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Clock monitoring is associated with age-related decline in time-based prospective memory

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Abstract

In laboratory time-based prospective memory tasks, older adults typically perform worse than younger adults do. It has been suggested that less frequent clock checking due to problems with executive functions may be responsible. We aimed to investigate the role of clock checking in older adults' time-based prospective memory and to clarify whether executive functions would be associated with clock checking and consequently, with time-based prospective memory. We included 62 healthy older adults (62-85 years of age) and applied tasks of time-based prospective memory as well as of executive functions (i.e., inhibition, fluency, and working memory). We used mediation analysis to test whether time-based prospective memory declined with advancing age due to less frequent clock checking. In addition, we tested whether there would be an association between executive functions and clock checking or time-based prospective memory. Time-based prospective memory declined with advancing age due to less frequent clock checking within 30s prior to intention completion. We only found a link between executive functions and clock checking (or time-based prospective memory) when not controlling for age. Our results support the importance of clock checking for time-based prospective memory and add to the current literature that older adults' prospective memory declines because they are less able to adapt their clock checking. Yet, the reason why older adults are less able to adapt their clock checking still remains open. Our results do not indicate that executive function deficits play a central role.

Keywords Healthy ageing · Prospective memory · Lock checking · Executive functions

Introduction

Remembering to do something at a future point in time is a mnemonic ability that is referred to as time-based prospective memory (Einstein & McDaniel, 1990; Waldum & McDaniel, 2016). Checking a clock with increasing frequency as that point in time nears helps to accomplish the intention on time (e.g., Mioni et al., 2020; Mioni & Stablum, 2014; Vanneste et al., 2016). Older adults seem not to increase clock checking frequency as younger adults do (McFarland & Glisky, 2009; Mioni et al., 2020; Park et al., 1997; Vanneste et al., 2016) and consequently, their time-based prospective memory is less accurate (e.g., Mioni et al., 2020; Mioni & Stablum, 2014; Vanneste et al., 2016). Previous studies, however, mostly compared older adults to younger adults and only reported that both groups checked the clock with different frequencies. It is not fully understood, yet, *when* - during ageing - people begin to check the clock less frequently. It could be that clock checking

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behaviour changes continuously as people age, translating to impairments of time-based prospective memory when a certain age is reached and then they remain stable. Alternatively, clock checking behaviour may continue to change with more pronounced impairments later in life. An investigation of clock checking within a sample of older adults of a broader age range would therefore complement previous studies that compared younger adults with older adults.

It is also not well understood *why* older adults check the clock less frequently. It has been suggested that problems with executive functions may play a role. According to the multiprocess theory by McDaniel and Einstein (2000), prospective memory requires executive resources particularly when the cues that trigger the intention are not salient or not part of the ongoing activity (which typically applies to time-based prospective memory tasks). The attentional-gate model by Block and Zakay (2006), which specifically addresses time-based prospective memory tasks, suggests that an estimation of time requires attentional resources that are allocated by an attentional gate. The model states that an estimation of time happens by comparing a perceived period of time to reference periods stored in long-term memory. If more attention is given to the estimation of the elapsed time, prospective memory responses become more accurate. On the contrary, if attention is given to other tasks (e.g., the ongoing task), accuracy decreases. Several studies tried to link performance in executive function tasks to clock checking or time-based prospective memory (Gonneaud et al., 2011; Kliegel et al., 2003; Mioni et al., 2020; Mioni & Stablum, 2014; Yang et al., 2013). The results of these studies, however, were not consistent. While some studies, for example, reported an association between time-based prospective memory and planning (e.g., Yang et al., 2013), others found no association with planning but reported that cognitive flexibility significantly predicted time-based prospective memory (e.g., Kliegel et al., 2003). Another study found a link between time-based prospective memory and inhibition but not updating (Gonneaud et al., 2011), while still others reported the opposite (Mioni & Stablum, 2014). In a study that included younger and older adults, working memory was associated with prospective memory and clock checking in older adults, whereas inhibition was linked to prospective memory and clock checking in younger adults (Mioni et al., 2020). Although the results of previous studies did not agree well, they suggest a link between executive functions and clock checking (or prospective memory). Only some of these studies, however, controlled for age in their statistical models (Gonneaud et al., 2011; Vanneste et al., 2016; Yang et al., 2013). Since age is known to influence executive functions (Ferguson et al., 2021), it is an important confound for any type of relationship between these cognitive domains. Studies that controlled for age in their models mostly reported that the link between executive functions and prospective memory was no longer significant (Gonneaud et al., 2011; Yang et al., 2013). So far, only one study found an age-independent association between executive functions and time-based prospective memory, but not clock checking (Vanneste et al., 2016). Thus, the association between executive functions and prospective memory or clock checking is still not fully understood.

