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Objective: a body of experimental, neuropsychological and neuroanatomical evidence suggests a relationship between autobiographical memory and the ability to generate mental images. This study investigated this relationship in Alzheimer's disease (AD).

Method: twenty-six AD participants and 28 control participants were asked to retrieve two autobiographical events. They were also administered measures of visual imagery (i.e., the Wider Taller task), and spatial imagery (i.e., the Clock Angles task).

Results: analysis showed preserved autobiographical memory and visual imagery but compromised spatial imagery in AD. Significant correlations were observed between autobiographical memory and visual and spatial imagery in AD and control participants. However, autobiographical memory was predicted by visual but not by spatial imagery.

Conclusions: the ability to retrieve (i.e., visual imagery) and manipulate mental images (i.e., spatial imagery) seems to be related with autobiographical recall in AD. In particular, visual imagery may contribute to autobiographical retrieval in AD participants by providing them with visual cues that increase the ease and speed of search through the hierarchical structure of autobiographical memory.

Keywords: Alzheimer's disease; autobiographical memory, mental imagery, spatial imagery, visual imagery

Public health significance: the finding that Alzheimer's disease patients have difficulty in generating visual images when remembering personal events implies that clinicians may stimulate autobiographical memory by providing patients with visual cues.

Autobiographical memory, or memory for personal experiences, allows individuals to define themselves, construct a life story, and attribute meaning to it. Decline in autobiographical memory in Alzheimer's disease (AD) leads to loss of knowledge about events and facts that defined the patient's life, and consequently to degradation of their self-knowledge and sense of identity (Addis & Tippett, 2004; El Haj, Antoine, Nandrino, & Kapogiannis, 2015; El Haj, Roche, et al., 2017). Since autobiographical retrieval has been argued to be dependent on the ability to generate mental images (Conway, 2009; Greenberg & Knowlton, 2014), this study assessed the relationship between decline in the latter ability and autobiographical compromise in AD.

AD is found to hinder autobiographical retrieval by lowering the production of specific memories or events that occurred at specific times and locations (Barnabe, Whitehead, Pilon, Arsenault-Lapierre, & Chertkow, 2012; De Simone et al., 2016; El Haj, Antoine, Nandrino, Gely-Nargeot, & Raffard, 2015; El Haj, Fasotti, & Allain, 2012; El Haj, Postal, Le Gall, & Allain, 2011; Graham & Hodges, 1997; Greene, Hodges, & Baddeley, 1995; Irish, Lawlor, O'Mara, & Coen, 2011; Ivanoiu, Cooper, Shanks, & Venneri, 2006; Kirk & Berntsen, 2017; Leyhe, Muller, Milian, Eschweiler, & Saur, 2009; Martinelli, Anssens, Sperduti, & Piolino, 2013; Muller et al., 2013; Seidl, Lueken, Thomann, Geider, & Schroder, 2011). The impaired ability to retrieve specific autobiographical events in AD can be attributed to the decontextualization or semantization of memories, which leads to a shift from the ability to mentally relive past events to a general sense of familiarity (El Haj, Antoine, Nandrino, & Kapogiannis, 2015; Piolino et al., 2003).

Decline in the ability to mentally relive past autobiographical events in AD may be associated with a compromise in the ability to generate mental images. This assumption is supported by studies in general populations showing that mental imagery contributes to several phenomenological properties of autobiographical memory, such as memory specificity

(Dewhurst & Conway, 1994; Williams, Healy, & Ellis, 1999), vividness (D'Argembeau & Van der Linden, 2006; Rubin, Schrauf, & Greenberg, 2003), and realness (Mazzoni & Memon, 2003). Moreover, individuals with high mental imagery were found to retrieve more autobiographical memories than those with low mental imagery (Vannucci, Pelagatti, Chiorri, & Mazzoni, 2016). The creation of mental images is thought to facilitate autobiographical recall by increasing the ease and speed of search through the hierarchical structure of autobiographical memory (El Haj & Lenoble, 2017; El Haj, Nandrino, Antoine, Boucart, & Lenoble, 2017; Lenoble, Janssen, & El Haj, 2018). According to Conway and Pleydell-Pearce (2000), mental imagery provides rich sensorial, perceptual, and/or contextual information that enhances access to general autobiographical knowledge, which acts as a powerful lever in the retrieval of specific autobiographical memories.

