Associations between Performance-based and Self-reported Prospective Memory, Impulsivity and Encoding Support

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Abstract

Prospective memory (PM) is the ability to execute future intended actions and may be negatively affected by impulsivity. The current study aimed to address questions on (1) relationships of PM with facets of impulsivity; (2) psychometric properties of a PM task, in particular convergent validity with self-reported PM; and (3) whether external support of the encoding process would improve PM or affect relationships with impulsivity. 245 participants performed the experiment online. Participants completed either a baseline version of the task, which combined blocks of an ongoing working memory task with PM trials involving a varying stimulus requiring an alternative response; or a version that provided external support of encoding by requesting that participants visualize and execute the intended prospective action before each block. The Prospective-Retrospective Memory Questionnaire (PRMQ) and Short Version of the UPPS-P Impulsive Behavior Scale (SUPPS) were used to assess self-reported prospective memory and facets of impulsivity. Reliability of PM performance was good and remained acceptable even with the exclusion of participants with low scores. PM performance was associated with self-reported PM, explaining variance in addition to that explained by working memory performance. PM performance was also negatively associated with impulsivity, in particular sensation seeking and positive urgency, but only in the baseline task. Support did not cause overall improvements in performance. In conclusion, results provided further evidence for a relationship between facets of impulsivity and PM. PM as assessed via the current task has good psychometric properties.

Keywords: Prospective memory; reliability; impulsivity; working memory; enactment

1. Introduction

Prospective memory (PM) is the ability to remember to execute an intended action in the future (Martin et al., 2003; McDaniel & Einstein, 2000; Meacham & Leiman, 1982). For instance, an individual might need to remember to buy milk on the way home; to convey a message when they see a certain person; or to take medication every day at five o'clock. The ability to perform such tasks correctly is essential for daily functioning (Beaver & Schmitter-Edgecombe, 2017; Pirogovsky et al., 2012; Schmitter-Edgecombe et al., 2009) and its decline is closely related to dementia and cognitive decline (Costa et al., 2011; Crawford et al., 2003; Van den Berg et al., 2012), making it important to better understand and measure this complex function (Mariani et al., 2007; Mauri et al., 2012) and its relationships to individual differences.

PM is a complex function with multiple components as described in the multiprocess framework (McDaniel & Einstein, 2000). These components include the ability to encode the memory of the intended future action and conditions, the maintenance of the intention over time and in the face of distraction, sustained attention to monitor for the time or event requiring the action, recall of the mapping from condition to action, and execution of the action in the possible context of other ongoing tasks (Einstein et al., 2000; McDaniel & Einstein, 2000; Zhou et al., 2012). The multiprocess framework includes both reflective and impulsive processes (McDaniel & Einstein, 2000); reflective processes in this context have also been termed strategic or executive functions, which appear to play an essential role in PM (Mahy & Moses, 2011; Martin et al., 2003). The basic binary distinction between these types of constituent processes builds on dual process models (Deutsch & Strack, 2006; Schneider & Chein, 2003; Schneider & Shiffrin, 1977) which have been strongly criticized on theoretical grounds (Keren, 2013; Keren & Schul, 2009). For instance, as more extensively discussed elsewhere, evidence taken for the existence of dual systems may simply reflect versions of the "Not-the-Liver" fallacy (Bedford, 1997), in which the distinction between any given process of interest versus any and all other processes is taken to reflect two fundamentally distinct or even opposed cognitive or neural systems (Keren & Schul, 2009; Pfeifer & Allen, 2012); emotional and motivational processes cannot be fully separated from executive functions, as this would create a motivational homunculus that decides when to use executive functions for the benefit of the individual (Gladwin & Figner, 2014); and the sets of features typically assigned to reflective versus impulsive processes do not appear to be consistently separated empirically (Bargh, 1994; Moors & De Houwer, 2006). However, it has been argued that such criticism, while valuable, is not fatal to the idea of dual processes, but reflectivity may need to be more flexibly understood. E.g., in the Reprocessing/Reentrance and Reinforcement model of Reflectivity, or R3 model, a continuum from reflective to automatic processing is defined in terms of the amount of time and information processing resources dedicated to the selection of (cognitive) actions (Gladwin et al., 2011; Gladwin & Figner, 2014). Fast responses will tend to be driven by easily accessible associations and fast computations, used to execute responses in those types of situations in which responding too slow has been learned to be unacceptable; while slow responses allow more complex, re-entrant or iterative processing (Cunningham et al., 2007; Edelman & Gally, 2013) at the cost of slower response times, when allowing time for considered responses has been learned to be optimal. In the context of PM, fast stimulus-driven responses will likely, at least under some conditions, not be the intended future action - otherwise, no PM would even be necessary. Thus, a range of theoretical perspectives would appear to agree that some reflectivity (or strategic process, or executive function) is necessary for good PM performance to the extent that performance of a given task truly taxes PM, That is, if task features effectively remove or reduce the role of a maintained intention, e.g., because a stimulus-response association has been automatized, then it could be questioned whether that task requires PM specifically. (Please note that this argument does not contradict the involvement of both strategic and automatic processes as per the multiprocess framework in task performance or in a naturalistic setting; many factors beyond reflective intentional processes could underlie PM-task performance, such as practical strategies.) From this perspective, it would therefore be expected that more impulsive individuals would show weaker PM performance. Relationships between PM and various facets of impulsivity have indeed previously been shown (Cuttler et al., 2014, 2016), but this was not the case in all studies or for all measures (Chang & Carlson, 2014; Uttl et al., 2018). Further evidence on this potentially important relationship between PM and impulsivity is thus needed, one way to do so being the use of tasks that reduce the ability to automatize.

