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The Role of Non-Cognitive Factors in Prospective Memory in Older Adults

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Abstract: A key neuro-cognitive function that promotes autonomy and everyday functioning in old age is prospective memory (PM), defined as the capacity to remember to carry out intentions in the future. This study aimed at understanding if non-cognitive factors of metacognition and motivation are related to event-based and time-based laboratory PM, as well as to naturalistic PM in older adults, above and beyond the influences of neuropsychological determinants. We applied regression analyses predicting individual differences in classical PM tasks, in a sample of 99 healthy older participants (aged 64–88 years). Results indicated that metacognition, measured as memory self-efficacy and perceived competence in cognitive tasks, was related to laboratory time-based PM. Consistency of interests, a motivational factor, was associated with naturalistic PM. None of the non-cognitive factors related to event-based PM. Our study underlines the importance of considering non-cognitive characteristics when evaluating PM capacity, a key component of cognitive aging.

Keywords: prospective memory; aging; non-cognitive; metacognition; motivation

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1. Introduction

Prospective memory (PM) is the ability to remember to carry out intended actions in the future while being absorbed in ongoing activities (e.g., remembering to pay bills before the end of the month) [1]. PM has been identified as a crucial cognitive process for independence, personal safety, and for maintaining good social relations and health, in a variety of neuropsychological populations, such as Parkinson's patients [2] and especially in older adults [3–5]. Studies underlined that PM is associated with daily functioning and quality of life in healthy and clinical older adults' populations, while it also declines with age [6–9]. Therefore, a better understanding of which non-cognitive factors are linked with PM, when accounting for neuropsychological correlates, can help improve clinical assessment and allow setting up appropriate interventions [10]. The aim of this study was therefore to explore, for the first time, the role of some aspects of motivation and metacognition on older adults' PM performance.

Conceptually, PM tasks have been classified with respect to the type of cue signaling the appropriate moment to initiate the delayed intention, thereby distinguishing *event-based* from *time-based* tasks [1]. In the case of an event-based task, an action has to be executed when an environmental cue appears. A time-based task concerns a planned action that has to be executed after some time has elapsed or at a specific point in time. Generally, time-based tasks have been argued to more heavily rely on attentional control processes

that allow monitoring the elapsing time to detect the target moment and to depend more highly on self-initiated retrieval than event-based tasks [11,12].

Regardless of the type of task, PM performance has been measured in different contexts, with a distinction between laboratory and naturalistic tasks [13]. In the lab, PM is evaluated following a paradigm proposed by Einstein and McDaniel [14]: The PM task is embedded in an ongoing task occupying the attention of the participant, in order to simulate activities in real life. PM naturalistic tasks, on the other hand, are measured in the participants' daily environment and are integrated into everyday activities. Both task types have resulted in markedly different findings, the so-called *age PM paradox* (see, e.g., [15]). This paradox resides in the fact that younger adults typically outperform their older counterparts in laboratory tasks, whereas older adults show greater performance in the naturalistic tasks [16,17].

Numerous studies have investigated links between cognitive functions and PM. In order to support demanding PM tasks, different neuro-cognitive processes have been related to each phase of PM [18,19]. It has been argued that, besides memory processes, PM should rely on specific executive functions (see [20], for a recent review and process model). More specifically, executive functions are thought to allow monitoring for the appropriate moment and the execution of the intended action after switching from the ongoing to the PM task. In the gerontological literature, PM performance had indeed been related to various neuropsychological variables such as shifting [21,22], inhibition [23,24], updating [22,25], working memory [26,27], and processing speed [28,29].

Whereas considerable work exists on the associations between neuropsychological variables and PM, very little is known about how such associations may be affected by non-cognitive factors. Non-cognitive measures have been defined as "varieties of self-beliefs and goal orientations—such as anxiety, confidence, self-efficacy, and self-concept—which are often seen as dispositional and motivational in nature" [30]. Recently, the role of multiple non-cognitive processes in PM performance has come into focus, with attention, for example, to stress [31], emotions [32], personality [33], and social relevance of intentions [34]. We were particularly interested in investigating possible associations between older adults' PM performance and both *motivation* and *metacognition* (see Figure 1 for a summary of links tested and our contribution).

