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Research Report

Relationship Between Future Thinking and Prospective Memory in Alzheimer's Disease

Mohamad El Haj[a,b,*], Ahmed A. Moustafa[c,d], Pascal Antoine[e] and Guillaume Chapelet[b,f]
[a] *Institut Universitaire de France, Paris, France*
[b] *CHU Nantes, Clinical Gerontology Department, Bd Jacques Monod, Nantes, France*
[c] *School of Psychology & Marcs Institute for Brain and Behaviour, University of Western Sydney, Australia*
[d] *Department of Human Anatomy and Physiology, the Faculty of Health Sciences, University of Johannesburg, Johannesburg, South Africa*
[e] *Université de Lille, CNRS, CHU Lille, UMR 9193 SCALab - Sciences Cognitives et Sciences Affectives, Lille, France*
[f] *Université de Nantes, Inserm, TENS, The Enteric Nervous System in Gut and Brain Diseases, IMAD, Nantes, France*

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Abstract.
Background: Future thinking and prospective memory are two cognitive processes oriented toward the future and reliant on the ability to envision oneself in future scenarios.
Objective: We explored the connection between future thinking and prospective memory in individuals with Alzheimer's disease (AD).
Methods: We invited both AD participants and control participants to engage in event-based prospective memory tasks (e.g., "please hand me this stopwatch when I inform you there are 10 minutes remaining") and time-based prospective memory tasks (e.g., "close the book you are working on in five minutes"). Additionally, we asked participants to engage in a future thinking task where they imagined upcoming events.
Results: Analysis revealed that AD participants exhibited lower performance in both prospective memory tasks and future thinking compared to the control group. Importantly, we identified significant positive correlations between the performance on event- and time-based prospective memory tasks and future thinking abilities among AD participants.
Conclusions: These findings underscore the connection between the decline in both prospective memory domains and the ability to envision future events in individuals with AD. Our results also shed light on the challenges AD individuals face when trying to project themselves into the future to mentally pre-experience upcoming events.

Keywords: Alzheimer's disease, event-based prospective memory, future thinking, prospective memory, time-based prospective memory

INTRODUCTION

While Alzheimer's disease (AD) has primarily been linked to a decline in the ability to recall past events [1, 2], the capacity to envision and process future events is also adversely affected by the disease. This impairment in processing future events in AD has been documented in studies related to prospective memory (the ability to execute planned actions at specific future times) and future thinking (the ability to mentally project oneself into the future and pre-experience upcoming events). Despite a sub-

*Correspondence to: Mohamad El Haj, Faculté de Psychologie, LPPL – Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, Chemin de la Censive du Tertre, BP 81227, 44312 Nantes Cedex 3, France. E-mail: mohamad.elhaj@univ-nantes.fr.

stantial body of research demonstrating the impact of AD on both future thinking and prospective memory, this paper underscores the paucity of evidence concerning the relationship between these two cognitive functions in individuals with AD.

Prospective memory can be categorized into two distinct types: event-based and time-based prospective memory [3, 4]. Event-based prospective memory involves carrying out an intended action in response to a particular event or cue (for example, telling your colleague about a conference as soon as you receive the conference program). On the other hand, time-based prospective memory entails executing an intended action at a specific time (such as notifying your colleague about the conference this afternoon). Research has demonstrated an impairment of both event-based [5–9] and time-based prospective memory [6, 10] in AD. For instance, Maylor et al. [6] asked AD participants to say “animal” when an animal appeared in a film (event-based prospective memory task) or to stop a clock every three minutes (time-based prospective memory task). Results demonstrated diminished prospective performances in both tasks in AD. Further, AD impairs prospective memory even more than episodic memory, that is, memory for information encountered in the past [11, 12]. The substantial compromise of prospective memory in AD has been attributed to impairment in frontal functions, especially, to impairment in working memory and executive functions [13–20].