However, studies of any relationships involving individual differences in PM hinge on the ability to measure it with adequate reliability and validity. This has particular clinical relevance for cognitive decline and dementia, as it is an early marker of future progression of deficits (Costa et al., 2011; Dermody et al., 2015; Hsu et al., 2014; Mariani et al., 2007; Mauri et al., 2012; Petersen et al., 1999). However, there are issues concerning the assessment of PM. First, although there are measures that have undergone validation studies and have been shown to be distinct from some unrelated concepts, measures of PM considered valid remain correlated with other measures of “higher” cognition such as working memory (Hernandez Cardenache et al., 2014; Kamat et al., 2014; Salthouse et al., 2004). While this would be theoretically expected to some extent, this raises the question whether we are measuring prospective memory specifically or simply executive function in general. Second, self-report measures of PM show a limited correlation with PM task performance (Uttl & Kibreab, 2011). If both measures are to be taken as measures of individual differences in PM, this would at least appear to indicate a limitation in terms of convergent validity; i.e., is this lack of convergence of performance and self-report due to the self-report measure or to the task? Complex relationships have similarly been found between various task-based and self-report measures of impulsivity, e.g., do tasks and questionnaires measure different aspects of PM, such as a state versus a trait, or a more versus less context-dependent ability, rather than the same individually stable construct (Sharma et al., 2014)? It is therefore important to determine the relationship between PM as assessed via performance and PM assessed via self-report questionnaire: Can convergent validity be found for certain task-questionnaire combinations in principle, e.g., when tasks emphasize reflective PM processes? Third, a practical issue is that assessment can be resource-intensive: with many tasks, the assessor must go through every measurement session with the patient or participant, presenting and scoring the tasks with paper-and-pencil. It would therefore be useful to know, from a clinical perspective, whether computerized tasks can assess PM with adequate psychometric properties. Use of such computerized measures would reduce the load on clinicians and potentially allow online testing, reducing the need for visits and making repeated measurements more feasible. Such tasks also allow for the flexible development of task variants and the use of different measures, for example via more precise assessment of reaction times.

One way in which impulsivity could impact PM is insufficient time and effort spent at the encoding phase. As noted above, reflective processing may be closely related to the time spent selecting cognitive responses, which include responses related to ending a process or continuing with subsequent actions. More impulsive participants would tend to prematurely cease the process of strategic preparation for responses to future events when given the opportunity prior to starting the ongoing portion of a PM task. This type of vulnerability of PM to impulsivity would therefore seem to be related to attempts to improve PM by strategically enhancing encoding of future tasks via some form of rehearsal of the intended future action. This broad concept of implementation rehearsal strategies has been described and studied in terms of imagery of the future conditions and response (Brewer et al., 2011), implementation intentions (Chasteen et al., 2001; McDaniel et al., 2008; McDaniel & Scullin, 2010; Meeks & Marsh, 2010; Scullin et al., 2017) and enactment of the actual response (Pereira et al., 2015). For instance, implementation intentions may strengthen the association between a concrete, specific future cue and an intended action, which can reduce distraction from goal pursuit and increase the availability of relevant responses (Gollwitzer & Sheeran, 2006). Implementation intentions do not however appear to fully automatize the future response (McDaniel & Scullin, 2010). All these strategies aimed at improving encoding have been shown to improve the chance of correct future responses. This, therefore, implies that some PM errors arise from issues at the encoding phase. Encoding-enhancement manipulations may support individuals in paying attention to this critical phase of PM, which would then ameliorate the impact of impulsive traits on encoding. This relationship has not, to our knowledge, been tested.