Strong motivation, more particularly high intrinsic motivation, is a factor often suggested to explain why older adults do better than younger ones on PM performance in everyday context [4,35]. The motivational–cognitive model of PM [36] suggests that motivation to perform an intention increases when a goal is perceived as personally relevant or intrinsically important, thus improving intention encoding, maintenance, and retrieval. Accordingly, older adults are supposed to be more motivated than younger adults to perform a PM task in their daily environment, especially on naturalistic PM tasks. Initial research obtained results corroborating this suggestion: when younger participants are motivated with money incentives on a naturalistic PM task, their PM performance improves [37,38] to the point of eliminating the paradoxical age effect [16]. Other studies on association between motivation and PM showed that older adults may be more committed to perform intentions in their everyday life than younger adults [39–41].

In this study, we were particularly interested in completing the extant literature by measuring other facets of motivation in relation to PM performance in older adults. We explored associations between classical PM tasks and both *need for cognition* [42] and *grit* [43]. Need for cognition is the tendency to enjoy engaging in a thinking process. This basic need has been conceptualized as reflecting an intrinsic and stable motivation. Individuals high on this need tend to be more likely to think about their thoughts, in other words, to engage in metacognition [44]. As metacognition has been linked to PM performance (see below) and as intrinsic motivation is postulated to influence PM performance, we decided to explore whether a need for cognition plays a role in PM. To our knowledge, this link has so far not been tested in older adults. Grit is perseverance and passion for long-term goals. Individuals high in grit work strongly towards challenges and maintain effort and interest

over time despite failure and adversity. The grit scale has two components, *consistency of interests* and *perseverance of effort*. The first component concerns the ability to remain focused on a specific activity or goal. The second component refers to the tendency to work hard and deal with challenges and failures. A recent study suggested that consistency of interests prevented cognitive decline in older adults [45]. Based on this result, we wanted to examine if the measure of grit was related to PM performance, a link never tested before to our knowledge.

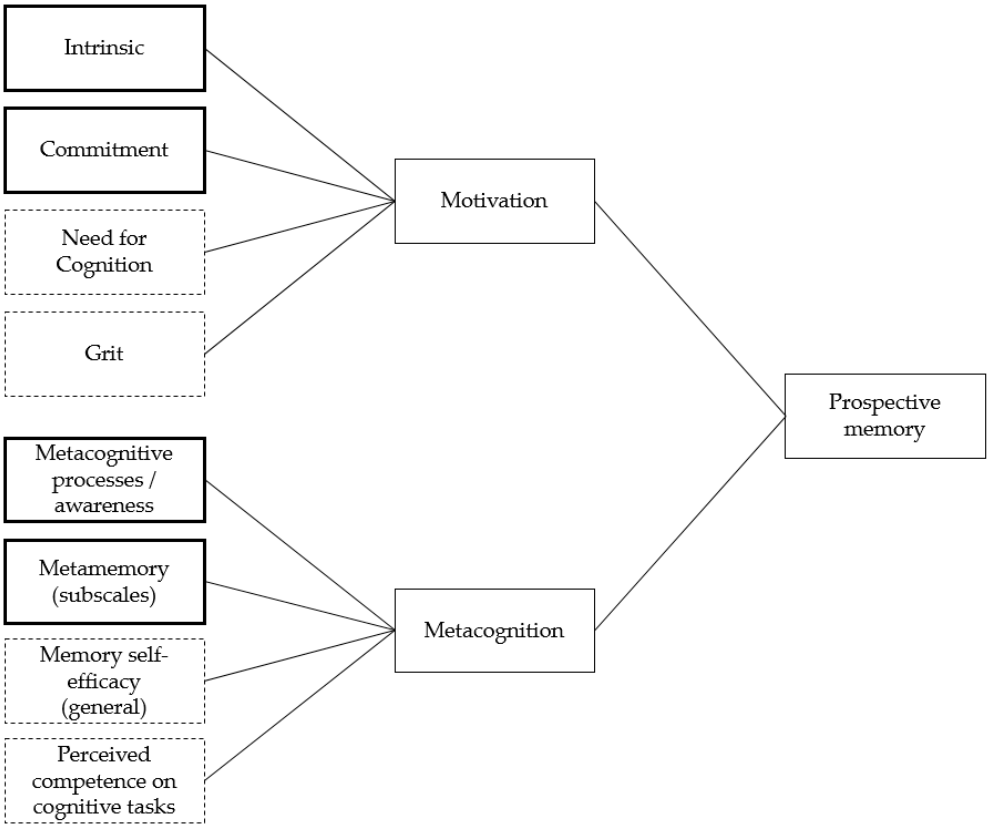


Figure 1. Motivation and metacognition dimensions studied in relation to prospective. Note: Thick, continuous boxes represent previous research, and thin, dashed boxes represent our present research.