As similar to prospective memory, future thinking has been found to be diminished in AD. In a pioneering study, Addis et al. [21] invited AD participants to remember past scenarios and to simulate future scenarios. AD participants demonstrated a poor ability to generate specific past and future scenarios. Similar outcomes were reported by research that demonstrated difficulties to generate past and future scenarios that are situated in a specific time and/or space in AD [22, 23]. Another study analyzed past and future scenarios in AD participants with respect to the ability to remember contextual information, such as when and where an event took/will take place, and who was/will be present during that scenario [24]. The study observed a poor ability to construct specific future events, i.e., events situated in time and space. The decline of future thinking in AD has been attributed to a poor ability to mentally transport oneself to pre-experience elements of a future scenario [24]. The decline in future thinking abilities among individuals with AD has been linked to their reduced capacity to creatively reassemble episodic information into innovative and adaptable configurations, which are crucial for envisioning future scenarios [23].

While the existing literature has indeed shown that both prospective memory and future thinking are compromised in individuals with AD, prior research has typically treated these cognitive abilities as separate entities. In other words, there is currently limited evidence to indicate a connection between the decline in prospective memory and the decline in future thinking among individuals with AD. This is a significant matter to address because it has been proposed that future thinking could be a crucial factor influencing prospective memory performance [25, 26]. More specifically, it has been suggested that mentally simulating a future scenario can enhance the encoding of a prospective intention during the intention formation stage, thereby increasing the likelihood of successfully carrying out the intended action [27]. This assumption leads to the following hypothesis: if prospective memory and future thinking are intimately linked, then a relationship will be observed between both abilities. At the clinical level, any relationship between the compromise of prospective memory and future thinking in AD can lead to the suggestion that rehabilitation programs on prospective memory should be implemented with regard to their impact on future thinking, and vice versa.

The link between future thinking and prospective memory was evaluated by Terrett et al. [28] who invited younger adults and older (healthy) adults to perform the Virtual Week task, a prospective task consisting of a board game simulating a virtual week with tasks and decisions to make. Participants were also invited to imagine future personal scenarios as part of a future thinking task. Results demonstrated significant positive correlations between future thinking and prospective memory in younger participants and older adults. In younger participants, future thinking accounted for a significant unique variance, suggesting that it may contribute to prospective memory. However, future thinking did not uniquely contribute to prospective memory in older adults, possibly indicating a decreased future thinking in normal aging [28].

Building on the findings of Terrett et al. [28], we evaluated the relationship between prospective memory and future thinking in AD. Our study may add to the growing evidence for links between prospective memory and future thinking in the general population. More specifically, our study may demonstrate associations between the compromise of prospective memory and future thinking in AD. At the clinical level, any relationship between prospective memory and future thinking in AD may draw attention to the potential effects of rehabilitation of prospective memory on the functioning of future thinking in the disease, and vice versa.

METHODS

Participants

The study encompassed a total of 31 participants who had received a clinical diagnosis of probable mild AD, consisting of 22 women and 9 men, with an average age of 72.55 years ($SD = 6.66$), and an average of 8.68 years of formal education ($SD = 2.52$). Additionally, there were 34 control participants, comprising 21 women and 13 men, with an average age of 73.24 years ($SD = 7.76$), and an average of 9.71 years of formal education ($SD = 2.76$). The individuals diagnosed with AD were recruited from nursing homes, and their diagnoses, characterized as probable AD, were established by experienced neurologists or geriatricians in accordance with the criteria outlined by the National Institute on Aging and the Alzheimer's Association for probable Alzheimer's disease [1]. The control participants, frequently spouses or companions of those with AD, were living independently. These participants were matched with the AD participants regarding sex [χ^2 (1, $N = 65$)=0.61, $p = 0.43$], age [$t(63)$=0.38, $p = 0.70$], and educational level [$t(63)$=1.58, $p = 0.12$].

Exclusion criteria applied to all participants encompassed the presence of substantial neurological or psychiatric disorders, as well as the misuse of alcohol or drugs. None of the participants displayed significant visual or auditory impairments that might hinder the assessment process. The study was conducted in accordance with the Declaration of Helsinki, with participants providing informed and voluntary consent to participate, and retaining the ability to withdraw from the study at any point if they so desired. The cognitive attributes of the participants were evaluated using the assessment procedures outlined below.