The current study therefore aimed to (1) test relationships between PM and impulsivity, (2) provide psychometric information on the PM measure, and (3) test the effect of a manipulation aimed at supporting participants' encoding of the future task. The PM task reduced the ability to automatize elements of the PM task by varying target stimuli for the PM task per block and providing no external cue that a different task needed to be performed than the ongoing task. Associations between PM measured via the task and self-reported prospective memory were tested and split-half reliability was assessed to study validity and reliability. To test the predicted associations with individual differences in impulsivity, associations were tested with specific factors of impulsivity, rather than an aggregate measure (Cyders et al., 2014; Whiteside & Lynam, 2001). It was tested whether task-based PM scores explained unique variance in impulsivity facets in addition to task-based scores reflecting general executive function. A baseline and an encoding support version of the task were compared. Encoding support consisted of requiring participants to visualize responding to an upcoming PM target stimulus and execute the response of the PM task. It was expected that this would lead to improved performance and reduced sensitivity to impulsivity.

2. Methods

2.1 Participants

The experiment was successfully performed online by 245 participants (136 male, 109 female, mean age 38, SD 10). Participants were recruited online for a monetary reward. This was done using Amazon's Mechanical Turk. A recruitment text was published on the MTurk system including a link to a webpage starting the experiment. Anyone signed up as an MTurk "worker" could choose to perform the study and complete it via the webpage, which provided a completion code. Ethical permission was given by the local ethical review board and all participants provided informed consent before participating.

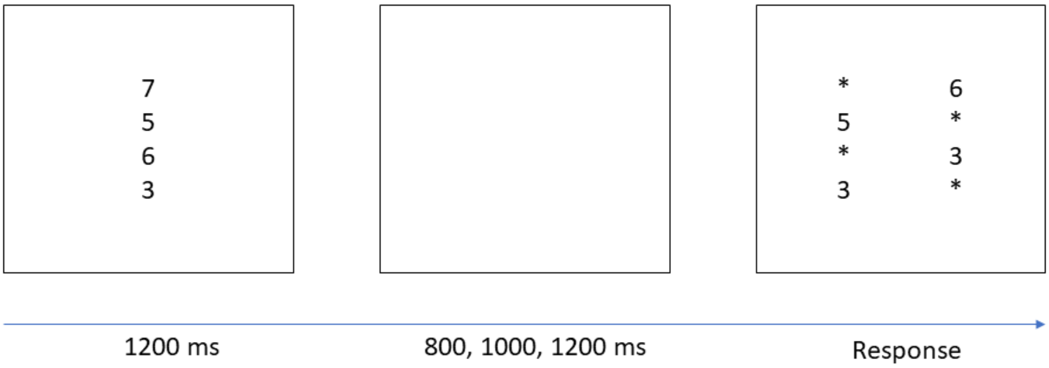
2.2 Materials

Questionnaires and tasks were presented using custom HTML/JavaScript/PHP code, based on the OnlineABM system (Gladwin, 2017).

The Prospective-Retrospective Memory Questionnaire, PRMQ (Crawford et al., 2003), was used as a self-report measure of memory function, providing a scale for retrospective and for prospective memory. Its items concern various examples of forgetting, such as “Do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?”, scored on a Likert scale from Very Often (1) to Never (5). Cronbach’s alpha was .88 for the retrospective and .87 for the prospective scale.

The Short Version of the UPPS-P Impulsive Behavior Scale, SUPPSP (Cyders et al., 2014), was used to assess multiple separable facets of impulsivity: negative urgency, lack of perseverance, lack of premeditation, sensation seeking, and positive urgency. Example items are: for negative urgency, “When I feel rejected, I will often say things that I later regret.”; for lack of perseverance, “I generally like to see things through to the end.”; for lack of premeditation, “I usually think carefully before doing anything”; for sensation seeking, “I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.”; and for positive urgency, “I tend to act without thinking when I am really excited.” Items are scored on a scale from 1 (strongly agree) to 4 (strongly disagree), reverse-coded where necessary. Cronbach’s alpha was .84 for negative urgency, .71 for lack of perseverance, .82 for lack of premeditation, .83 for sensation seeking, and .91 for positive urgency.

Figure 1. Illustration of the task



Note. The figure shows an example of the memory set and probe stimulus of a trial on the working memory task. The correct response is the left-hand key, as the visible items of the left column of the probe match the correct items and positions of the memory set. On probe trials, the special number specified at the start of the block would be presented as the top item of the left column, and the right column would be the correct answer for the working memory task.