Another non-cognitive factor recently linked to PM performance is metacognition, the knowledge about our own cognitive capacities. Albiński et al. [46] found that young adults implicitly judge task difficulty and consequently adapt their behavior, underlining the importance of metacognitive processes in the encoding phase of PM. However, a recent study highlighted that younger, compared to older, individuals had deficient metacognitive awareness about their PM performance in a naturalistic context: they are overconfident, possibly explaining why they perform badly compared to their older counterparts in everyday environment [47]. In this line of research, Schnitzspahn et al. [41] found that older adults had better knowledge about their PM ability than younger ones, thereby possibly explaining the age PM paradox. Moreover, McDonald-Miszczak et al. [48] found that aspects of metamemory, particularly beliefs of high mnemonic capacity and stability, as well as low anxiety, are related to greater time-based PM performance in older adults.

Yet studies on associations between metacognition and PM performance in older adults are sparse. In this study, we were interested in measuring some metacognitive aspects not considered before, namely *memory self-efficacy* [49], and *perceived competence on cognitive tasks* [50]. The memory self-efficacy questionnaire assesses the evaluation about our own memory ability in different situations. Beaudoin et al. [51] found weak or no correlations between memory self-efficacy and measures of retrospective and working memory. We were interested in testing whether memory self-efficacy is related to PM,

because, to our knowledge, this relation was never tested previously, and the work of McDonald-Miszczak et al. [48] showed promising results. The perceived competence on a specific task is a dimension of the intrinsic motivation inventory [50]. Based on this work, we assessed a question measuring metacognition about one's own performance on multiple cognitive tasks to study whether a global evaluation about one's abilities on cognitive tasks is linked to one's PM performance.

In sum, in this work, we intended to study the influence of so-far neglected aspects of motivation and metacognition on various classical PM tasks (an event-based laboratory task, a time-based laboratory task, and a naturalistic task) after controlling for the effects of cognitive factors. We chose to target those non-cognitive variables, because they seem to play a role in the age PM paradox and because we are interested in knowing whether they also play a role in PM performance in a sample of older adults. Furthermore, for laboratory time-based PM, we also studied the monitoring of time, because of its importance for this type of task (see, e.g., [52]). The aim of this study was, therefore, to disentangle relations between classical PM tasks and individual differences on non-cognitive factors in older adults, above and beyond typical neuropsychological correlates. Given the lack of previous research in this regard, we refrained from formulating specific directional hypotheses about the expected relations between measures of motivation and metacognition and the different types of PM tasks. Our research questions are exploratory in nature, so we interpreted results with bilateral statistical significance tests.

2. Materials and Methods

2.1. Participants

We computed a power analysis with an effect size of $R^2 = 0.17$, based on the experiment of Schnitzspahn et al. [24], with the G*Power 3.1 program [53]. It resulted that, to detect such an effect size with 80% power, we would need a sample size of 87 participants. The characteristics of the participants are summarized in Table 1. We included 99 Caucasian older adults aged from 64 to 88 years old in the study. The data came from the baseline session of a training study. They were community-dwelling volunteers, were paid 10 Swiss Francs for their participation, and were recruited with flyers left in places often visited by older adults (for example, at the senior university, senior gym classes, senior clubs, and pharmacies) and by newspaper advertisements. Inclusion criteria were: to be native or fluent French speakers, to have good vision (they were screened for color blindness with the Ishihara test; [54]), no neurological and cognitive impairments, and no dementia, screened with the French Telephone Interview for Cognitive Status Modified (F-TICS-M, [55]). All older adults scored > 27 on the F-TICS-M [56] (we compared analyses with F-TICS-M scores > 31 to exclude possible mild cognitive impairment cases and obtained the same pattern of results (with a sample of 87 participants, composed of 67 women)). All participants gave their informed consent and the study was approved by the ethics committee of the University of Geneva.