The aims of the current study were, therefore, twofold. First, we aimed to investigate the role of clock checking for time-based prospective memory within a group of healthy older adults. We hypothesized a decline in prospective memory with advancing age that would be explained by less frequent clock checking. Second, we aimed to clarify whether executive functions would be associated with clock checking or time-based prospective memory even when controlling for age. We hypothesized that we would only find an association between executive functions and clock checking (or prospective memory) when *not* controlling for age.

Methods

Participants

We included $N = 62$ older adults (mean age 72.5 years, $SD = 5.93$, range 62-85 years; 32 women; Table 1). All participants were Caucasian, 60 years or older and had no history of any psychiatric or neurological disorder, severe head injury, or drug or alcohol abuse. No participant was taking

Table 1 Participants' demographics and performance in cognitive tasks

	Mean	Standard deviation
Demographics		
Women/men (number)	32/30	
Age (years)	72.45	5.93
Education (years)	16.87	4.97
Montreal Cognitive Assessment (score; 0-30)	26.42	2.63
Prospective Memory task		
Hits (number)	1.11	1.36
Deviation time (in seconds)	13.23	12.96
Misses (number)	1.06	1.50
Not-on-time responses (number)	1.82	1.37
Clock monitoring (frequency)	8.18	5.37
Executive Functions		
Go/No-go: Misses (number)	2.08	3.45
Go/No-go: False alarms (number)	5.41	3.63
Corsi block tapping backwards (number)	4.16	1.35
Design fluency (number)	26.82	6.93
Verbal fluency (number)	36.98	8.74

any medication that interfered with cognition at the time of the study. All participants needed to be fluent in German, with normal or corrected to normal vision and hearing. We screened for possible subtle cognitive impairment using the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005) and included participants with MoCA ≥23 (Luis et al., 2009; O'Caoimh et al., 2016). In addition, we screened for possible depressive symptoms using the Geriatric Depression Scale (GDS, Yesavage & Sheikh, 1986) and included participants with GDS ≤ 5. The local Ethics Committee approved the study, which was conducted according to the Declaration of Helsinki. All participants gave written informed consent before the study.

Measures

Prospective Memory

Time-based prospective memory was assessed with a computerized task adapted from Jäger and Kliegel (2008). The task consisted of three blocks: During the first and the third block, participants had to perform a 1-back working memory task (i.e., an ongoing-task). Since we were primarily interested in prospective memory, we report details on the ongoing task in the Supplement. For the second block, a time-based prospective memory task was added to the ongoing task. During the prospective memory task, the participants had to press a button (i.e., 'enter') whenever they felt two minutes had elapsed. They had the possibility to press yet another button (i.e., 'space') to find out how much time really had passed; then, a stopwatch appeared for 3 s at the bottom of the screen. The duration of the task was fixed to ten minutes (Fig. 1). We considered minute 2, 4, 6, and 8 as prospective memory targets (i.e., where the participants were meant to press 'enter'). We did not include minute 10 since the task stopped almost directly after 10 min and therefore, there may not have been enough time for the participants to remember that they should have pressed the button. Thus, the prospective memory task consisted of 4 time-based prospective memory targets.