The baseline prospective memory task (Figure 1) consisted of 18 blocks of 6 trials each. The task consisted of an ongoing working memory task with an additional prospective memory component. Trials on the working memory task started by presenting a column of four single-digit numbers between 1 and 8, for 1200 ms, centrally. This was followed by a maintenance period of 800, 1000, or 1200 ms. Subsequently the stimulus requiring a response, i.e., the probe stimulus, appeared. The probe consisted of two columns presented on the left and right side of the screen, consisting of numbers and stars. One of the columns had the correct numbers at the identical location to the column of the memory set; the other column had numbers from the memory set but at the incorrect location. The participant had to indicate which of the two columns was correct, using the left or right response key (F or J key). The working memory task therefore required maintenance of the relationships between stimulus features and could not be performed based on mere recognition. After incorrect responses, feedback was provided for 250 ms as a red “Incorrect!” for normal trials, and a red “Special number: <special number for the current block>” for PM trials (see below). Trials were separated by an intertrial interval of 400, 450 or 500 ms; when error-feedback occurred, it was presented from the start of the intertrial interval.

The PM sub-task involved a special number that was presented on PM trials. At the start of each block of trials, a special number was given to remember for that block; the number changed per block. Participants therefore could not automatize the response to one constant special number, which would seem to potentially reduce the degree to which specifically PM would be involved in the PM task. Any time this item appeared in a probe, the participant had to press the space bar instead of the left or right key. The special number would appear once per block, on a random trial of the second half of trials. The special number was always presented at the top of the left-hand column of the probe, which would tend to be the first item read assuming a left-to-right reading order; although we do not know which proportion of participants followed this reading order, and it should not be strictly necessary if participants are correctly monitoring for the special number, this was done to reduce the likelihood of the situation of participants detecting a correct column for the ongoing task and responding quickly, as instructed, on PM trials. The right-hand column was the correct answer for the ongoing task on PM trials, so that failing to recall the intention when seeing the special number would lead to the right-hand response being given. An incorrect response was followed by a repeat of the same trial until a correct response was given, unless this would cause the total number of trials to exceed the number of trials per block. Note that this meant that, by the end of the block, participants would have received explicit feedback reminding them of the correct special number and have been given the opportunity to correct their response. This was done to reduce noise related to forgetting the task context, which could occur if PM errors were not followed by clear feedback and opportunity for correction. There was no test of retrospective memory of the special number, as that would have been influenced by the error feedback procedure.

The encoding support version of the task was identical to the baseline version, with the exception only of the start of each block which provided help to encode the correct intended action into memory. After the screen presenting the upcoming block's special number, participants were told: "Visualize as clearly as possible seeing the item: <current special item>" and "Then physically press SPACE as if responding to it." 1500 ms after pressing space, these instructions faded away over 3000 ms.

2.3 Procedure

Firstly, participants completed questionnaires and provided demographic information. They then performed a brief practice run of the task of only 6 blocks. They then performed either the baseline or the encoding support version (with random assignment) of the full task. Finally, they received a debriefing screen explaining the aims of the study.

2.4 Preprocessing and statistical analyses

The first trial per block was considered likely to be abnormal due to the starting up of performance following the start of a new block and was removed in preprocessing. Further, per participant, for the calculation of median RTs per condition, trials with extreme RTs (absolute $z > 3$) within that condition were removed, as were error trials. Analyses were performed for all participants for accuracy scores and for the restricted subset of participants with non-zero accuracy for RT scores, as RT for PM trials would not be defined for participants with zero PM accuracy. Results on accuracy are also provided for the restricted subset for some analyses; please note that this provides a more stringent test of reliability, as the range of scores has been restricted by removing the lowest-scoring individuals. Importantly, accuracy for the – relatively complex itself – working memory task was good, indicating that low PM scores did not merely reflect low engagement with the task.

Reliability of performance measures was tested using the Spearman-Brown formula, for even versus odd blocks. Reliability was tested for accuracy and RT, and for the WM and PM scores. Additional analyses were performed using only the first *M* blocks of the task, with *M* increasing from 2 blocks in steps of 2, to determine whether shorter tasks could provide sufficient reliability for future work.

Relationships between task performance and questionnaire data for impulsivity and self-reported PM were tested, first, using pairwise Spearman's rho correlations for each task type separately. Further, hierarchical linear regression was used to test (1) whether PM scores explained additional variance over WM scores and (2) whether the effect of PM significantly differed between the task types. Analyses were performed separately for accuracy and RT scores. For (1), the baseline model contained the WM score, and the full model contained WM and PM scores. For (2), interactions with task type were tested via the additional variance explained by the interaction term PM scores x group membership, dummy coded as -1 for baseline versus 1 for encoding support, over a baseline model with the PM and WM scores and the Group x WM interaction term. All variables were centered (i.e., mean-removed) for these analyses. *F*-tests were used to test the significance of additional explained variance of the model including the variable of interest above the baseline model.