Cognitive characteristics

The cognitive assessment included tests to measure general cognitive ability, episodic memory, working memory, and depression, and the summarized scores are provided in Table 1. General cognitive functioning was assessed using the Mini-Mental State Examination [29], with a maximum score of 30 points. Episodic memory was evaluated using a French version [30] of the episodic task developed by Grober and Buschke [31]. In this task, participants were required to remember 16 words, each representing an item (e.g., stool) from a different semantic category (e.g., furniture). A distraction phase followed immediate cued recall. In this distraction phase, participants had to count backwards from 374 within a 20-s time frame. After the distraction phase, there was a 2-min free recall period, and the score obtained during this phase served as a measure of episodic recall (maximum score of 16 points). Working memory was assessed through span tasks, where participants were asked to repeat a sequence of single digits in the same order or in reverse order. Depression was evaluated using the Hospital Anxiety and Depression Scale [32], which comprises seven items rated by participants on a four-point scale ranging from zero (not present) to three (considerable). A depression cutoff score of > 10 out of 21 points was utilized [33].

Procedures

We evaluated event-based and time-based prospective memory, as well as future thinking in all participants.

Prospective memory

We followed the procedures established by Kamminga et al. [34] and Groot et al. [35], which involved a paper-and-pencil assessment of time-based and event-based prospective memory in individuals with dementia. Our aim was to use a relatively short (20-min) and easily administered assessment to avoid fatigue and distractibility, thereby avoiding floor effects in the patients. The assessment comprised two subscales, one for event-based and the other for time-based prospective memory, with each containing three prospective tasks. Throughout the assessment, a clock, a pencil, and a paper were clearly visible to the participants. Participants were given the following instructions: "You will be given a series of tasks. I will read aloud the instructions, and I ask you to remember to perform the actions. Feel free to use the paper and pencil to make notes that will help you remember my instructions. You can also refer to your watch or this clock to watch the time." Subsequently, the experimenter read aloud instructions for

Table 1
Cognitive characteristics of Alzheimer's disease (AD) participants and control participants

	Task	AD $n = 31$	Older adults $n = 34$	
General cognitive functioning	MMSE	21.68 (1.40)***	27.61 (1.40)	$t(63) = 20.67, p < 0.001$
Episodic memory	Grober and Buschke	5.58 (1.99)***	11.24 (3.08)	$t(63) = 8.69, p < 0.001$
Working memory	Forward span	5.26 (1.32)**	6.56 (1.74)	$t(63) = 3.38, p = 0.001$
	Backward span	3.61 (1.17)***	5.35 (1.43)	$t(63) = 5.32, p < 0.001$
Depression	HADS	7.23 (1.99)***	4.38 (2.78)	$t(63) = 4.69, p < 0.001$

Standard deviations are given between brackets; the maximum score on the Mini-Mental State Examination (MMSE) was 30 points; the maximum score on the Grober and Buschke task was 16 points; performances on the forward and backward spans refer to number of correctly repeated digits; the cut-off on the HADS (Hospital Anxiety and Depression Scale) was > 10/2 points.

the six tasks, one after the other. The order of the time-based and event-based subscales was balanced among participants, and a filler activity involving a 5-min reading test on mushroom picking was placed between the two subscales.

I. Event-based prospective memory tasks:
   - Placing a notebook under the table after an alarm rings (set to go off 15 min after the session begins): "When the alarm goes off, please place the notebook on the floor.''
   - Returning the stopwatch once the tester announces that there are 10 min remaining: "When I inform you that there are 10 minutes left, please return the stopwatch.''
   - Handing over an envelope labeled "message" to the tester at the end of the session: "When I announce that our session is finished, please give me the message.''

II. Time-based prospective memory tasks:
   - Reminding the experimenter not to forget his keys after 15 min: "In fifteen minutes, please remind me not to forget my keys."
   - Requesting a pencil from the tester after 10 min: "In ten minutes, please ask me for a pencil.''
   - Opening or closing the booklet for the filler task 5 min after receiving the instruction: "In five minutes, please either open or close the book you are currently working on.''

We employed the scoring methodology outlined by Kamminga et al. [34] to calculate scores for each of the event-based and time-based subscales. Specifically, we assigned one point for correctly executing the intended action and an additional point for completing it at the right time, resulting in a total of six points per subscale (three tasks x two points = six points per subscale). For the time-based subscale, an action was correct if it was performed within 5 min of the instructed time. Any action carried out outside of this 5-min window was considered as incorrect. Furthermore, we awarded one additional point if a participant used external aids (i.e., pen and notepad) to make notes for any of the tasks within each subscale. This scoring approach yielded a potential total of seven points for each subscale, with a score range spanning from zero to seven.

