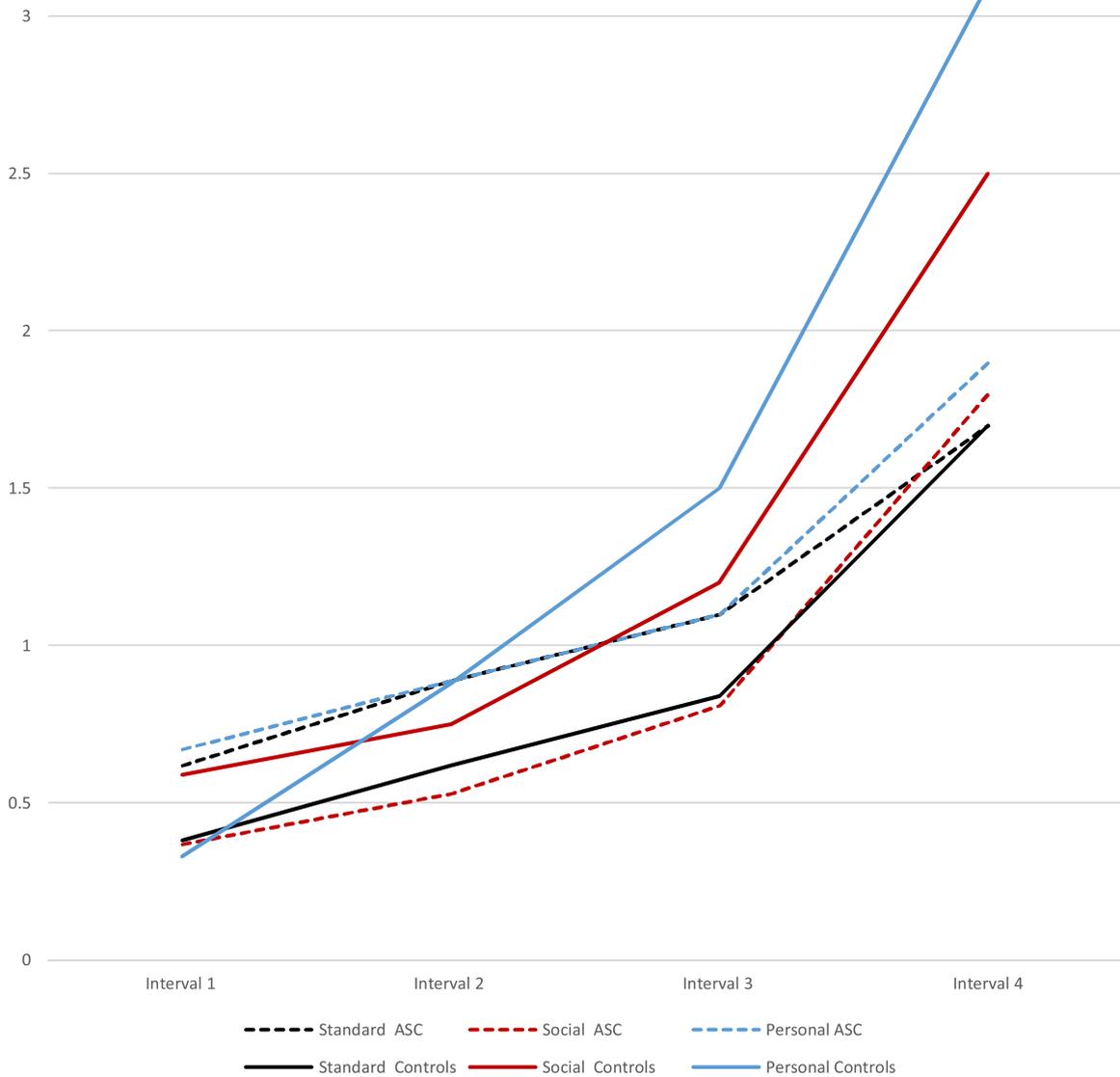
Fig. 2. Time monitoring across the four intervals.
Note: ASC = Autism Spectrum Condition.

and non-verbal abilities as covariates indicated a significant main effect of group ($F(1,107) = 4.23$, $p = .04$, $\eta_p^2 = .04$), and task block ($F(1,107) = 4.21$, $p = .04$, $\eta_p^2 = .04$), but no effect of condition ($F < .09$). There was one significant interaction of block by group by condition $F(2,107) = 3.21$, $p = .04$, $\eta_p^2 = .06$; all other interactions were not significant ($Fs < 1.32$). Thus, the autism 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. Age was a significant covariate ($F(1, 107) = 10.99$, $p = .001$, $\eta_p^2 = .09$); while all other covariates had no significant impact (all $Fs < .55$).