Finally, effects of task type on task performance were tested via mixed design ANOVA, with task type (baseline or encoding support) as the between-subject factor and score type (WM or PM) as within-subject factor.

Statistical analyses were performed using Matlab (The Mathworks, 2015), R (R Core Team, 2014), JASP (JASP Team, 2018), and the R package apaTables (Stanley, 2018).

3. Results

The baseline task was performed by 126 participants and the encoding support task by 119 participants. Descriptive statistics are provided in Table 1. Notably, there was high overall accuracy for the WM task, indicating good task engagement; despite this, 78 participants had 0% correct on the PM task. Some analyses, as noted below, used the restricted subset of participants with non-zero PM accuracy (overall or within either of the split-half subsets), e.g., any RT-based analyses as RT scores required at least some accurate trials, and the more stringent reliability analyses.

Table 1. Descriptive statistics

A. Baseline task

	Mean (SD)
Sex	58% male, 42% female
Age	37 (10)
Negative urgency	1.16 (0.709)
Lack of perseverance	2.87 (0.500)
Lack of premeditation	2.62 (0.330)
Sensational seeking	1.37 (0.810)
Positive urgency	0.91 (0.760)
Retrospective memory	2.79 (0.710)
Prospective memory	2.54 (0.665)
Task WM accuracy	0.87 (0.160)
Task PM accuracy	0.45 (0.350)
Task WM RT	1258 (404)
Task PM RT	1108 (593)

B. Encoding support task

	Mean (SD)
Sex	53% male, 47% female
Age	38 (11)
Negative urgency	1.03 (0.712)
Lack of perseverance	2.83 (0.491)
Lack of premeditation	2.61 (0.298)
Sensational seeking	1.27 (0.657)
Positive urgency	0.72 (0.600)
Retrospective memory	2.90 (0.639)
Prospective memory	2.63 (0.650)
Task WM accuracy	0.88 (0.140)
Task PM accuracy	0.44 (0.350)
Task WM RT	1207 (390)
Task PM RT	1009 (442)

Note. Table 1 shows means, with standard deviations in parentheses, of questionnaire scores and task performance (for the unrestricted datasets). Table A shows results for the group performing the baseline task, and Table B shows results for the group performing the encoding support task. The Short Version of the UPPS-P Impulsive Behavior Scale (SUPPSP) provides the following facets of impulsivity: negative urgency, lack of perseverance, lack of premeditation, sensation seeking, and positive urgency. The Prospective-Retrospective Memory Questionnaire (PRMQ) provides a scale for retrospective and prospective memory functioning. Accuracy and RT are reported for the (ongoing) WM and PM trials of the PM task.

For the baseline task, the reliability of PM scores was .92 for accuracy and .71 for RT, and the reliability of WM scores was .96 for accuracy and .95 for RT. For the encoding support task, the reliability of PM scores was .97 for accuracy and .91 for RT, and the reliability of WM scores was .85 for accuracy and .50 for RT. Exploratory analyses were performed to determine how many blocks were needed to achieve .80 reliability for PM accuracy scores. Reliability generally increased with an increasing number of included blocks. The baseline task required 8 blocks and the encoding support task required 6 blocks to achieve .80 reliability.

Reliability analyses were repeated for the restricted subset. For the baseline task, the reliability of PM scores was .76 for accuracy and .71 for RT (presented here for convenience; note that the reliability would not change for RT for the PM task, as this already concerned the restricted subset), and the reliability of WM scores was .91 for accuracy and .94 for RT. For the encoding support task, the reliability of PM scores was .85 for accuracy and .91 for RT, and the reliability of WM scores was .91 for accuracy and .97 for RT.

Correlations between facets of impulsivity, self-reported PM and task-based PM scores are shown in Table 2. Of most interest, for the baseline task, PM accuracy was positively correlated with self-reported prospective memory and negatively correlated with two facets of impulsivity: sensation seeking and positive urgency. For the encoding support task, PM accuracy was not correlated with any self-report measure. Correlations involving PM accuracy for the restricted subset with zero-accuracy participants excluded are provided in Appendix A; the results were globally similar, but the significant correlations in the baseline task were higher and in the encoding support task the correlations with PRMQ scores reached significance.