For statistical analyses, we included all button presses (i.e., 'enter' and 'space') within ± 60 s around the four prospective memory targets (i.e., minute 2:00, 4:00, 6:00, and 8:00). For the evaluation of prospective memory task performance, we calculated the mean absolute deviation time of 'enter' presses around the target times (e.g., for a button press at 4:12, the deviation would be 12 s). If that mean deviation time was ≤ 2.5 s, the event was rated as a hit, otherwise it was rated as a response that was not-on-time (Jäger & Kliegel, 2008). If the participants did not respond within ± 60 s around a target time, this was rated as a miss. Thus, we calculated the number of hits, not-on-time responses, misses, and the mean deviation time for each time interval. For clock monitoring, we calculated how often the participants pressed 'space' within ± 60 s around each target time. Comparable to previous studies (e.g., Gonneaud et al., 2011; Mioni et al., 2020; Mioni & Stablum, 2014), we separated the 60 s prior to and after each target time into four intervals: T - 60 corresponds to the interval 60 to 30 s and T - 30 to the interval 30 to 0 s before that point in time. Consequently, the intervals 0 s to 30 s or 30 s to 60 s after that point in time were labelled as T + 30 or T + 60 (Fig. 1). Before and after the task, we double-checked with the participants that they understood what the task was about (i.e., we asked them to explain the task in their own words). In addition, we applied a short training of the ongoing task (i.e., 14 objects were presented with 4 n-back targets). The participants were told that solving the ongoing task and the prospective memory task was equally important.

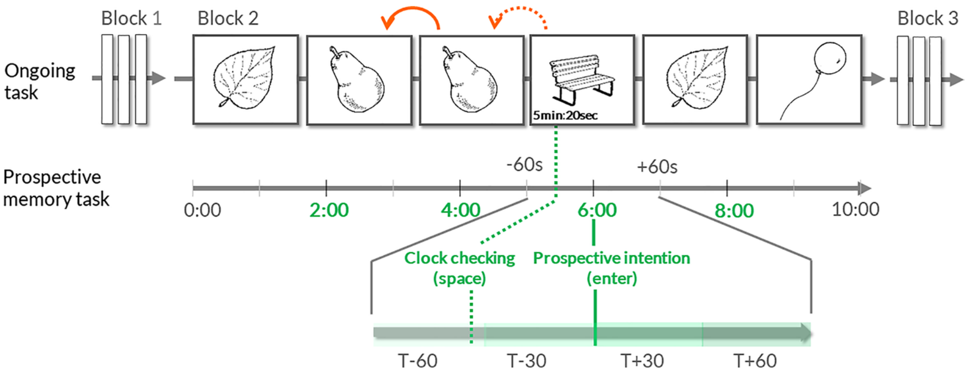

Fig. 1 Illustration of the time-based prospective memory task. Block 1 and 3 consisted of an ongoing task and for block 2, a time-based prospective memory task was added to the ongoing task. During the ongoing task, the participants performed a 1-back working memory task. For the prospective memory task, they needed to press 'enter' whenever they felt two minutes had elapsed. They could press yet another button (i.e., 'space') to find out how much time really had elapsed

Executive Functions

For the assessment of executive functions, we applied a Go/No-Go task, a computerized backward Corsi block tapping task as well as verbal fluency tasks (Schuhfried, 2011). In addition, we applied a paper-pencil version of the design fluency task (i.e., the 5-point test; Regard et al., 1982).

With the Go/No-Go task, we investigated the ability to inhibit a response. Triangles or circles were presented on a computer screen and the participants were required to either respond (i.e., by pressing a button) or withhold a response depending on whether a Go-stimulus or a No-Go-stimulus was presented. We assessed false alarms as well as missed Go-stimuli, with the number of false alarms indicating inhibitory control and the number of missed Go-stimuli indicating attentional deficits.

With the Corsi block tapping task, we assessed spatial working memory capacity. Participants watched different orders in which a number of rectangles highlighted. After each sequence, they needed to click the rectangles with the mouse in reverse order. That is, they needed to begin with the one they saw highlighted last. We assessed the backward span, that is, the longest sequence a participant correctly repeated in reverse order.