2.2. Procedure

Inclusion criteria (except for color blindness) and demographic questionnaire were checked and filled by phone, before the beginning of the study. Then, the data collection took place over a period of two weeks. During the first week, participants were measured on neuro-cognitive and non-cognitive variables (except on the naturalistic PM task; see Table 1 for the means and standard deviations on all variables), described below in detail. They came individually to our lab twice on different days, for a session of approximately 2 h, with at least one short break. Tests were presented in the same pseudorandomized order across participants, such that tasks assessing the same construct were not administered after each other or at all in the same session. In the course of this first week, we also gave participants the instructions for the naturalistic PM (phone) task, which they then carried out in their everyday life during the second week.

2.3. Prospective Memory Measures

We measured PM with three different tasks: two laboratory (event-based and time-based) tasks and a naturalistic task. The laboratory tasks closely followed the standard Einstein–McDaniel paradigm [14] (see also [18]).

Laboratory event-based PM. This computerized task was taken from Ballhausen et al. [57]: The ongoing task was a 1-back task wherein participants had to indicate if the white capital letter (i.e., A, D, E, H, I, K, M, O, T, and U) surrounded by a colored frame (i.e., blue, white, yellow, brown, orange, pink, red, light green, dark green, and violet) and presented on a black screen was of the same category (vowel or consonant) as the preceding letter. Participants pressed the green key to answer YES (right arrow, 50% of the trials) or the red key for NO (left arrow). A trial consisted of a white fixation cross, appearing for 1000 ms, followed by a stimulus appearing for up to 5000 ms if no response was given. The PM instruction was to press the space bar when the colored frame surrounding the letter was pink or blue, before responding to the ongoing task. Participants began with an ongoing task practice block of 20 trials, followed by an ongoing task block of 38 trials, then 2 blocks of PM of 48 trials each, finishing with an ongoing task block of 38 trials with no PM cue. Each PM block contained 3 PM cues, therefore 6 PM cues were presented in total. We assessed event-based laboratory PM performance as the proportion of correct PM responses. We also scored the ongoing task performance, as the percent of correct responses on a 1-back task in PM blocks.

Laboratory time-based PM. This task was taken from Jäger and Kliegel [11] and was also based on an *n*-back ongoing task: Participants had to decide whether the picture [58] displayed on the screen was the same as the picture presented two trials before. Participants pressed the green key to answer YES (right arrow, 33% of the trials) and the red key for NO (left arrow). Every trial lasted 5000 ms, and one trial consisted of a stimulus appearing at most for 4000 ms, followed by a blank screen for 5000 ms minus the response time (RT) to the stimulus. The PM instruction was to press the enter key every 2 min, with five target times. To monitor time, participants could see the elapsed time since the beginning of the task by pressing the space bar, which displayed a clock for 3000 ms. Participants began with an ongoing task practice block of 14 trials, followed by an ongoing task block of 24 trials, then the prospective block with 122 trials, finishing with an ongoing task block of 24 trials with no PM instruction. A PM hit was scored when participants responded in a symmetric window of 6 s around the target times (see, e.g., Schnitzspahn et al., 2011, for the same scoring scheme). We assessed laboratory time-based PM performance as the proportion of correct PM responses. We also scored the ongoing task performance, as the percent of correct responses on a 2-back task in the PM block. To explore time monitoring frequency, we recorded the number of clock checks 30 s prior to each PM target time (see e.g., [11], for a similar procedure).

Naturalistic PM. This task was taken from Aberle et al. [16] and again represents a standard task procedure for naturalistic PM research (see [1]): participants were asked to remember to call an answering machine and leave their name or to send their name as a text message to the first author 3 times a day for 6 consecutive days (Monday to Saturday). The possible task times varied between 7:35 a.m. and 8:55 a.m., 1:05 p.m. and 2:55 p.m., and 3:05 p.m. and 4:55 p.m., and ended 05, 25, 35, 55 min after the hour (e.g., 2:05 p.m., 2:25 p.m., 2:35 p.m., 2:55 p.m.). Participants could choose 3 prearranged times shown on a list. Once participants chose their schedule, they were explicitly asked to memorize it and to not use any external aid to accomplish the task. A PM hit was scored when participants responded in a symmetric window of 12 min around the target times (see, e.g., [47], for the same procedure). We scored naturalistic PM performance as the proportion of correct PM responses.

2.4. Neuropsychological Assessments

Vocabulary. Participants completed part B of the Mill Hill vocabulary scale [59], assessing verbal knowledge. For each word shown, participants had to choose a synonym out of six items. We used the usual scoring system that accounts for correct responses only.

