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Similarity between remembering the past and imagining the future in Alzheimer's disease: Implication of episodic memory

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ABSTRACT

Recent studies suggest that common cognitive processes and neuroanatomical substrates underlie the ability to remember the past and imagine the future. We studied these cognitive processes in patients with Alzheimer's Disease (AD). We asked 27 participants with AD and 30 older controls, matched by age, sex, and educational level, to generate past and future autobiographical events. Autobiographical generation was analyzed with respect to theme, general autobiographical performance, contextual performance, self-defining memories, and autonoetic reliving/re-experiencing. Unlike older controls, most AD participants evoked similar themes when generating past and future events (n=23/30 participants). These participants also showed similar autobiographical and contextual performance, similar amount of self-defining memories, and similar autonoetic states when generating past and future events. Further, significant correlations were detected between hippocampal-dependent memory decline in AD participants and their ability to relive past and future events. These outcomes suggest striking similarities between remembering the past and imagining the future in AD. Due to their memory decline, imagining the future in AD patients is likely to draw heavily from the little amount of available information from past episodes, resulting in striking similarities between remembering the past and imagining the future. Finally, and unlike AD participants, older controls mentally "try out" alternative approaches to upcoming situations without replicating the same schemes of past events.

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A growing body of literature has been documenting striking similarities between remembering the past and imagining the future. Both abilities have been found to employ common cognitive processes and neuroanatomical substrates. In regard to cognitive processes, projecting oneself into the past or into the future may trigger similar phenomenological experiences. According to the work of Tulving (1985, 2005), subjective experience of the past and future involves autonoetic consciousness, "the kind of consciousness that mediates an individual's awareness of his or her existence and identity in subjective time extending from the personal past through the present to the personal future" (Tulving, 1985, p. 1). Accordingly, the subjective experience associated with both remembering the past and imagining the future is determined by similar factors, such as combination of sensory features within a specific temporal and spatial reference system, retrieving of contextual details, mental simulation and imagery, and attribution of personal significance (D'Argembeau et al., 2012, 2008). In regard to neuroanatomical substrates, fMRI studies indicate that both remembering the past and imagining the future activate the default mode network, which includes medial prefrontal and medial parietal nodes, such as the retrosplenial, posterior cingulate and precuneus cortices (e.g., Addis et al., 2007; Okuda et al., 2003; Viard et al., 2012).

Interestingly, the hippocampus (e.g., Laakso et al., 1998; Rauchs et al., 2007), as well as the posterior nodes of the default mode network, such as the retrosplenial/posterior cingulate/precuneus cortex (Seeley et al., 2009), are preferentially targeted by Alzheimer's Disease (AD) neuropathology. Therefore, one may expect that, besides their well-known impairment in remembering the past, patients with AD are proportionately impaired in their ability to imagine the future. This issue was investigated by Addis and associates (Addis et al., 2009) who asked AD patients to generate past and future autobiographical events. Autobiographical generation was further separated into episodic (i.e., unique occurrences of specific events or thoughts) and semantic components (i.e., general or repeated events). Results showed deficits in

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remembering the past and imagining the future. Moreover, these abilities were closely related, as significant correlations were detected between past and future episodic, as well as semantic, autobiographical generation. Further evidence of the close linkage between past and future autobiographical generation was provided by Addis et al. (2009) who observed no significant differences between both generations in terms of personal significance, temporal distance, or emotional intensity.

The aim of the present study was to further investigate the similarities between past and future autobiographical generation in AD. Although the distinction of autobiographical recall into episodic and semantic components, in the work of Addis et al. (2009), may be conceptually appealing, it does not evaluate core aspects of episodic recall, such as the ability to retrieve contextual information which is involved in both remembering the past and imagining the future (D'Argembeau et al., 2008). Moreover, episodic memory has been related to autonoetic consciousness, which is defined as subjective feeling of reliving/re-experiencing or mental time travel into the past of future (Tulving, 1985, 2005). Thus, imagining the future may trigger retrieval of contextual details and autonoetic consciousness, similar to remembering the past.