The contribution of mental imagery to autobiographical memory is highlighted by neuropsychological studies showing autobiographical amnesia in patients with acquired imagery deficits. For instance, a study showed no impaired ability to retrieve general autobiographical knowledge but difficulty in retrieving specific events in a patient with occipital lobe damage. Interestingly, the patient experienced considerable difficulty in processing visual aspects of specific autobiographical events (Conway & Fthenaki, 2000). In a similar vein, patients with occipital lobe damage tend to demonstrate reduced ability to construct mental images of events that occurred prior to their brain injury (Greenberg & Rubin, 2003). A study showed retrograde amnesia and difficulty in recognizing common objects from memory as well as difficulty in generating and manipulating mental images in a patient with damage to the right occipital lobe and the occipitotemporal junction (Greenberg, Eacott, Brechin, & Rubin, 2005). Other insights into the contribution of mental imagery to autobiographical memory come from studies of individuals with optical blindness. A study found fewer specific autobiographical memories in blind participants than in sighted controls

(Ogden, 1993). Other studies also found higher retrieval of autobiographical memories in sighted controls than in congenitally blind participants, suggesting the contribution of visual imagery, or at least vision, to autobiographical recall (Eardley & Pring, 2006; Tekcan et al., 2014). The contribution of visual imagery to autobiographical memory is also highlighted by neuroimaging studies showing an association between autobiographical retrieval and increased activation in the posterior cortical regions, brain areas that play a major role in the ability to generate mental images (Cabeza & St Jacques, 2007; Svoboda, McKinnon, & Levine, 2006). Taken together, there is substantial behavioral and neurological evidence to suggest the contribution of mental imagery to autobiographical memory.

Since our aim was to assess the relationship between mental imagery and autobiographical memory in AD, we investigated the distinction between visual and spatial mental imagery. Although both processes allow mental images to be generated, visual imagery allows the visual appearance of objects to be represented (e.g., color, shape, and brightness), whereas spatial imagery allows the representations of objects to be rotated, their spatial characteristics to be scanned, and relationships to be determined between several objects in space (Farah, Hammond, Levine, & Calvanio, 1988; Stephen M. Kosslyn, Ganis, & Thompson, 2001). Therefore, while visual imagery may contribute to the vividness of autobiographical memory, spatial imagery may contribute to the ability to create and manipulate the visual characteristics of memories (e.g., the characteristics of the location in which the event was encoded). Visual and spatial mental imagery in AD were investigated by Hussey, Smolinsky, Piryatinsky, Budson, and Ally (2012). They assessed visual imagery with the Taller/Wider task (Kosslyn, Holtzman, Farah, & Gazzaniga, 1985) and spatial imagery with the Clock Angles test (Grossi, Becker, & Trojano, 1994). In the Taller/Wider task, participants had to generate a mental image of an object (e.g., pen) presented as a word and determine whether the object was taller than it was wide. In the Clock Angles test, they had to imagine the angle created by the hands on a clock set to a certain time and determine whether that angle was < 90 degrees. Compared to controls, AD participants showed similar performance on the Taller/Wider task but lower performance on the Clock Angles test. According to Hussey et al. (2012), basic visual imagery seems to be spared by AD, unlike spatial imagery which requires heavy executive demand. This assumption is supported by research showing typical impairment on the Clock Angles test in AD (Leyhe, Saur, Eschweiler, & Milian, 2009), although no such impairment was observed in a study by Grossi et al. (1994), probably because their AD participants were preselected from a large pool that performed within normal limits on executive assessments.