With verbal fluency tasks, we assessed how many different words starting with the letter ‘S’ (i.e., lexical fluency) or how many animals (i.e., semantic fluency) can be named within one minute. We counted the total number of correctly named words without repetitions for both subtasks and used the sum of both for statistical analysis. During design fluency, we asked participants to connect two or more dots of five-dot matrices to generate as many unique designs as possible within three minutes. Again, we used the number of correct designs without repetitions for statistical analysis.

Statistical Analyses

First, we tested whether the participants checked the clock with increasing frequency when the point in time of intention completion became near. Therefore, we compared the mean clock monitoring frequency per time interval (T - 60, T - 30, T + 30, T + 60) using repeated measures ANOVA. Then, we tested whether age was predictive of clock checking or time-based prospective memory. Therefore, we used linear (or quadratic) regression with age as a predictor for prospective memory or clock checking. We next conducted mediation analysis to test whether age-related changes in prospective memory were mediated by clock checking. Mediation analysis tests the assumption that the bivariate relationship between a predictor variable X and an outcome variable Y is explained via a third variable M (MacKinnon et al., 2007). We used age as the predictor (X), the number of hits or the mean deviation time as the outcome variable (Y), and clock checking as the mediator (M). We preferred bootstrapping (5000 iterations) over the Sobel test because it provides greater statistical power in testing the significance of the indirect effect (MacKinnon et al., 2004). Finally, we tested the association between performance in executive function tasks and clock checking or prospective memory by using Pearson correlations or partial correlations, when holding age statistically constant. Again, we applied bootstrapping with 5000 iterations.

We used R (version 3.6.3) and RStudio with $p < .05$ considered statistically significant. We applied Bonferroni-Holm correction for multiple comparisons.

Results

Descriptive Findings

The participants had 1.11 (± 1.36) prospective memory hits, 1.06 (± 1.50) misses and 1.82 (± 1.37) not-on-time responses. On average, they responded 13.2 s (± 12.9) before or after each target time and checked the hidden clock 8.18 times (± 5.37). Other descriptive data can be found in Table 1.

Clock Checking Increases when an Intention is Meant to be Accomplished

We found a significant main effect of time-interval for clock checking ($F_{(3.183)} = 32.31$, $p < .001$). Post-hoc tests indicated that clock checking was highest within 30 s before the point in time when the participants were meant to carry out the prospective memory intention (i.e., T - 30 vs. T - 60: $t_{(61)} = 4.97$, $p < .001$; vs. T + 30: $t_{(61)} = 5.89$, $p < .001$; vs. T + 60: $t_{(61)} = 7.39$, $p < .001$). Likewise, clock checking was significantly higher within 60 s before that point in time (i.e., T - 60 vs. T + 30: $t_{(61)} = 3.91$, $p < .001$; vs. T + 60: $t_{(61)} = 5.09$, $p < .001$) than after that point in time had passed. No significant difference was observed between the two time intervals after the point in time, when an intention had to be retrieved (i.e., T + 30 vs. T + 60: $t_{(61)} = 0.563$, $p = .576$). These results indicate that the participants gradually increased clock checking prior to the point in time when they were meant to respond and once that point in time had passed, clock checking decreased (Fig. 2).

Higher Age is Associated with Less Clock Checking and Worse Prospective Memory

We then tested whether age was predictive of prospective memory or clock checking frequency. We found that age significantly predicted prospective memory hits ($\beta = -0.083$, $p = .003$, see supplementary Fig. S1) as well