Table 2. Correlations

A. Baseline task

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Sex												
2. Age	-.28** [-.43, -.11]											
3. NegUrg	.10 [-.08, .27]	-.29** [-.45, -.13]										
4. LackPers	.11 [-.07, .28]	-.18* [-.35, -.01]	.03 [-.14, .21]									
5. LackPremed	.05 [-.13, .22]	-.20* [-.37, -.03]	.24** [.07, .40]	.49** [.35, .61]								
6. SensSeek	.34** [.18, .49]	-.40** [-.54, -.25]	.44** [.29, .57]	.08 [-.09, .25]	.21* [.03, .37]							
7. PosUrg	.21* [.04, .37]	-.38** [-.52, -.22]	.72** [.62, .79]	.11 [-.07, .28]	.25** [.08, .41]	.60** [.48, .70]						
8. PRMQ-RM	-.19* [-.35, -.01]	.29** [.12, .44]	-.53** [-.64, -.39]	-.02 [-.19, .16]	-.17 [-.33, .01]	-.34** [-.49, -.18]	-.59** [-.69, -.46]					
9. PRMQ-PM	-.03 [-.20, .15]	.13 [-.05, .30]	-.41** [-.55, -.26]	-.02 [-.20, .15]	-.04 [-.21, .14]	-.16 [-.33, .01]	-.37** [-.51, -.21]	.76** [.68, .83]				
10. PM acc	.00 [-.17, .18]	.06 [-.11, .24]	-.19* [-.35, -.01]	.05 [-.13, .22]	-.09 [-.26, .09]	-.23** [-.39, -.06]	-.32** [-.47, -.15]	.25** [.08, .41]	.27** [.10, .42]			
11. PM RT	-.09 [-.28, .12]	.00 [-.20, .21]	.10 [-.11, .29]	-.24* [-.42, -.04]	-.18 [-.37, .02]	.16 [-.05, .35]	.07 [-.14, .26]	.02 [-.18, .22]	-.06 [-.26, .14]	-.33** [-.50, -.14]		
12. WM acc	-.02 [-.20, .15]	.24** [.07, .40]	-.18* [-.34, -.00]	-.33** [-.48, -.17]	-.28** [-.43, -.11]	-.20* [-.36, -.02]	-.27** [-.42, -.10]	.28** [.11, .43]	.08 [-.09, .25]	.30** [.13, .45]	.05 [-.15, .25]	
13.	.01	.17	-.13	-.20*	-.26**	-.06	-.17	.22*	.15	.50**	.42**	.48**

	1	2	3	4	5	6	7	8	9	10	11	12
WM acc	[-.17, .18]	[-.00, .34]	[-.30, .05]	[-.36, -.02]	[-.42, -.09]	[-.23, .12]	[-.34, .00]	[.05, .38]	[-.03, .31]	[.36, .62]	[.24, .58]	[.34, .61]

B. Encoding support task

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Sex												
2. Age	-.18 [-.34, .00]											
3. NegUrg	-.02 [-.20, .16]	-.20* [-.37, -.02]										
4. LackPers	.12 [-.06, .29]	-.17 [-.34, .01]	.32** [.15, .47]									
5. LackPremed	-.04 [-.22, .14]	.02 [-.16, .20]	.36** [.19, .51]	.36** [.19, .51]								
6. SensSeek	.40** [.23, .54]	-.34** [-.49, -.17]	.24** [.06, .40]	-.05 [-.23, .13]	.11 [-.07, .28]							
7. PosUrg	.08 [-.10, .26]	-.21* [-.37, -.03]	.75** [.66, .82]	.30** [.13, .46]	.40** [.23, .54]	.39** [.23, .53]						
8. PRMQ-RM	.05 [-.13, .23]	.16 [-.02, .33]	-.49** [-.61, -.34]	-.21* [-.38, -.03]	-.14 [-.31, .05]	-.14 [-.31, .04]	-.49** [-.62, -.34]					
9. PRMQ-PM	.16 [-.02, .33]	.11 [-.07, .28]	-.40** [-.54, -.24]	-.18 [-.35, -.00]	-.15 [-.32, .03]	-.07 [-.24, .12]	-.38** [-.52, -.21]	.84** [.78, .89]				
10. PM acc	-.06 [-.24, .12]	-.03 [-.21, .15]	-.10 [-.28, .08]	.02 [-.16, .20]	-.03 [-.21, .15]	-.03 [-.21, .15]	-.18* [-.35, -.00]	.13 [-.05, .30]	.05 [-.13, .23]			
11. PM RT	-.08 [-.29, .14]	.30** [.09, .48]	.14 [-.08, .34]	-.15 [-.36, .06]	.06 [-.16, .27]	-.10 [-.30, .12]	.13 [-.09, .33]	-.05 [-.26, .16]	-.01 [-.23, .20]	-.31** [-.49, -.10]		
12. WM acc	.06 [-.13, .23]	.11 [-.08, .28]	-.09 [-.27, .09]	.06 [-.13, .23]	-.05 [-.23, .13]	-.12 [-.29, .06]	-.17 [-.34, .02]	.19* [.01, .36]	.12 [-.06, .30]	.35** [.19, .50]	-.19 [-.39, .03]	