Future thinking

We replicated procedures used in studies on future thinking in AD [21, 23, 24]. Participants were instructed to imagine two future events; the two events were separated by performing the Mini-Mental State Examination. Each future event was initiated with the following instruction: "imagine in detail a future event," irrespective of when the event would take place. Participants were encouraged to envision events that could reasonably occur in the future. They were explicitly instructed not to recount or describe any part of a past event but instead to create entirely new scenarios. Precision and specificity were emphasized; the events were limited to a duration of no more than a day, and participants were required to provide specific details such as the time and location of these events. To illustrate what constituted a specific event, some examples were provided. Additionally, participants were invited to describe their feelings and emotions associated with these imagined events. Each participant was allotted three minutes for this exercise, with the duration stated at the beginning so that participants could plan their responses accordingly. This time limit was imposed to prevent potential repetition or distraction, a practice consistent with previous research [21, 36, 37]. Descriptions of future events were recorded with a smartphone and subsequently transcribed for analysis.

The assessment of specificity in future thinking was conducted utilizing a scale developed by Piolino and colleagues [38–40]. Each imagined future event was evaluated as follows:

– Zero points were assigned if there was no memory or if participants provided only general information about a theme.
– One point was given for a repeated or extended event.
– Two points were awarded if the event was situated in time and/or in space.
– Three points were assigned for a specific event lasting less than 24 h and situated in both time and space.
– Four points were allotted for a specific event that was not only situated in time and space but also enriched with phenomenological details.

The mean score for the two events was calculated, with the maximum possible score being four points. To ensure unbiased scoring, events were independently rated by both the first author and an external rater who was unaware of the study's objectives and the group membership of individual participants (i.e., AD patients versus control participants). Inter-rater agreement was assessed using Cohen's Kappa coefficient [41], and high coefficients of inter-rater agreement were achieved (κ=0.90). Any instances of disagreement between raters were discussed and resolved through consensus between the raters.

RESULTS

In our analysis, we compared the performance of both time-based and event-based prospective memory, as well as future thinking scores, between the AD and control groups. We also explored the correlations between event-based and time-based prospective memory and future thinking in AD as well as in and control participants. It is worth noting that the Kolmogorov-Smirnov test revealed that the data related to prospective memory had an abnormal distribution, as the scores were scalar (e.g., specificity scores ranged from zero to four). Consequently, we conducted our comparisons using non-parametric tests. Between-group differences were assessed using the Mann-Whitney U test, while within-group differences were evaluated using the Wilcoxon matched-pairs signed-rank test. In addition, for correlation analysis, we employed Spearman's correlation.

Low prospective memory and future thinking in AD

Performances on prospective memory and future thinking are described in Fig. 1. Compared with controls, AD participants showed lower event-based prospective memory ($Z = -6.36$, $p < 0.001$, Cohen's $d = 2.57$), time-based prospective memory ($Z = -6.70$, $p < 0.001$, Cohen's $d = 2.99$), and future thinking ($Z = -5.04$, $p < 0.001$, Cohen's $d = 1.58$). Regarding prospective performances, analysis showed similar time-based and event-based prospective memory in AD ($Z = -1.46$, $p = 0.14$, Cohen's $d = 0.54$) and control ($Z = -0.46$, $p = 0.64$, Cohen's $d = 0.16$) participants.

Significant positive correlations between future thinking and prospective memory in AD

Analysis showed significant positive correlations between event-based prospective memory and future thinking (see Fig. 2A) and time-based prospective memory and future thinking (see Fig. 2B) in AD. However, any significant correlation was observed between event-based prospective memory and future thinking ($r = 0.19$, $p = 0.61$) or between time-based prospective memory and future thinking ($r = 0.16$, $p = 0.76$) in control participants. Significant correlations were observed between time- and event-based prospective memory in AD ($r = 0.50$, $p = 0.021$) and control ($r = 0.52$, $p = 0.018$) participants.