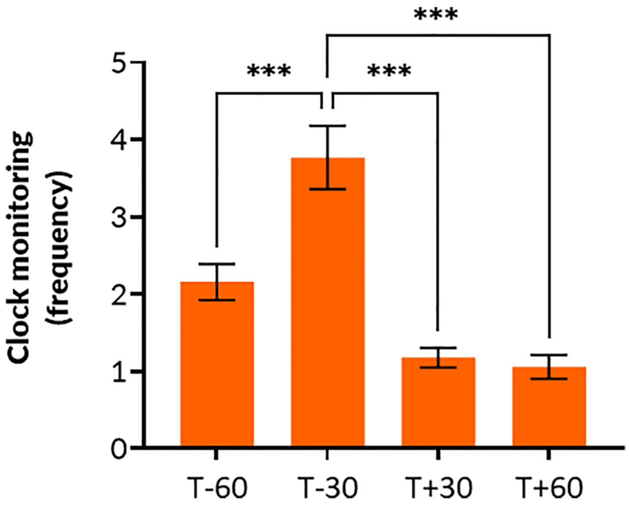

Fig. 2 Clock monitoring during different time intervals of a time-based prospective memory task. The 60 s before or after the point in time where the participants were meant to respond were divided into four 30 s time intervals (i.e., T - 60, T - 30, T + 30, and T + 60). Significant at *** $p < .001$. Error bars depict the standard error of the mean

as mean deviation time (β = 0.660, $p = .027$, see supplementary Fig. S2). In addition, age significantly predicted overall clock checking (β = −0.237, $p = .040$) and was particularly associated with clock checking within the time intervals prior to the point in time where the participants were meant to respond (T - 60, β = −0.078, $p = .047$; T - 30, β = −0.171, $p = .012$). In contrast, age was not predictive of the number of misses (β = 0.062, $p = .055$) or not-on-time responses (β = 0.021, p = .484). None of the quadratic regressors were significant. These results indicate that with advancing age, less time-based intentions were carried out and responses were less accurately on time. In addition, the frequency of clock checks increased less with advancing age, particularly when the moment of intention completion came near.

Clock Monitoring Mediates Age-Related Prospective Memory Decline

Next, we tested whether reduced clock checking was responsible for age-related decline in time-based prospective memory. With mediation analysis, we found that clock checking within 30 s before intention completion fully mediated the effect of age on prospective memory hits (indirect effect a x b = −0.05, 95% CI [−0.10, −0.01], $p = .01$; direct effect c' = −0.03, 95% CI [−0.07, 0.01], $p = .117$; Fig. 3). Within 60 s prior to intention completion, clock checking partly mediated the effect of age on prospective memory hits (indirect effect a x b = −0.02, 95% CI [−0.05, 0.00], $p = .042$; direct effect c' = −0.06, 95% CI [−0.11, −0.01], $p = .012$; Fig. 3). This indicates that advancing age was accompanied by a less distinct increase in clock checking, which in turn led to lower prospective memory task performance. We found similar results when using the mean deviation time instead of the number of time-based intentions that were correctly carried out (see Supplement Fig. S3).