13. WM RT	.01	.17	.02	-.12	.00	.03	-.05	.05	.05	.35**	.60**	.28**
	[-.17, .19]	[-.01, .34]	[-.16, .20]	[-.29, .07]	[-.18, .18]	[-.15, .21]	[-.23, .13]	[-.13, .23]	[-.13, .23]	[.18, .50]	[.44, .72]	[.11, .44]

Note. Table 2 shows correlations for the baseline and for the encoding support task. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates p < .05. ** indicates p < .01. Variables represent age in years; sex (dummy coding with 0 = female, 1 = male); the subscales of the Short Version of the UPPS-P Impulsive Behavior Scale (SUPPSP): negative urgency, lack of perseverance, lack of premeditation, sensation seeking, and positive urgency; the retrospective and prospective scales of the Prospective-Retrospective Memory Questionnaire (PRMQ); and Accuracy and RT for the (ongoing) WM and PM trials of the PM task.

Detailed statistical output for the hierarchical regressions is provided in Appendix B; here, we report the F-test of the change in explained variance in the dependent variable from the baseline model to the model with added predictor and the coefficient indicating the direction of effect of that predictor; the analyses' dependent variables were the self-report measures. For accuracy, the hierarchical regression showed that PM scores explained additional variance to WM scores for positive urgency, b = -0.40, F(1, 243) = 9.6, R^2 change = 0.036, p = 0.0022 and self-reported prospective memory, b = 0.26, F(1, 243) = 4.5, R^2 change = 0.018, p = 0.036. That is, higher PM scores predicted lower positive urgency and better self-reported PM on the PRMQ. The interaction between task type and PM scores, in addition to the model containing WM, PM, and the WM x task type interaction, did not explain significant additional variance for any questionnaire. For completeness, we report exploratory analyses of effects using the restricted set excluding participants with zero PM accuracy. There was a PM x group interaction for sensation seeking, b = 0.64, F(1, 163) = 5.8, R^2 change = 0.026, p = .017, and a trend for positive urgency, b = 0.43, F(1, 163)

= 3.2, R^2 change = 0.017, *p* = .076. This interaction reflects the association between PM performance and these facets of impulsivity for the baseline task only.

For RT, PM scores did not explain significant additional variance to WM scores for any questionnaire. There was a significant test for the PM x task type interaction for sensation seeking, *b* = -0.00077, $F(1, 162) = 6.16$, R^2 change = 0.036, *p* = 0.014; this appeared to be due to non-significant correlations in opposite directions in the two tasks: positive in the baseline task and negative in the encoding support task.

The mixed ANOVA with factors task type and trial type showed only a difference between WM and PM trials for accuracy, $F(1, 244) = 410$, $p < .001$, $\eta_p^2 = 0.63$, PM trials being less accurate than WM trials. Results were similar in the restricted subset. For RT, it was found that PM trials (1030 ms) were faster than WM trials (1350 ms), $F(1, 166) = 100$, $p < .001$, $\eta_p^2 = 0.38$.

4. Discussion

The current study aimed to test whether PM is related to impulsivity; test effects of supporting encoding of the future task; and evaluate psychometric properties of the PM scores derived from the PM task.

For the baseline task, impulsivity, in particular sensation seeking and positive urgency, was associated with reduced performance. This agrees with previous positive findings on impulsivity and PM (Cuttler et al., 2014, 2016) and with the theoretical perspectives in which PM would be expected to require reflective processing/executive functions/strategic processes and therefore be negatively affected by impulsivity. Impulsivity could affect PM performance at the point of performing the intended task, or by causing participants to skip past PM task instructions and failing to encode the instructed PM task into memory in the first place. The current findings provide some indication of the latter possibility, as correlations with impulsivity were found for the baseline task but not for the encoding support task. The support manipulation would be expected to help more impulsive participants pay sufficient attention to the encoding of the PM task via the external reminder, thereby reducing the impact of a lack of reflective processing during PM instructions. However, we note that the interaction testing a difference between regression coefficients for the two task variants was only significant for sensation seeking within the restricted subset of non-zero accuracy participants; thus, any differences between tasks must be considered tentative. We did not have a priori predictions on precisely which facets of impulsivity would be involved. Why could positive urgency and sensation seeking in particular play a role in PM? The positive urgency subscale concerns items describing a lack of control related to excitement (Cyders et al., 2014) . Sensation seeking concerns items related to exciting but potentially dangerous experiences (Cyders et al., 2014) and is associated with reward sensitivity (Harden et al., 2018) and increased brain activity related to reward expectation (Edmiston et al., 2019). The two facets are weakly mutually correlated and both predict risky behaviours (Chase et al., 2017), including problematic alcohol use (Cyders et al., 2014) and risky driving (Scott-Parker et al., 2013). In the current study, positive urgency could have led to reduced reflective processing due to the arousal involved in performing the effortful task, while sensation seeking could have led participants to prematurely start new blocks without sufficient time to encode the new target and prepare the relevant intention; however, such interpretations on the role of particular facets of impulsivity must be acknowledged to be speculative.