We also investigated whether remembering the past and imagining the future contribute to the construct of self in AD patients. Although Addis et al. (2009) found that past and future events were of personal significance to AD patients, it is unknown whether imagining the future triggers self-defining memories in AD. The latter memories refer to events that are associated with self-discovery, self-understanding, and self-images, contributing to a life story and sense of identity (Blagov and Singer, 2004; Singer and Salovey, 1993; Thorne et al., 2004; Wood and Conway, 2006). The default mode network, which is the main target of AD pathology (Seeley et al., 2009), is the neuroanatomical substrate for projection of the self to the past and future or, perhaps, the basis of "ego" itself (Carhart-Harris and Friston, 2010). Self-defining memories are prone to degradation in AD and a relationship between autobiographical memory impairment and weakened sense of self exists in AD (Addis and Tippett, 2004; Fargeau et al., 2010; Massimi et al., 2008; Orona, 1990). More specifically, Martinelli et al. (2013) found difficulties in retrieving self-defining memories in AD patients, which they attributed to impaired reconstruction of episodic autobiographical memories. However, the study assessed self-defining memories in AD based solely on generation of past events, leaving open whether the same difficulties may be observed in generation of future events.

The similarities between remembering the past and imagining the future and the degradation of both in AD patients may be interpreted in the terms of the "constructive episodic simulation hypothesis". According to this hypothesis, imagining the future requires retrieving details from episodic memory and flexibly recombining them into a coherent simulation (Schacter and Addis, 2007a, 2007b). The "constructive episodic simulation hypothesis" hence suggests episodic memory as a common cognitive function that unifies past and future thinking. If this is the case, any decline in past and future thinking in AD should be related to the decline in episodic memory, a hypothesis that we pursued in the present study.

Taken together, a body of literature has suggested intimate relationships between past and future thinking. With this study, we extend and complement this literature by assessing whether AD participants mentally "try out" alternative approaches to future situations without replicating the same schemes as in past events. In that regard, we compared AD patients to control older adults in terms of contextual details, consciousness states, and self-implication in past and future thinking. Specifically, we assessed contextual similarities in terms of spatio-temporal and affective contextual conceptualization by Tulving (1985, 2005); consciousness state was assessed with a reliving assessment [(an adaptation of the Remember/know paradigm (Gardiner, 2001)]; and self-defining memories were defined as memories contributing to a life story and sense of identity (Blagov and Singer, 2004; Singer and Salovey, 1993; Thorne et al., 2004; Wood and Conway, 2006). In accordance with the literature suggesting common cognitive (D'Argembeau and van der Linden, 2004, 2006; D'Argembeau et al., 2008) and neuroanatomical mechanisms (see, Schacter et al. (2012a)) for remembering the past and imagining the future, we hypothesized that both abilities trigger generation of similar themes, with the same amount of contextual details, similar phenomenological experience, and self-defining memories. Another objective of our work was to provide support for the "constructive episodic simulation hypothesis" (Schacter and Addis, 2007a, 2007b), suggesting episodic memory as a common underpinning of past and future thinking. Following this view, we hypothesized that difficulties in both remembering the past and imagining the future would be related with memory deterioration in AD.

1. Method

1.1. Participants

We tested 27 participants with a clinical diagnosis of probable AD at the mild stage (17 women and 10 men; *M* age = 71.85 years, *SD* = 7.01; *M* years of formal education = 8.67, *SD* = 2.73) and 30 control older adults (19 women and 11 men; *M* age = 72.47 years, *SD* = 7.04; *M* years of formal education = 9.92, *SD* = 2.99). The AD participants were recruited from local retirement homes. The patients were diagnosed with probable AD dementia of the amnestic form by an experienced neurologist or geriatrician based on the National Institute on Aging-Alzheimer's Association clinical criteria (McKhann et al., 2011). The fact that all patients had the amnesic form of AD is confirmed by their performance on the neuropsychological battery. The control participants, who were often spouses or companions of AD patients, were independent and living at their homes. These participants were matched with the AD patients according to age [$t(55) = .33$, $p > .10$], sex [X^2 (1, $N = 57) = .01$, $p > .10$], and educational level [$t(55) = 1.53$, $p > .10$].

Exclusion criteria for both AD patients and control participants were: significant psychiatric or neurological illness, history of clinical depression, alcohol or drug use. All participants presented no major visual or auditory acuity difficulties that would have prevented completion of study tasks. They freely consented to participate and were able to withdraw whenever they wished. Of the 35 AD participants originally recruited, three participants leaved the study for personal reasons, four due to health problems, and one participant was excluded for ensuing visual impairment associated with recent eye surgery. Of the 35 control participants originally recruited, five participants were excluded for severe executive dysfunction raising doubts about their classification as controls.

1.2. Neuropsychological characteristics

Neuropsychological characteristics of all participants were evaluated with a battery tapping general cognitive functioning, episodic memory, working memory, inhibition, set-shifting, and depression. General cognitive functioning was assessed with the Mini Mental State Exam (MMSE) Folstein et al. (1975). Non-associative hippocampal-dependent verbal memory was evaluated with the task of Grober and Buschke (1987); in its French adaptation (Van der Linden et al., 2004) the participants had to retain

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