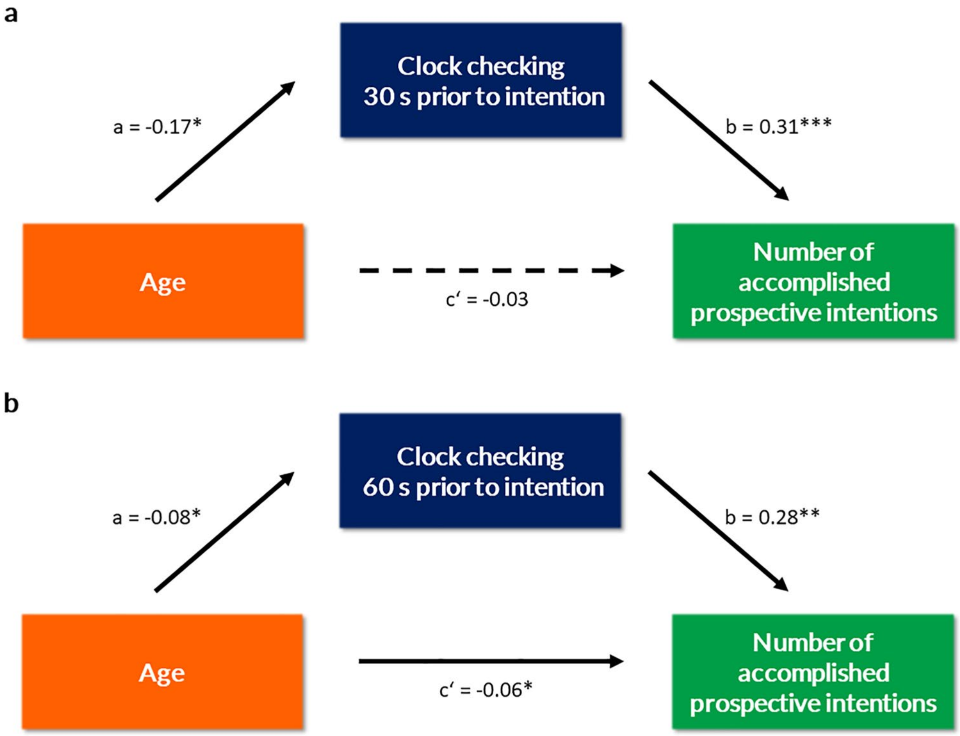

Fig. 3 Results of the mediation analysis. We tested whether clock monitoring mediated the relationship between age and the number of times the prospective memory intention was carried out. Clock monitoring was assessed during the time interval up to 30 s (**a**) or 30-60 s (**b**) prior to the point in time when the participants were meant to accomplish the intention. A dashed line indicates full mediation, while a solid line indicates partial mediation. Significant at * $p < .05$, $p <$ 0.01, or *** $p < .001$

When Controlling for Age, No Significant Association Remains Between Executive Functions and Prospective Memory

Finally, we tested whether executive functions would be associated with clock checking or prospective memory. When not controlling for age, we found significant correlations between design fluency and the number of prospective intentions that were carried out ($r = .28$, $p = .027$) or missed ($r = -.27$, $p = .035$). In addition, participants with better design fluency performance checked the clock more frequently ($r = .29$, $p = .023$), especially within 30 s prior to intention completion ($r = .33$, $p = .009$). Those with an increased number of false alarms during the Go/No-Go task also showed an increased number of not-on-time responses during the prospective memory task ($r = .29$, $p = .039$), while those with better Corsi block tapping performance carried out a higher number of prospective intentions ($r = .28$, $p = .029$; see supplementary Table S3). This suggests that problems with executive functions may influence prospective memory task performance. When we controlled for age, however, none of these correlations remained significant (see supplementary Table S4).

Discussion

In the current study, we examined the role of clock checking in older adults time-based prospective memory and aimed to clarify whether executive functions would be associated with clock monitoring or prospective memory, when (or when not) keeping age statistically constant.

We found an age-related decline in time-based prospective memory that was due to less frequent clock checking within 30 s prior to intention completion with advancing age. Although our participants gradually increased the frequency of clock checking towards intention completion, the increase was less distinct in the oldest participants. Consequently, their prospective memory performance was less accurate. This is in line with previous studies reporting positive correlations between the number of clock checks and prospective memory task accuracy (Mioni et al., 2020; Mioni & Stablum, 2014). It is also in line with studies showing that an age-related decline in time-based prospective memory was associated with a change in clock monitoring (Vanneste et al., 2016). Our results, though, extend previous findings by showing that within the age range of our participants (i.e., 62-85 years of age), clock checking became less distinct towards intention completion with increasing age. This indicates that the ability to adapt clock checking prior to intention completion declines in a linear fashion with increasing age rather than dropping at a certain age and then remaining stable from then on. The results of our study, thus, provide a more comprehensive picture than has previously been established.