Impairment on the Clock Angles test, as may be observed in AD, can be related to neuropathology in the posterior parietal regions. Studies using functional magnetic resonance imaging suggest that the left parietal cortex is heavily involved in the Clock Angle test (Conson, Cinque, & Trojano, 2008; Formisano et al., 2002). One study showed the involvement of the left parietal lobe in generating mental images of the clock and involvement of the right parietal lobe in comparing the angles (Sack, van de Ven, Etschenberg, Schatz, & Linden, 2005). Given evidence suggesting the early accumulation of plaque in AD in the posterior parietal regions (McKee et al., 2006), it is likely that performance on the Clock Angles task is impaired in AD patients.

Altogether, the ability to generate mental images has been considered to play an important role in autobiographical retrieval (M. A. Conway, 2009; El Haj et al., 2014; Greenberg & Knowlton, 2014). The present study assessed the contribution of mental imagery to autobiographical memory in AD. In accordance with the previously reviewed literature (Barnabe et al., 2012; De Simone et al., 2016; El Haj, Antoine, Nandrino, Gely-Nargeot, et al., 2015; El Haj et al., 2012; El Haj et al., 2011; Graham & Hodges, 1997; Greene et al., 1995; Irish et al., 2011; Ivanoiu et al., 2006; Kirk & Berntsen, 2017; Leyhe, Muller, et al., 2009; Martinelli et al., 2013; Muller et al., 2013; Seidl et al., 2011), we expected to evidence autobiographical compromise in AD. In line with research suggesting a compromise in spatial but not in visual imagery in AD (Hussey et al., 2012; Leyhe, Saur, et al., 2009), we expected the same outcome in our AD participants. Critically, we expected that autobiographical performance in AD patients would be correlated with, and predicted by, their ability to process mental images. To test our hypothesis, we first compared mean performances of AD and control participants on visual imagery, spatial imagery, and autobiographical memory. We then assessed correlations between visual imagery, spatial imagery, and autobiographical memory in each population. Finally, to determine which mental imagery dimension better predicted autobiographical memory, we carried out stepwise regression analyses.

Method

Participants

The study included 26 participants with a clinical diagnosis of probable mild AD and 28 healthy controls. The AD participants were recruited from local retirement homes and were diagnosed by experienced neurologists or geriatricians with probable mild AD dementia based on the NINCDS-ADRDA clinical criteria (McKhann et al., 2011). Mild AD was also mirrored by scores on the Mini Mental State Exam (see below). Controls were often spouses or companions of AD participants and were living independently at home. As shown in Table 1, AD participants had lower cognitive ability than controls, but no significant differences were observed between the two groups in terms of sex, age, and educational level. All participants were native French speakers. They consented freely to participate in the study and were given the opportunity to withdraw whenever they wished. Exclusion criteria were significant neurological or psychiatric illness and major visual or auditory acuity difficulties that could prevent adequate assessment.

[INSERT TABLE 1 APPROXIMATELY HERE]

Procedures and materials

We assessed neuropsychological and clinical performances of AD patients and controls, as well as their visual and spatial mental imagery and autobiographical performance.

Neuropsychological and clinical assessment

General cognitive functioning was assessed with the Mini Mental State Exam in which the maximum score was 30 points (Folstein, Folstein, & McHugh, 1975). Phonological loop of working memory was evaluated with spans. Participants had to repeat a string of single digits in the same order (i.e., forward spans) or in reverse order (i.e., backward spans). The score refers to number of correctly repeated digits. Verbal episodic memory was evaluated with the task of Grober and Buschke (1987). Participants had to retain 16 words, each of which described an item that belongs to a different semantic category. After immediate cued recall, participants proceeded to a distraction phase, during which they had to count backwards from 374 in 20 s. The distraction phase was immediately followed by two minutes of free recall and the score/16 from this phase provided a measure of episodic recall. On the verbal fluency task, participants had two minutes to generate as many words as they could beginning with the letter P. In this procedure, proper nouns and variations on words (e.g., “psychology” and “psychologist”) were not allowed. The score was the number of correctly generated words. The Hospital Anxiety and Depression Scale was administered to assess depression (Zigmond & Snaith, 1983). This evaluation consisted of seven items that were scored by the participants on a four-point scale from zero (not present) to three (considerable). As recommended by Herrmann (1997), the cut-off for depression was set at > 10/21 points. Scores on all these pencil-and-paper tasks are summarized in Table 1.