DISCUSSION

We evaluated the relationship between prospective memory and future thinking in AD. Our analysis uncovered noteworthy findings. Specifically, we observed significant positive correlations between event-based prospective memory and future thinking, as well as between time-based prospective memory and future thinking among AD participants. However, in the control group, no significant correlations were detected between prospective memory and future thinking. These results suggest that in AD participants, there is a notable connection between their abilities in prospective memory and future thinking, whereas such a relationship does not appear to be as evident in the control group.

The main result of our study was the significant correlation between prospective memory and future thinking in AD. This correlation aligns with theoretical accounts suggesting a relationship between

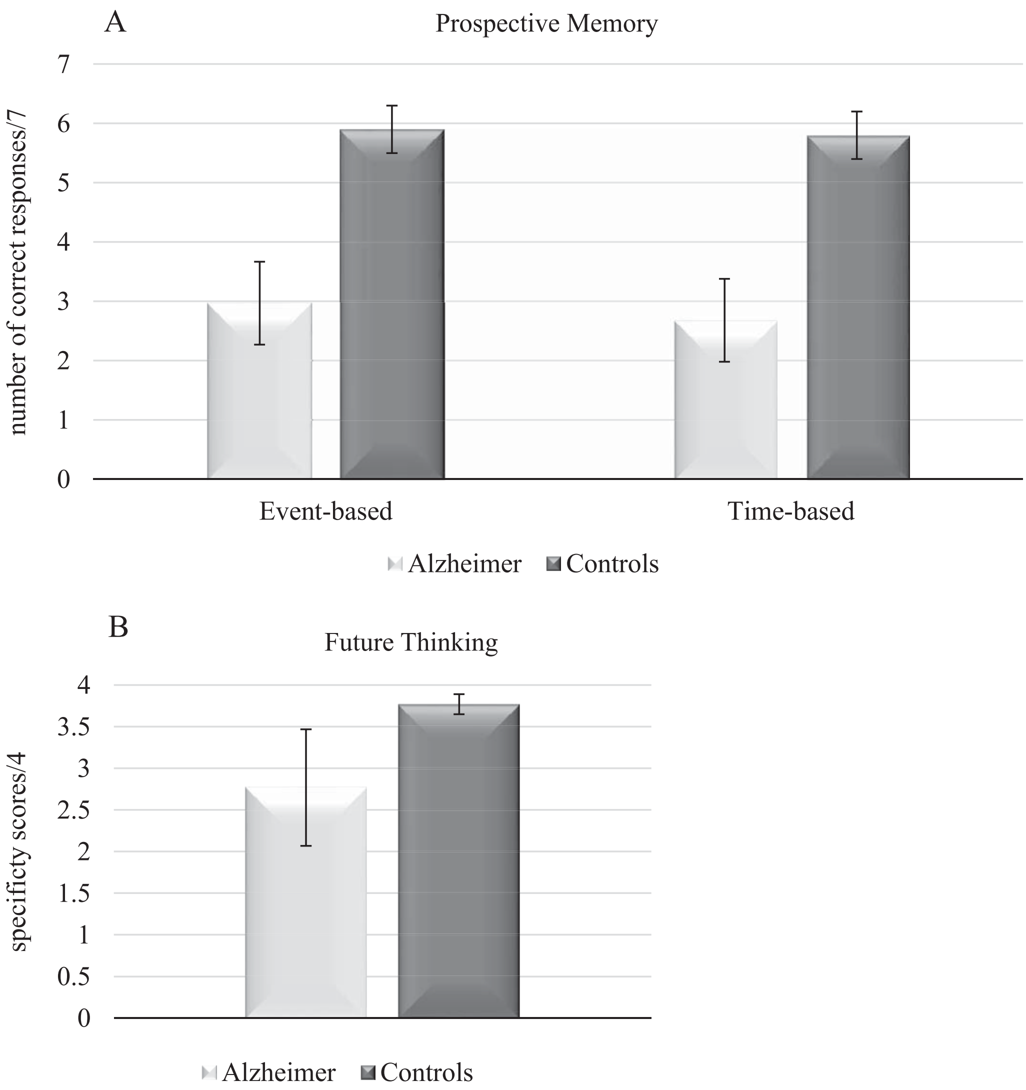

Fig. 1. Performances on event-based and time-based prospective memory (A) and future thinking (B) in Alzheimer's disease participants and control participants. Error bars are 95% within-subject confidence intervals.