It still remains open *why* older adults are less well able to increase clock checking. One possible explanation, according to the literature, may be executive function deficits (Gonneaud et al., 2011; Kliegel et al., 2003; Mioni et al., 2020; Mioni & Stablum, 2014; Yang et al., 2013). If that would be the case, there should be an association between performance in executive functions tasks and clock checking (or prospective memory). Our results do not support this view. Although we found significant correlations between design fluency, working memory, or inhibition and prospective memory (or clock checking), these correlations where no longer significant, when we controlled for age. This may seem surprising given that executive functions and prospective memory do overlap. During the time interval between forming an intention and its retrieval, for example, participants need to shift their attention repeatedly from the ongoing activity to clock monitoring. When the point in time for intention completion comes near, the ongoing activity needs to be inhibited for the intention to be carried out. All these activities reflect executive functions. In our study, ongoing task performance was reduced and reaction times were slower within ± 30 s around the point in time when prospective memory intentions were carried out (see supplementary results), reflecting a shift of attention from the ongoing task to the prospective memory task. It seemed, though, that all participants showed a similar reduction in ongoing task performance when the prospective memory task was added (see supplementary results), while only the oldest participants had difficulties with clock checking. Thus, they may have had proper executive functions but still problems with prospective memory. This would explain why we did not find a link between executive functions and prospective memory that was independent of age. Although the reason why older adults are less able to increase clock checking still remains open, we add to the current literature that the age of participants needs to be considered statistically when checking for associations between executive functions and prospective memory. In future studies other factors that may influence time-based prospective memory, such as time perception, may be considered.

Limitations

Our study may have several limitations. Although we used a fairly broad range of executive functions task, adding a shifting or updating task may have been helpful to fully explore the relationship between executive functions and time-based prospective memory. Second, calculating several correlations between executive functions and prospective memory may not have been ideal. When we instead computed an index of executive function and correlated this index with prospective memory, we again found significant correlations only when we did not control for age. Third, we did not exclude participants that scored below the MoCA cut-off of 26 (Nasreddine et al., 2005). However, several studies argued that a less conservative cut-off (i.e., scores below 23) led to higher sensitivity and specificity in detecting subtle cognitive impairment (Luis et al., 2009; O'Caoimh et al., 2016). In our study, 7 participants had a MoCA score between 21 and 23. Thus, some of our healthy volunteers possibly may have had very mild cognitive impairment. However, when repeating the analyses only with participants that achieved a MoCA score of ≥ 23, our results as well as the implications still held.

Conclusion

Time-based prospective memory declines as people age because they are less able to check the clock with increasing frequency prior to intention completion. We did not find a clear link between performance in executive function tasks and time-based prospective memory that was independent of age. Further research is therefore needed to clarify the causal relationship between executive functions and prospective memory. An intervention study that aims to improve older adults' executive functions may consider assessing transfer effects on time-based prospective memory.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12144-022-03005-1.

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Authors' Contribution Author contributions included conception and study design (Jessica Peter, Matthias Kliegel), data acquisition (Christine Krebs), statistical analysis (Jessica Peter, Nadine Schmidt), interpretation of results (all authors), drafting the manuscript or revising it critically for important intellectual content (all authors), and approval of the final version to be published and agreement to be accountable for the integrity and accuracy of all aspects of the work (all authors).

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Data Availability or Code Availability The datasets generated and/or analysed during the current study will be made available on an online platform hosted by the University of Bern (i.e., BORIS portal).

Declarations

Ethics Approval The Cantonal Ethics Committee Bern approved the study, which was conducted according to the Declaration of Helsinki.

Consent Statement All participants gave written informed consent before the study.

Competing Interests There are no conflicts of interest.

References

Block, R. A., & Zakay, D. (2006). Prospective remembering involves time estimation and memory processes. In J. Glicksohn & M. S. Myslobodsky (Eds.), *Timing the Future* (pp. 25–49). World Scientific. https://doi.org/10.1142/9789812707123_0002

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 717–726. https://doi.org/10.1037/0278-7393.16.4.717

Ferguson, H. J., Brunsdon, V. E. A., & Bradford, E. E. F. (2021). The developmental trajectories of executive function from adolescence to old age. *Scientific Reports, 11*(1), 1382. https://doi.org/10.1038/s41598-020-80866-1

Gonneaud, J., Kalpouzos, G., Bon, L., Viader, F., Eustache, F., & Desgranges, B. (2011). Distinct and shared cognitive functions mediate event- and time-based prospective memory impairment in normal ageing. *Memory, 19*(4), 360–377. https://doi.org/10.1080/09658211.2011.570765