Processing speed. A computerized version of the digit-symbol was used to measure processing speed [60]. A table associating 9 digits with 9 geometrical symbols was presented on the screen. Participants judged if the digit-symbol pair presented below this table was correctly associated or not, responding YES with the green key (right arrow, 50% of the trials) and NO with the red key (left arrow). A trial consisted in a stimulus appearing for 4000 ms at most, followed by a blank screen for 1000 ms. Participants began with a practice block of 20 trials, followed by a test block of 40 trials. We excluded trials with RTs below 500 ms, resulting in 0.03% of total trials (cf. [60]). The processing speed score was the mean RT across trials multiplied by -1, so that high scores reflected fast processing speed.

Working memory. We administered the digit ordering subtest from the Wechsler adult intelligence scale [61]. Participants had to memorize a sequence of digits and recall them in ascending order. We considered the total amount of sequences of digits correctly recalled as the working memory score.

Inhibition. We used the paper Stroop interference task to measure inhibition [62], taken from the Nürnberger Altersinventar [63] translated in French. In the first condition, participants read words of colors ("red," "green," "yellow," "blue") written in black. In the second condition, they named the color of rectangles printed in red, green, yellow, or blue. In the third condition, they named the printed color of color names written incongruently (the color and the name were different; for instance the word "red" was printed in blue color). We administered 36 items per condition and recorded the time in seconds to read all the items. We scored inhibition as the time difference between the second and the third condition (see, e.g., [64], for the same scoring scheme).

2.5. Non-Cognitive Measures

Motivation. We administered two measures of motivational factors. The first was the French translation of the short scale of the need for cognition, which measures the individual tendency to engage in and enjoy cognitive effort [65]. Eleven statements were presented: For example, "I would prefer complex to simple problems", and participants responded with a 4-point scale, ranging from *totally wrong* (1, low need) to *totally correct* (4, high need). The need for cognition score was the sum of all items, and its Cronbach alpha value was 0.84.

We also administered the grit scale to measure perseverance and passion for long-term goals [66]. This scale is composed of two subscales, the *consistency of interests* component and the *perseverance of effort* component. Six items measured the (lack of) consistency of interests over time: For example, "I often set a goal but later choose to pursue a different one", and six items measured the perseverance of effort, for example, "I have achieved a goal that took years of work". Participants responded with a 5-point scale, ranging from *not at all like me* (1, low grit) to *very much like me* (5, high grit). The grit scores, i.e., consistency-of-interests and perseverance-of-effort scores, were based on the mean across the 6 items of each subscale. The Cronbach alpha values were 0.81 and 0.67, respectively.

Metacognition. We administered two measures of metacognitive factors. The first was a memory self-efficacy questionnaire [51]. Six memory-related scenarios were described with five levels of difficulty to succeed in the task: For example, "If someone showed you the pictures of 16 familiar objects (e.g., lamp, umbrella, etc.), would you be able to look at them once and recall the names of all 16 objects, of 12 (8, 4, 2) of the 16 objects?". Participants responded YES or NO at each level of difficulty. The memory self-efficacy score was the mean number of YES selected across all items, and its Cronbach alpha value was 0.78.

The second metacognitive measure concerned the perceived competence participants had about the various cognitive tasks administered in the lab (based on work by [50]). The

statement "I'm satisfied with my performance in this study" was presented to participants who responded on a Likert scale from 1 = *not agree at all* to 5 = *totally agree*. The perceived competence score was composed by the score rated on this single item and represented the feeling participants had about their performance on cognitive tasks we measured in our study (listed above). Given this is a single item assessed once, we cannot estimate its reliability.

2.6. Statistical Analyses

We present results in three sections. First, we report descriptive analyses of PM performance. Then, we describe how we used items from the questionnaires to create aggregate variables of need for cognition and grit, based on their validity, estimated with confirmatory factor models with the software AMOS (version 25; [67]). We evaluated model fit with the root mean square of approximation (RMSEA) and the comparative fit index (CFI). RMSEA ≤ 0.06 and CFI ≥ 0.95 are generally indicative of a good fit [68]. Finally, we report linear regressions carried out with the software Statistica (version 14; [69]), with neuropsychological and non-cognitive factors as predictors and performance on the three PM tasks as dependent variables.