Against expectations, there were no overall differences in performance between the baseline and encoding support tasks. The simple, consistent nature of the responses may have contributed to this, as opposed to responses involving a variety of richer, more complex actions as in paper-and-pencil tests and in some previous research (Pereira et al., 2015). It may be the case that the rehearsal was insufficiently engaging, as the encoding support simply requested visualization of a particular number and a simple motor response. Alternatively, processes not related to encoding the correct stimulus-response mapping may have played the limiting role on PM performance in this task. Future research is needed to explore different forms of encoding support, focusing on differentiating more theoretically precise manipulations (Brewer et al., 2011; Pereira et al., 2015; Scullin et al., 2017). Other forms of support also could be explored within the current type of task, for instance by making error feedback on PM trials more salient to help sustain attention to the PM task.

Reliability of PM scores was good for accuracy in both task versions, and remained reasonable within the set of participants excluding those with zero accuracy on PM trials. RT-based scores showed somewhat less consistent reliability. Although not the focus of the current study, we note that reliability was high for both accuracy and RT scores for the WM trials. The PM scores on the baseline task were correlated with a self-report subscale for prospective memory, providing cross-validation, but this relationship was weaker in the encoding support task. Importantly, PM scores showed incremental predictive validity above WM scores: The relationship between the task-based PM scores and self-reported PM was not simply due to a general overlap in executive functioning, although it is possible that other aspects of working memory would more strongly overlap with PM on the current task. It is thus in principle possible for PM tasks to provide performance-based PM scores that correlate with self-reported PM.

Limitations of the study include, first, the convenience sample, which does not permit inferences to clinical disorders. Given the current results, it would appear worthwhile to focus on specific groups in future work, e.g., elderly participants with memory impairments. The current sample was relatively young in this sense and this may have led to the lack of correlations indicating age-related decline in PM; this may have further been related to the reduction in impulsivity with age in this sample. The sample was furthermore not described beyond sex and age, thus limiting the ability to relate the current sample to other results. Second, the study was performed online and thus there was less experimental control of performance of the experiment. We note that the performance of online tasks can be similar to lab studies (Chetverikov & Upravitelev, 2016). Nevertheless, it is possible that in a lab session fewer participants would have had very low PM scores. Alternatively, especially given the overall good performance on the working memory task, perhaps there truly is a proportion of participations with specifically low PM performance in this context, which would then be potentially highly informative. Deciding this will require laboratory studies with focused guidance and training of participants on the task. Third, the current task represents only one of many variations. For example, the ongoing task required working memory performance, which could tend to interfere more with PM performance than a simpler task. Future research could explore effects of using simpler ongoing tasks. The PM task could also be varied, for instance to explore differences between time-based and cue-based PM (Aberle et al., 2010; Troyer & Murphy, 2007). The current task variant was cue-based, but cues required PM to be recognized as being cues rather than normal stimuli; this may differ from other tasks in which cues could automatically provide recall of the requirement to perform the PM task. The PM response could also have required an additional response provided after the usual response, rather than requiring an interruption of ongoing task performance. Similarly, different measures of impulsivity and components of working memory could be used, such as go-nogo tasks rather than the current self-reported facets of impulsivity. Finally, it must be acknowledged that results are exploratory, as there was multiple testing due to the number of questionnaire subscales and the exclusion or not of participants with PM zero-accuracy. Replication is necessary to fully establish the current findings, in particular the relatively complex relationship between the encoding support manipulation, PM accuracy, and sensation seeking.

In conclusion, PM was strongly related to impulsivity, especially in a baseline task without external support of encoding. This suggests that impulsivity is a potentially important factor to consider in PM research and raises the question whether interventions aimed at reducing impulsivity, such as response inhibition training, could be relevant to PM decline (Houben & Jansen, 2015; Jones et al., 2016; Lawrence et al., 2015; Manuel et al., 2013). No direct effects of an encoding support manipulation were found. Performance-based scores were reliable overall and correlated with a self-report PM scale.

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