Visual and spatial mental imagery assessment

The Taller/Wider task and the Clock Angles task are widely used to assess visual and spatial mental imagery in AD, respectively (Hussey et al., 2012; Jorgensen, Kristensen, Waldemar, & Vogel, 2015; Leyhe, Saur, et al., 2009). In our assessment, each task consisted of one mental imagery and one perceptual condition, the latter ensuring that any failure on the mental imagery trial was not due to a problem with visual perception. The Clock Angles task was based on that of Grossi et al. (1994) but adapted by Hussey et al. (2012) to fit with cognitive demand in AD. In the control condition, participants saw 20 clock faces without numbers (but hands included) and were asked to determine whether the angle between the hands was < 90 degrees. They then proceeded to the mental imagery condition in which they viewed 20 digitally represented clock times, each of which was printed in black on a white A4 paper sheet. Participants had to imagine the angle between the minute and hour hands (as represented on an analog clock) and determine whether that angle was < 90 degrees. In the Taller/Wider task based on that of Kosslyn (1985), participants were exposed in the mental imagery condition to 20 objects (e.g., pen, knife, screwdriver), each object being presented as a word printed in black on a white A4 paper sheet. Participants were asked to decide whether each object was taller than it was wide. In the subsequent perceptual condition, participants were exposed to colored pictures of these words, each picture being printed on a white A4 paper sheet to allow the same judgment.

Performances on the Taller/Wider and the Clock Angles tasks refer to the percentage of correct responses. Thanks to the control conditions, three AD participants and one control were excluded from the original sample size (n = 29 AD + 29 controls) because they performed two standard deviations below the group mean. For all participants, the Taller/Wider task was presented prior to the Clock Angles tasks, both tasks being separated by spans.

Autobiographical assessment

Participants were asked to recount in detail two events in their lives. They were especially instructed to be precise and specific, so events had to have lasted no more than a day and spatiotemporal details had to be provided, such as time and place at which the events had occurred. Some examples were provided to illustrate what would be considered as a specific event. Participants were also instructed to describe their feelings and emotions during these events. Recall was limited to three minutes for each event and the duration was stated from the outset so participants could plan their time accordingly. This time limit was adopted to avoid potential redundancy and/or distractibility (El Haj & Antoine, 2017). We assessed only two memories to avoid bias such as fatigability and redundancy. Retrieval of the two events was separated by the mental imagery assessment. All autobiographical constructions were recorded using a smartphone and were transcribed subsequently.

Autobiographical performance was scored with the scale from the Test Episodique de Mémoire du Passé (Piolino et al., 2006), an autobiographical instrument based on autobiographical models (M. A. Conway, 2005) and classic autobiographical evaluations (Kopelman, Wilson, & Baddeley, 1989) and adapted for normal and clinical French populations. For each memory, we attributed zero if there was no memory or only general information about a theme (e.g., I was a child). We attributed one point for a repeated or an extended event (e.g., I worked every day); two points for an event situated in time and/or space (e.g., I worked every day in X factory); three points for a specific event lasting less than 24 h and situated in time and space (e.g., one day we went on strike in the factory); and four points for a specific event situated in time and space and enriched with phenomenological details (e.g., thoughts, feelings, perceptions, or visual imagery) (e.g., the strike paid off, we got what we wanted and I was proud to have been part of it). Therefore, a high score on this scale meant that participants succeeded in retrieving specific memories. High inter-rater agreement coefficients were obtained (Cohen's Kappa coefficient κ = .90) (Brennan & Prediger, 1981). The maximum autobiographical score for each participant was eight points (four points for each of the two memories).