Jäger, T., & Kliegel, M. (2008). Time-based and event-based prospective memory across adulthood: Underlying mechanisms and differential costs on the ongoing task. *The Journal of General Psychology, 135*(1), 4–22. https://doi.org/10.3200/GENP.135.1.4-22

Kliegel, M., Ramuschkat, G., & Martin, M. (2003). Exekutive Funktionen und prospektive Gedächtnisleistung im Alter. *Zeitschrift für Gerontologie und Geriatrie, 36*(1), 35–41. https://doi.org/10.1007/s00391-003-0081-5

Luis, C. A., Keegan, A. P., & Mullan, M. (2009). Cross validation of the Montreal Cognitive Assessment in community dwelling older adults residing in the Southeastern US. *International Journal of Geriatric Psychiatry, 24*(2), 197–201. https://doi.org/10.1002/gps.2101

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioral Research, 39*(1), 99–128. https://doi.org/10.1207/s15327906mbr3901_4

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual Review of Psychology, 58*(1), 593–614. https://doi.org/10.1146/annurev.psych.58.110405.085542

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology, 14*(7), 127–144. https://doi.org/10.1002/acp.775

McFarland, C. P., & Glisky, E. L. (2009). Frontal lobe involvement in a task of time-based prospective memory. *Neuropsychologia, 47*(7), 1660–1669. https://doi.org/10.1016/j.neuropsychologia.2009.02.023

Mioni, G., & Stablum, F. (2014). Monitoring behaviour in a time-based prospective memory task: The involvement of executive functions and time perception. *Memory, 22*(5), 536–552. https://doi.org/10.1080/09658211.2013.801987

Mioni, G., Grondin, S., McLennan, S. N., & Stablum, F. (2020). The role of time-monitoring behaviour in time-based prospective memory performance in younger and older adults. *Memory, 28*(1), 34–48. https://doi.org/10.1080/09658211.2019.1675711

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society, 53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

O'Caoimh, R., Timmons, S., & Molloy, D. W. (2016). Screening for mild cognitive impairment: Comparison of "MCI specific" screening instruments. *Journal of Alzheimer's Disease, 51*(2), 619–629. https://doi.org/10.3233/JAD-150881

Park, D. C., Hertzog, C., Kidder, D. P., Morrell, R. W., & Mayhorn, C. B. (1997). Effect of age on event-based and time-based prospective memory. *Psychology and Aging, 12*(2), 314–327. https://doi.org/10.1037/0882-7974.12.2.314

Regard, M., Strauss, E., & Knapp, P. (1982). Children's production on verbal and non-verbal fluency tasks. *Perceptual and Motor Skills, 55*(3), 839–844. https://doi.org/10.2466/pms.1982.55.3.839

Schuhfried, G. (2011). *CogniPlus, Wiener Testsystem (Viennea Test System)* (Dr Gernot Schuhfried GmbH Patent).

Vanneste, S., Baudouin, A., Bouazzaoui, B., & Taconnat, L. (2016). Age-related differences in time-based prospective memory: The role of time estimation in the clock monitoring strategy. *Memory, 24*(6), 812–825. https://doi.org/10.1080/09658211.2015.1054837

Waldum, E. R., & McDaniel, M. A. (2016). Why are you late? Investigating the role of time management in time-based prospective memory. *Journal of Experimental Psychology: General, 145*(8), 1049–1061. https://doi.org/10.1037/xge0000183

Yang, T., Wang, Y., Lin, H., Zheng, L., & Chan, R. C. K. (2013). Impact of the aging process on event-, time-, and activity-based prospective memory: The aging of prospective memory. *PsyCh Journal, 2*(1), 63–73. https://doi.org/10.1002/pchj.19

Yesavage, J., & Sheikh, J. (1986). Geriatric Depression Scale (GDS). *Clinical Gerontologist, 5*(1-2), 165–173. https://doi.org/10.1300/J018v05n01_09