prospective memory and future thinking as these abilities are inherently future oriented [25, 26]. Additionally, these correlations mirror the neural overlap between prospective memory and future thinking, particularly in the activation of the BA10 region, which is typically active during the performance of both tasks [42] as well as future thinking [43]. Future thinking has been also considered as an important determinant of prospective memory performance [28]. Future thinking may support the encoding of prospective intention during the intention formation stage [27]. Future thinking may also contribute to prospective memory by introducing a pre-instatement of the context that will be encountered at the moment at which the prospective intention is to be performed [28]. Although previous research has suggested a causal relationship between prospective memory and future thinking, the reverse can also be true. Prospective memory may contribute to future thinking, as the former ability requires simulating plausible event-based and time-based future scenarios (e.g., "I should send that email after the evening meeting" or "I should send that email at 6 PM." Regardless of the causality of the link between future thinking and prospective memory, it is evident that both cognitive abilities are associated with each other, as they are both future-oriented. Our correlational analyses demonstrate a relationship

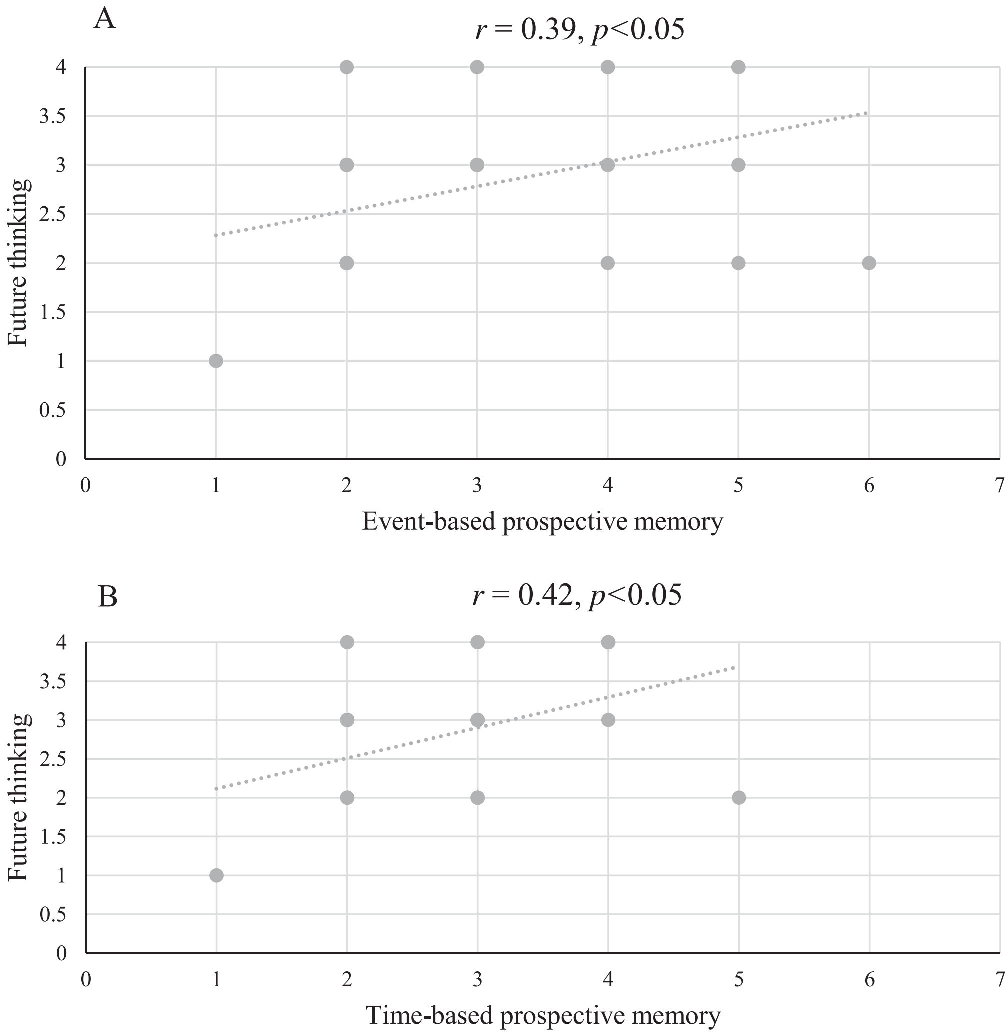

Fig. 2. Correlations between event-based prospective memory and future thinking (A) and time-based and future thinking (B) in Alzheimer's disease participants.