3. Results

3.1. PM Performance

Table 1 displays means and standard deviations of the PM tasks. A repeated measures ANOVA on PM performance showed a significant main effect of PM type of task, $F(2, 196) = 40.51$, $p < 0.001$, η^2 partial = 0.29. A Tukey HSD test revealed that performance was significantly lower on the laboratory time-based PM task than on all other PM tasks. The time-based laboratory and the event-based laboratory PM tasks correlated significantly ($r = 0.20$, $p = 0.04$), whereas the other correlations between PM tasks were not significant ($r = 0.05$ between the time-based laboratory and the naturalistic PM tasks; $r = 0.08$ between the event-based laboratory and the naturalistic PM tasks).

Table 1. Characteristics of the sample.

Variable	*M*	*SD*
Sex (female, *n*)	73	
Age (years)	71.83	5.27
Education (years)	16.01	3.70
Health (self-rated [a])	4.30	0.66
HADS score	10.39	4.61
F-TICS-M	34.69	3.05
Vocabulary (Mill Hill)	37.70	4.04
Processing speed (digit symbol)	−1865.63	306.58
Working memory (digit ordering)	8.56	1.93
Inhibition (Stroop)	−21.21	8.93
Need for cognition	26.87	4.71
Consistency of interests	3.55	0.68
Memory self-efficacy	2.94	0.50
Perceived competence	3.19	0.66
Time monitoring	3.46	3.28
Prospective memory		
Event-based laboratory	0.60	0.32
Time-based laboratory	0.28	0.31
Naturalistic	0.59	0.27

Notes. HADS score = hospital anxiety and depression scale score [70]. F-TICS-M = French Telephone Interview for Cognitive Status Modified. [a] Self-rated health responses varied from 1 (very bad) to 5 (very good).

3.2. Measurement Models of Questionnaires

We performed confirmatory factor analyses in order to assess if the presupposed structure of the questionnaires held in our sample and adapted scores when necessary. For the need-for-cognition questionnaire, many participants reported that item 11 was ambiguous (in French, the words "relief" and "satisfaction" are related). We thus excluded this item, which had a low standardized factor loading compared to those of the other items (b^z = 0.22 vs. b^z = 0.44–0.72). We obtained an acceptable fit for a one-factor confirmatory model (χ^2 = 55.38, *df* = 35, *p* = 0.02, RMSEA = 0.08, CFI = 0.92, AIC = 95.38).

For the grit scale, we first tested the theoretical two-factor model, consisting of two aspects of grit: *consistency of interests* and *perseverance of effort* [43]. We obtained a poor fit (χ^2 = 105.31, *df* = 53, *p* = < 0.001, RMSEA = 0.10, CFI = 0.82, AIC = 155.31) and non-significant factor loadings for the factor of perseverance of effort. We then excluded items with non-significant loadings, one by one, until we obtained a model with a satisfying fit. The final model excluded all of the items that measured the perseverance of effort and thus retained only the consistency of interests' items (χ^2 = 26.26, *df* = 9, *p* = < 0.01, RMSEA = 0.14, CFI = 0.91, AIC = 50.26).

3.3. Regressions Predicting PM

We predicted each of the three PM measures with linear regression analyses. We analyzed the role of motivation measures (i.e., need for cognition and consistency of interests) and metacognition measures (i.e., memory self-efficacy and perceived competence), with the control variables of age and a composite score of general cognition (summarizing vocabulary capacity, processing speed, working memory, and inhibition), as well as ongoing task performance for the PM tasks assessed in the laboratory. We decided to use a composite score of general cognition to limit the number of predictors and because the focus of the study was on the relation between PM and non-cognitive factors, not on each cognitive domain separately. The composite score was created by computing the mean of the Z-scores of each variable. For the dependent variable of time-based laboratory, we further added time monitoring. Table 2 displays the regression results for each PM task (we used an alpha threshold of 5%). All of the tolerance values were between 0.79 and 0.94.

Table 2. Regression models predicting prospective memory.