Results

We first compared performances of AD and control participants on visual imagery, spatial imagery and autobiographical memory (as shown in Table 2). Comparisons were conducted using the Mann-Whitney test owing to abnormal distribution of data, and we provided effect sizes by using Cohen's *d* (Cohen, 1992): 0.20 = small, 0.50 = medium, 0.80 = large. Note that Cohen's *d* was calculated for non-parametric tests following the recommendations of Rosenthal and DiMatteo (2001) and Ellis (2010). We then carried out Spearman rank correlations to assess the relationship between visual imagery, spatial imagery, and autobiographical memory in each population. To determine which mental imagery dimension better predicted autobiographical memory, we carried out stepwise regression analyses.

Visual imagery and spatial imagery analysis

AD participants showed lower spatial imagery (Z = -5.24, $p < .001$, Cohen's $d = 2.03$) and autobiographical memory (Z = -5.59, $p < .001$, Cohen's $d = 2.34$) than control participants. However, no significant differences were observed between both populations on visual imagery (Z = -1.03, $p > .1$, Cohen's $d = .28$). As for the control condition of visual imagery, no significant differences were observed between both populations (Z = -1.39, $p > .1$, Cohen's $d = .38$), as for the control condition of spatial imagery (Z = -1.01, $p > .1$, Cohen's $d = .28$).

[INSERT TABLE 2 APPROXIMATELY HERE]

Correlations analyses

We applied Bonferroni correction for multiple comparisons (0.05/3 = 0.017), as shown in Table 3. Spearman rank correlations showed significant correlations between visual imagery, spatial imagery and autobiographical memory in AD and control participants. Note that no significant correlations were observed between perceptual tasks of visual and spatial imagery and autobiographical memory in either population ($p > .01$).

Regression analyses

To identify which mental imagery dimension better predicted autobiographical memory, we performed stepwise regression analyses. The dependent variable was autobiographical memory and predictors were performance on the Wider Taller and the Clock Angles tasks. Analysis showed that performance on the Wider Taller task was the main and only variable predicting autobiographical memory in AD (adjusted $R^2 = .25$, $p < .01$) and control participants (adjusted $R^2 = .40$, $p < .001$). We ran additional analyses in which the dependent variable was autobiographical memory and predictors were performance on the Wider Taller, the Clock Angles, the Mini Mental State Exam and the Grober and Buschke tasks. Analysis showed that performance on the Wider Taller task was the main and only variable predicting autobiographical memory in AD (adjusted $R^2 = .20$, $p < .05$) and control participants (adjusted $R^2 = .34$, $p < .001$).

[INSERT TABLE 3 APPROXIMATELY HERE]

Discussion

We assessed the relationship between mental imagery (i.e. visual and spatial imagery) and autobiographical memory in AD. The results showed preserved visual imagery but compromised spatial imagery and autobiographical memory in AD. We also found significant correlations between visual imagery, spatial imagery and autobiographical memory in AD and control participants. Autobiographical memory in AD and control participants was predicted by visual but not by spatial imagery.

In line with a substantive body of research, our data showed that AD participants had difficulty in retrieving specific autobiographical memories (Barnabe et al., 2012; De Simone et al., 2016; El Haj, Antoine, Nandrino, Gely-Nargeot, et al., 2015; El Haj et al., 2012; El Haj et al., 2011; Graham & Hodges, 1997; Greene et al., 1995; Irish et al., 2011; Ivanoiu et al., 2006; Kirk & Berntsen, 2017; Leyhe, Muller, et al., 2009; Martinelli et al., 2013; Muller et al., 2013; Seidl et al., 2011). As shown by our assessment, AD participants had difficulty in retrieving specific memories or a shift from specific to general autobiographical retrieval. This shift occurred despite explicit instructions to provide detailed descriptions of personal events that had occurred at specific times and places.