between the decline of both prospective memory and future thinking in amnesia. This relationship can be attributed to a diminished ability to process future thinking and, more specifically, to project oneself into the future to pre-experience an event in AD. Overall, our findings contribute to the existing literature that suggests an intimate relationship between future thinking and prospective memory and demonstrate a correlation between the decline of both cognitive abilities in amnesia.

Besides demonstrating correlations between prospective memory and future thinking in AD, our findings demonstrate decline of both prospective memory and future thinking in the disease. These results replicate earlier findings that AD impairs both event-based prospective memory [5–9] and time-based prospective memory [6, 10]. The impairment of prospective memory in AD has been generally attributed to an impairment in working memory and executive functions [13–20]. Like prospective memory, future thinking has been found to be impaired in AD as patients typically demonstrate difficulties to generate past and future scenarios that are situated in a specific time and/or space [21–23]. The impairment of future thinking in AD has been attributed to the hampered ability to mentally travel in subjective time to pre-experience a future scenario [24]; this impairment has been also attributed to a decline in the ability to recombine different episodic information into novel future scenarios [23].

Unlike the significant correlations observed in AD participants, no significant correlations were observed between prospective memory and future thinking in control participants. The lack of significant correlations in the control participants can be attributed to their near-to-ceiling performances. The future thinking task in our study was likely too easy for older adults. This issue is important because research has demonstrated that older adults tend to generate fewer specific future scenarios than younger adults [44, 45]. Additionally, older adults tend to demonstrate a reduced sense of pre-experiencing future scenarios compared to younger adults, suggesting an age-related shift towards semantic retrieval [46]. These age differences can be embedded within a larger body of cognitive aging literature demonstrating age-related deficits in episodic memory [47, 48]. Age-related deficits in episodic memory have been also associated with age-related deficits in prospective memory [49]. However, prospective performances of older adults can be characterized by little decline on tasks involving low levels of controlled strategic demand [49], which may explain the high performances of our control participants on the prospective tasks. Together, our findings add to the literature by demonstrating the relatively high performances of older adults on tasks involving the construction of few future scenarios and on tasks involving naturalistic prospective actions.

While our results suggest that normal aging may have little effect on relatively easy prospective memory and future thinking tasks, one limitation of the present study is that control participants demonstrated near-ceiling performances. Future research should address this limitation by using easy-but-challenging tasks. Additionally, future research could investigate the relationship between future thinking and negative prospective memory, which involves remembering not to execute a future intention, such as "I should not send the email" [50]. Like prospective memory, negative prospective memory involves processing future scenarios, and therefore, a decline of negative prospective memory, as observed in AD [51], may be associated with a decline of future thinking.

Our study has some clinical implications. The significant correlations between prospective memory and future thinking in AD leads to the assumption that any rehabilitation of future thinking in AD may involve positive effects on prospective memory, and vice versa. Research has demonstrated that future simulation can be a useful strategy for improving prospective memory [27, 52, 53]. According to this research, simulating the performance of a prospective intention makes it more likely that this intention will actually be executed. Interestingly, the beneficial effects of future thinking on prospective memory have been also observed in older adults despite age-related deficits in future thinking [52]; future research may test these findings in AD.

To summarize, our findings demonstrate how a decline in prospective memory and future thinking in AD can be associated. These findings are important as researchers and clinicians tend to deal separately with prospective memory and future thinking in AD. These findings are also important as they demonstrate how the ability to project oneself in the relatively near (prospective memory) and relatively far (future thinking) future is impaired in AD.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

DATA AVAILABILITY

Raw data is available upon request to the correspondent author.

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