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 individuals with autism 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 autism group. In contrast, for controls no significant

correlation between PM performance and clock checks was observed in the Personal condition, whereas 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.

Due to an unequal availability of SRS forms across motivation conditions (see Table 1), we correlated PM hits separately for both diagnostic groups (but across motivation conditions) with the SRS total score and the SRS subscores (social awareness, social cognition, social communication, social motivation, restricted interests and repetitive behaviour). Only for the autism group and only between PM hits and the subscales social motivation ($r = .28$, $p = .044$) and restricted interests and repetitive behaviours ($r = .27$, $p = .047$) significant correlations emerged. There were no other significant correlations for either group (all $rs < .18$).

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 only the potential mismatch of task demands and individual cognitive resources; social-cognitive skills must also be taken into account, given their role in perceiving and assessing social motives when exploring social importance effects.

At a first glance, as expected, controls outperformed autistic individuals in the time-based PM task (Altgassen et al., 2009, 2012; 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 motivation condition (in which controls performed best), whereas group effects tended towards significance in the standard condition and were non-existent in the social motivation condition. The fact that the group effect only tended towards significance in the standard condition was somewhat surprising given that all previous studies using time-based PM tasks did report a PM deficit in autism (cf. a review, Sheppard et al., 2018). This spared performance could be due to the ongoing task being too easy (given the high performance scores of both groups; above 90% correct responses) and, thus, leaving sufficient cognitive resources to simultaneously perform the PM task (Kliegel et al., 2011). In terms of supporting autistic individuals' PM performance in everyday life, it may be important to consider what ongoing tasks are likely to be when the PM intention needs to be executed. Importantly, there were also no significant differences between diagnostic groups in terms of PM temporal accuracy; both groups were comparably close to the target times in their PM responses. Hence, findings of the present study do not point towards temporal processing difficulties.

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, there was only a trend towards a significant main effect of condition when considering the number of correct PM responses. This trend was (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. Similarly, when regarding PM temporal accuracy, there was a significant main effect for condition with overall participants showing more timely responses in the Personal condition, followed by the Social and then the Standard condition. These findings contrast with Brandimonte and Ferrante's (2008), Brandimonte et al.'s (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 motivation 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, whereas controls performed significantly best in the Personal motivation condition, compared to both the Standard and Social motivation conditions. It is somewhat surprising that autistic individuals seemed to not be affected by importance manipulations. Possibly, the importance manipulation was too subtle or indirect for the autistic participants. For both the Social and the Personal motivation condition, the higher importance of the PM task, relative to the ongoing task, had to be inferred (e.g., help the experimenter or receive 5 EUR) with no explicit statement emphasising that the PM task was more important and should be focussed upon. This is contrast to the study by Sheppard et al. (2016) in which the value of the reward, a colourful toy spring, was explicit and clear, and which yielded comparable PM performance in even severely autistic children. 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 (Happé, 1993; Happe, 1995; 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. Furthermore, it is possible that both the Social and the Personal motivation condition were simply not more important to autistic individuals than the Standard condition. In fact, there is some evidence for altered neural reward processing in autism. Kohls et al. (2013) compared brain activations during a Go/NoGo task offering either neutral, social or monetary rewards. In the monetary reward condition participants were promised money for correct responses, while in the social

condition a picture of a person with a positive facial expression was presented for correct responses and the picture of a neutral facial expression upon errors. Findings suggested that the reward circuitry in the brain is affected in autism for both social and monetary rewards. Kohls and colleagues concluded that this aberrant brain reactivity with regards to social and monetary rewards may point towards a general reward dysfunction and may underlie the atypical motivated behavior in autism (e.g., preference for autism-specific objects instead of environmental rewards). Future studies should investigate whether autistic individuals may benefit more from tailored autism-specific rewards that are of high value to them (e.g., receiving an item related to a special interest or a reward that they chose themselves prior to performing the task instead of a monetary reward). Moreover, future studies should include an objective measurement of participants' theory of mind abilities to assess their impact on social importance manipulations.