The autobiographical overgenerality in AD can be related to the ability to generate and manipulate mental images. As shown by our correlation analyses, a significant relationship was observed between autobiographical memory and visual and spatial imagery. The ability to generate visual images has been defined as a fundamental aspect of autobiographical retrieval. Powerful autobiographical memories, especially those that trigger a strong sense of reliving, almost always come with vivid visual images (Rubin et al., 2003). Empirical support for this assumption comes from studies showing that mental imagery contributes to the phenomenological characteristics of autobiographical memory, such as memory specificity Dewhurst & Conway, 1994; Williams et al., 1999), vividness (D'Argembeau & Van der Linden, 2006; Rubin et al., 2003) and realness (Mazzoni & Memon, 2003). In a similar vein, individuals with high mental imagery were found to retrieve more autobiographical memories than those with low mental imagery (Vannucci et al., 2016). The contribution of mental imagery to autobiographical memory was also highlighted by studies showing autobiographical amnesia in patients with occipital lobe damage (Conway & Fthenaki, 2000; Greenberg & Rubin, 2003;

Ogden, 1993), and fewer specific memories in blind participants than in sighted controls (Eardley & Pring, 2006; Tekcan et al., 2014). Neuroimaging findings have also shown an association between autobiographical retrieval and increased activation in the posterior cortical regions, brain areas that play a major role in the ability to generate visual and spatial images (Cabeza & St Jacques, 2007; Svoboda et al., 2006).

As for spatial imagery, this ability may be required to generate and construct the spatial context of retrieved memories. Episodic memory has been defined as the ability to retrieve memories situated in time and space (Tulving, 2002). Therefore, the ability to construct the spatial context of retrieved memories can be considered as an essential component of episodic retrieval, this assumption being supported by the positive correlations between spatial imagery and memory specificity in our study. In other words, the more participants were able to process spatial imagery, the more they were able to retrieve specific memories, probably because they succeeded in retrieving memories situated in a specific spatial context. Regarding AD patients, their difficulty in generating spatial imagery might have limited their ability to retrieve memories situated in a specific spatial context, resulting in difficulty in retrieving specific memories compared with the control participants.

Although our correlation analyses showed a significant relationship between autobiographical memory and visual and spatial imagery in AD, autobiographical memory was solely predicted by visual imagery. This finding can be attributed to the preserved visual imagery in AD. According to Hussey et al. (2012), AD patients tend to perform similarly to controls on tasks that rely on basic visual imagery. However, one study showed impairment on the Taller/Wider task in AD (Tippett, Blackwood, & Farah, 2003), probably because participants were in the moderate-to-advanced stages of the disease (*M* MMSE = 18.63, *SD* = 4.18). Unlike their relatively preserved visual imagery, AD patients tend to experience difficulties on tasks assessing spatial imagery, probably because the latter ability requires heavy executive demand (Hussey et al., 2012). Performance of AD patients on visual and spatial imagery tasks may be associated with the neuroanatomical correlates of both abilities. The primary visual areas V1 and V2 are involved in basic mental imagery (Slotnick, Thompson, & Kosslyn, 2005), whereas areas V3, V4, and V5 play a role in higher-level imagery such as the inspection and transformation of mental images (Conson et al., 2008; Ishai, Ungerleider, & Haxby, 2000). Although AD mainly affects the medial temporal regions associated with autobiographical memory (Pennanen et al., 2004; Philippi et al., 2012), neuropathologic studies suggest that areas involved in higher-level imagery, especially V5, are targeted early by amyloid plaque accumulation in AD (McKee et al., 2006). In contrast, the primary visual areas seem to remain relatively spared until the later stages of the disease (Hussey et al., 2012). Furthermore, neuronal function along the dorsal pathway (known as the “where” pathway) has been found to be affected in the ventral pathway (known as the “what” pathway) in AD (Bokde et al., 2010). Mirroring these data, our AD participants showed spared visual imagery but impaired spatial imagery, which may explain why autobiographical retrieval was solely predicted by visual imagery. Visual imagery might provide more visual cues than impaired spatial imagery, thereby contributing to autobiographical memory in AD participants. The same assumption might also be valid for the control participants since performance on spatial imagery tasks has been found to be sensitive to normal aging (De Simone, Tomasino, Marusic, Eleopra, & Rumiati, 2013).

Visual imagery might have contributed to autobiographical memory in our participants by providing them with visual cues during memory retrieval. According to Conway and Pleydell-Pearce (2000), visual images provide rich sensory-perceptual cues that enhance access to general autobiographical knowledge, which acts as a powerful lever in the retrieval of specific autobiographical memories. In this view, it is likely that visual imagery contributed to the autobiographical performance of our AD and control participants by providing them with more cues than spatial imagery. These cues may then have facilitated the retrieval of specific memory in these participants.