Predictors	**Prospective Memory**			
	Event-Based	**Time-Based Laboratory**		**Time-Based Naturalistic**
Control variables		Step 1	Step 2	
Age	−0.10	−0.06	0.04	0.07
Cognition	0.19 *	0.13	0.05	0.05
Motivation				
Need for cognition	0.05	−0.14	−0.07	−0.02
Consistency of interests	−0.14	−0.13	−0.06	0.21 *
Metacognition				
Memory self-efficacy	0.04	0.31 **	0.13 *	−0.08
Perceived competence	0.14	0.23 *	0.16 **	0.01
Time monitoring			0.76 ***	
R^2	0.10	0.20	0.72	0.06

Notes. Parameters displayed are standardized betas. Cognition score is composed of measures of *vocabulary*, *processing speed*, *working memory*, and *inhibition*, as well as *ongoing task performance* for models predicting event-based and time-based laboratory PM. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Event-based PM was only predicted by the general cognition score (cf. Table 2). Performance in the laboratory time-based PM task was not predicted by age, cognition, or motivation. However, both the metacognition predictors had a significant effect. When we included time monitoring (Step 2), the effects of metacognitive measures diminished

but remained significant. This final model obtained an R^2 of 0.72. Performance in the naturalistic PM task was not predicted by the cognitive variables or the metacognition variables. Consistency of interests, a motivational measure, was the only significant non-cognitive predictor.

4. Discussion

4.1. Summary of Main Results

The aim of the present study was to explore links between non-cognitive factors (motivation and metacognition) and three types of widely used PM tasks (event-based and time-based laboratory, and naturalistic) in older adults, when controlling for the classical neuropsychological correlates of PM performance. Results indicated that event-based PM was not predicted by non-cognitive factors but rather by cognitive ability (composite score of cognition). However, metacognition played a role in laboratory time-based PM performance. In terms of motivational factors, consistency of interests explained naturalistic PM performance, but a need for cognition was related to none of the three PM tasks used in the present study.

4.2. The Role of Non-Cognitive Factors on Prospective Memory

For the event-based PM task, only an effect of general cognition emerged. Our analyses suggest that older adults with better cognitive capacity perform better on event-based PM. This result agrees with past studies [20]. The fact that non-cognitive factors did not impact this PM task confirms previous reasoning suggesting that, in this type of task, participants have little means to engage in metacognitive control and use compensational strategies due to the unpredictability of the appearance of the PM cue that is supposed to trigger the action related to intention in a more or less spontaneous fashion [71]. Instead, individual differences in attentional capacity may be the key resource to succeed in this task.

Interestingly, this may be different for time-based PM (despite being structurally very similar and also being an abstract laboratory task). Our results suggest that metacognition (measured as memory self-efficacy and perceived competence while performing the different tasks in the laboratory sessions) is positively related to laboratory time-based PM. This result is in line with McDonald-Miszczak et al. [48], highlighting associations between PM performance and subscales of a metamemory questionnaire. In our study, we assessed general measures of metacognition, but asking to predict the performance in a specific PM task also appears to have an effect [41,47]. These results have important implications: if individuals with positive memory self-efficacy or high perceived cognitive competence can enhance their actual PM performance, this might suggest a potential angle for interventions in populations generally showing reduced PM performance, such as older adults. Obviously, the directionality of this effect remains to be explored in future studies with stricter research settings (e.g., intervention studies with appropriate control groups). Perhaps a better PM performance improves the awareness about one's own memory or general cognitive capacity. A conceptually interesting result was that we observed an association between self-efficacy and PM only in the laboratory time-based PM task, which was the most difficult (performance on this task was significantly lower than on the two other PM tasks). This task was particularly complex, because participants worked on an ongoing 2-back task, had to remember to check the clock with a key and had to respond to the PM target times with another key. The instructions could thus have discouraged participants with low levels of memory self-efficacy. A study on stereotype-threat effects in older adults' PM performance obtained results corroborating this hypothesis [72]. In older adults, when the memory dimension of the PM task was emphasized, performance was worse than if another aspect of the task was highlighted (for example, reading capacity).

Furthermore, in order to succeed on the laboratory time-based PM task, the strategic monitoring of time appears essential [11,52]. After controlling for the effects of the cognitive and non-cognitive variables that explained 20% of the variance in the laboratory time-based PM task, we obtained an effect of time monitoring explaining 52% of the additional variance

of the PM performance. Including this factor in the model, however, diminished the effects of metacognitive measures. This result follows the proposal that time-based tasks strongly rely on attentional control processes that permit the monitoring of time [12]. Effectively monitoring time is essential to be exact on time-based PM tasks in the lab, because the PM cue is generally a time interval lasting a few minutes [73].