While our findings on controls' performance contrast with Brandimonte and Ferrante's (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. A further possibility is that importance manipulations are sensitive to methodological differences, such as differences in the phrasing of the social motivation condition and the promised reward. While the current study (similarly to Altgassen, Kliegel et al., 2010) introduced the PM task in the social motivation 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 <u>not</u> 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. It is possible that Brandimonte and colleagues' PM task may have 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 min, 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, whereas this may have been less clear for the adolescents of the present study that all still attended school. Similarly, the prospect of receiving 5 EUR may have been very appealing and thus highly motivating for adolescents, whereas 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 <u>not</u> 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, Kliegel et al.'s (2010), Altgassen, Schmitz-Hubsch 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, Loomis, & 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. Generalisability of results may also be limited by the fact that many of the participants with ASC were recruited from one school which may have introduced clustering effects.

Another potential caveat is that the planned comparisons of groups' PM performance across conditions were conducted on a non-significant group by motivation interaction. The finding that diagnostic groups differ in one condition (the personal reward condition), but not in the other two conditions (the standard and social importance condition) does not necessarily mean that the difference between the two groups was significantly greater in the personal reward condition as compared to the other conditions (Gelman & Stern, 2006).

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. As indicated before, overall, ongoing task performance was very high ($> 90\%$) which may indicate that the task was rather easy for participants; thus, leaving sufficient cognitive resources to simultaneously work on the PM task. This may have prevented the occurrence of importance effects given that strategic factors may only become relevant when cognitive load is high (McDaniel & Einstein, 2000). Importantly though, interpretation is limited given that due to experimenter error only non-target responses of the nback task (thus, commission errors) could be considered. Meule (2017) states that commission errors may not be related to omission errors (missed n-back targets) as omission errors occur more frequently than commission errors

in n-back tasks. However, the n-back performance of our autism group does not seem to differ from previous studies (taking overall nback performance, thus, percentage of correct responses to n-back targets and non-N-back targets, into account). For the baseline and dual-task condition, the autism group showed an accuracy of 89% and 87%, respectively. This level of performance is comparable to that of previous studies also using a 2-back task (de Vries & Geurts, 2014; Rahko et al., 2016) and reporting no significant performance differences between the autism and control group. Therefore, both groups may have well been matched on the ongoing task.

With regards to response times, surprisingly, autistic individuals responded faster to ongoing task items than controls which may further support the assumption that the task was rather easy for them. 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. Importantly, the only significant correlation 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. These findings may partly be in line with Walter and Meier's postulation of additional allocation of resources when people are extrinsically motivated (e.g., trying to get a reward), but no changes in resource allocation and thus no ongoing task costs when people are intrinsically (e.g., socially) motivated due to a then stronger representation of the intention (cf. similar results, Altgassen, Kliegel et al., 2010; Altgassen et al., 2007).

With regards to time monitoring behaviour, overall, participants increased the average number of clock checks each 15 s 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 autistic participants in the 4th interval. This may indicate less strategic monitoring behaviour in the autism 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 motivation 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, possibly this missing correlation is due to controls performing at ceiling in the Personal rewards condition which may have confounded results.

Furthermore, this observation is in line with previous research (Altgassen, Kliegel 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 similiar 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).

Although conclusions regarding time-based PM, motivation and autism can only be tentative at this point, the results still contribute to better understanding PM in autism, and the context/task-specific PM characteristics that may facilitate optimal performance. In line with all published evidence on time-based PM in autism, this study replicated reduced PM performance in autistic individuals (Landsiedel, Williams, & Abbot-Smith, 2017; Sheppard et al., 2018). However, further analyses indicated that groups actually only differed in the 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. Possibly, the autistic participants were simply not motivated by either the social or personal reward and given benefits of motivation seen in the Sheppard et al. (2016) study, it is important to ensure incentives offered for good PM in everyday life represent high value for participants. Critically, controls' improvement in the Personal motivation 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 s 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.

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