A limitation of this study is the lack of an exhaustive neuropsychological assessment (e.g., the Rey Test, Stroop, Wisconsin Card, Mental rotation, Semantic Fluency). Another limitation is that the imagery tasks, as used in our paper, draw on different basic cognitive processes soliciting different resource-demanding loads: for instance, semantic knowledge for the Taller-Wider task and semantic knowledge, visuospatial processes, and executive functions for the Clock Angles task. Therefore, the two imagery processes (i.e., visual imagery and mental imagery) were probably not assessed in a balanced way in our study. Nevertheless, cognitive tests typically evaluate separate domains rather than a single domain (Miyake et al., 2000).

Mental imagery has been considered as a fundamental aspect of autobiographical retrieval. The findings of this study now extend this notion to AD. The ability to retrieve and manipulate mental images seems to be related to autobiographical recall in AD. Visual imagery seems to influence autobiographical specificity and probably the ability to mentally relive past events in AD.

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Table 1.

Demographical and clinical characteristics of Alzheimer's disease (AD) and control participants

		AD $n = 26$	Controls $n = 28$	
Women/Men		18/8	21/7	X^2 (1, N = 54) = .37, p > .10
Age in years		73.35 (6.55)	70.67 (8.99)	t(52) = 1.25, p > .10
Education in years		8.73 (2.28)	9.36 (2.31)	t(52) = .89, p > .10
General Cognitive functioning	Mini-Mental State Examination	23.23 (1.50)	27.96 (1.53)	t(52) = 11.46, p < .001
Episodic memory	Grober and Buschke	6.00 (2.33)	10.86 (3.31)	t(52) = 6.19, p < .001
Working memory	Forward span	4.73 (1.22)	6.32 (1.68)	t(52) = 3.96, p < .001
	Backward span	3.62 (1.09)	4.89 (1.37)	t(52) = 3.76, p < .001
Verbal Fluency	Fluency task (letter P)	17.15 (5.50)	23.07 (5.21)	t(52) = 4.06, p < .001
Depression	Hospital Anxiety and Depression Scale	8.27 (1.66)	6.11 (2.16)	t(52) = 4.09, p < .001

Note. Standard deviations are given between brackets; performance on the Mini-Mental State Examination refers to correct responses/30; performance on the Grober and Buschke task refers to correct responses/16; performance on the forward and backward spans refers to number of correctly repeated digits; performance on verbal fluency refers to number of correctly generated words; the cut-off for depression was > 10/21 points

Table 2.

Performance of Alzheimer's disease (AD) and control participants on visual (Taller/Wider task) and spatial imagery (Clock Angles task) and autobiographical assessments

	AD *n* = 26	**Controls** *n* = 28
Visual imagery	89 (4.23) n/s	91 (5.76)
Perceptual (control) condition	94 (3.74) n/s	96 (2.43)
Spatial imagery	70 (4.29)***	80 (4.49)
Perceptual (control) condition	95 (2.91) n/s	96 (2.28)
Autobiographical memory	5.65 (.94)***	7.54 (.74)

Note. Standard deviations are given between brackets; score of visual and mental imagery refers to percentage of correct responses; the maximum score of autobiographical performance was eight points (two memories x four points); differences between groups were significant at ***$p < .001$; n/s differences between groups were non-significant; comparisons were established with Mann-Whitney's U test (abnormal distribution).

Table 3.

Correlations between visual imagery, spatial imagery, and autobiographical memory in Alzheimer's Disease (AD) and control participants.

		1.	2.	3.
AD	1. Visual imagery	-		
	2. Spatial imagery	.55**	-	
	3. Autobiographical memory	.54**	.47*	-
Controls	1. Visual imagery	-		
	2. Spatial imagery	.58**	-	
	3. Autobiographical memory	.63**	.56**	-

Note. $^{*}p = 0.015$, $^{**}p < .01$