Comparing both laboratory PM tasks and their relation with metacognition, one can therefore conclude, that in contrast with event-based tasks, time-based tasks allow for the strategic allocation of (possibly limited) cognitive resources to (more or less) monitor for the target moment (see [74]), which can be seen as metacognitive control exerted because of metacognitive beliefs about one's own cognitive efficiency; thus, being consistent with the association obtained between time-based PM and memory self-efficacy, perceived competence, and time monitoring.

We also tested the link between motivation (measured as need for cognition and consistency of interests) and PM, because some authors proposed the key role of this factor in explaining the superior performance of older adults over their younger counterparts in PM evaluated in a naturalistic context [4]. Interestingly, our analyses revealed that consistency of interests (a measure of grit) had a positive effect on the naturalistic time-based PM task only. As supplemental analyses, we also tested the role of lifestyle factors [75] on naturalistic PM, but we did not obtain significant results. Our naturalistic task was particularly demanding in terms of long-term effort, because participants were asked to do the PM task three times a day for six consecutive days. Contrarily to the tasks conducted in labs, wherein the prospective intention has to be maintained and executed over only a few minutes, PM tasks in the environmental context generally last several days. Thus, consistency of interests may help to keep motivation high enough to perform the PM task. This could explain why older adults outperform younger adults in naturalistic contexts. Given that we only tested older adults here, we cannot compare their intrinsic motivation in consistency of interests and PM performance with those of younger adults; hence, more studies are needed to confirm this hypothesis regarding the age PM paradox.

4.3. Limitations and Future Directions

Our study is somewhat limited in four aspects that suggest avenues for future research. First, we assessed motivation with general motivation questionnaires, rather than with a specific PM task-related assessment. Disentangling the effect of general versus task-specific motivation would strengthen substantive conclusions about this non-cognitive factor. For instance, in an intervention scheme, it might be more profitable and likely to increase motivational factors specific to a task rather than general motivational aspects.

Second, we found that time monitoring explained a substantial part of the laboratory time-based PM task variability. Therefore, we can imagine that time monitoring could also predict the time-based PM performance in a naturalistic context, but unfortunately, just like most of the available literature, we did not assess this variable. We suggest that future research focuses on this issue, for example, by asking participants to call or to send a text message when they check the time for the phone task or by entering this information in a portable device.

Third, our three PM tasks were selected to represent classical PM paradigms that are typically used and therefore allow comparisons with the majority of the available literature. In consequence, they somewhat differ in task demands, especially when comparing laboratory and naturalistic tasks. Future research aiming at a fine-grained comparison of the relative importance of non-cognitive processes might benefit from finding ways of parallelizing PM tasks across types and settings.

Fourth, generalizability from our sample to the general population might be somewhat limited, because our sample was predominantly composed of women and of older adults who were highly educated and quite healthy and also because all of the participants in this study took part in a larger training study, which might reflect a greater level of general motivation. Finally, we did not conduct specific gender analyses, because previous studies

have not found any gender differences (e.g., [76]) and because our sample was, as is the case of most convenience samples in cognitive aging studies, not gender-balanced.

5. Conclusions

This was the first study that tested older adults' PM performance on typical event-based and time-based laboratory, as well as naturalistic, tasks and that related performance to non-cognitive factors (motivation and metacognition), in the same sample of older adults. The results clearly suggest that individual differences in those variables can explain a substantial part of older adults' PM performance, above and beyond neuro-cognitive functioning. Our results suggest that intentions related to enough environmental support (event-based PM tasks) did not require non-cognitive factors in addition to cognitive resources. However, difficult PM tasks, like time-based laboratory tasks, seem to benefit from the controlled attentional resources of the strategic monitoring of time and also from metacognition. Feeling competent and confident in one's memory skills thus appears to be positively related to succeeding on difficult time-based PM tasks. In the everyday environment, consistency of interests, a motivational measure, appears beneficial to PM performance. To better understand associations between different types of PM tasks and non-cognitive variables, further studies with a multidimensional approach on the same sample of older adults are needed. As PM tasks in the lab and in the naturalistic environment typically differ in terms of duration and type, future studies should make more use of parallel tasks to permit better comparisons.

In conclusion, given that PM is often used in cognitive assessment because of its ecological validity, understanding associations between PM and cognitive functions, as well as non-cognitive factors, ought to help researchers and clinicians to build tailored interventions for older adults. In particular, our study suggests that metacognition about memory and cognitive abilities in general play a role in time-based laboratory PM performance, and that consistency of interests, a motivational factor, is linked to naturalistic PM performance in older adults.

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