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Prospective and retrospective time perception are related to mental time travel: Evidence from Alzheimer's disease

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ABSTRACT

Unlike prospective time perception paradigms, in which participants are aware that they have to estimate forthcoming time, little is known about retrospective time perception in normal aging and Alzheimer's disease (AD). Our paper addresses this shortcoming by comparing prospective and retrospective time estimation in younger adults, older adults, and AD patients. In four prospective tasks (lasting 30 s, 60 s, 90 s, or 120 s) participants were asked to read a series of numbers and to provide a verbal estimation of the reading time. In four other retrospective tasks, they were not informed about time judgment until they were asked to provide a verbal estimation of four elapsed time intervals (lasting 30 s, 60 s, 90 s, or 120 s). AD participants gave shorter verbal time estimations than older adults and younger participants did, suggesting that time is perceived to pass quickly in these patients. For all participants, the duration of the retrospective tasks was underestimated as compared to the prospective tasks and both estimations were shorter than the real time interval. Prospective time estimation was further correlated with mental time travel, as measured with the Remember/Know paradigm. Mental time travel was even higher correlated with retrospective time estimation. Our findings shed light on the relationship between time perception and the ability to mentally project oneself into time, two skills contributing to human memory functioning. Finally, time perception deficits, as observed in AD patients, can be interpreted in terms of dramatic changes occurring in frontal lobes and hippocampus.

1. Introduction

Patients with Alzheimer's disease (AD) exhibit great deviations from true clock time, as they tend to show significant alterations in the judgment of time intervals (Nichelli, Venneri, Molinari, Tavani, & Grafman, 1993). Several investigations have provided support for this idea (Carrasco, Guillem, & Redolat, 2000; Caselli, Iaboli, & Nichelli, 2009; Nichelli et al., 1993; Papagno, Allegra, & Cardaci, 2004; Rueda & Schmitter-Edgecombe, 2009). However, all these studies have been concerned by one facet of time perception, namely, prospective time perception.

In prospective time perception measures, participants are instructed in advance that they have to estimate time intervals. In retrospective measures, on the contrary, they are not. Prospective and retrospective timing are thought to be related to different processes: the first to timing mechanisms, the second to general cognitive mechanisms not specifically related to time, such as memory (Block, 2003). The common feature between retrospective timing and memory may lie in mental time travel. Mental time travel, or the ability to mentally project oneself backward in time to relive past experiences, is the mean feature of autonoetic consciousness characterizing episodic recall (Tulving, 2002; Wheeler, Stuss, & Tulving, 1997). Autonoetic consciousness, or mental time travel, is described as a sense of a subjective experience of time, and according to Tulving's (2002) quote "no sense of subjective time, no mental time travel" (p. 2). According to this assumption mental time travel, allowing episodic recall, is likely to be heavily relying on retrospective time perception, or the subjective experience of the past.

Research on time perception is mainly concerned by prospective timing and only a few papers have focused on retrospective timing in normal aging (Block, Zakay, & Hancock, 1998), and this absence of studies on retrospective timing is even more striking in AD. A typical measure of prospective time perception in AD has been described by Rueda et al. (2009). These authors asked

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17 AD patients and 17 older adults to give a verbal estimation of four time intervals: 10 s, 25 s, 45 s or 60 s. During each interval, the participants had to read aloud series of numbers that appeared on a computer screen. At the end of each interval, they had to answer the question "How long did that trial last?" by providing a verbal estimation in seconds. This procedure showed significant differences between the AD patients and the older adults, with regard to the absolute error measure as well as to the degree to which estimations deviate from true clock time.

In the described procedures, participants were aware that they had to estimate time. This kind of prospective task is widely used in investigations of time perception in AD (Carrasco et al., 2000; Caselli et al., 2009; Nichelli et al., 1993; Papagno et al., 2004). Broadly speaking, the focus on prospective timing is characterizing all the studies on time perception (Block, 2003). Our work is aimed at closing this gap of studies assessing retrospective time perception in normal aging and AD. However, before outlining our objectives, it is of interest to shed light on the neuroanatomical basis of time perception.

Clinical reports suggest a key role of the frontal lobes in the processing of temporal information. Binkofski and Block (1996) described a patient with a left frontal tumor overproducing long duration >60 s. Koch, Oliveri, Carlesimo, and Caltagirone (2002) described the case of a patient with a right prefrontal lesion underestimating long duration. Another case of a patient with bilateral frontal lobe abnormalities was reported by Wiener and Coslett (2008). This patient underproduced and overestimated long duration. Although these studies report contradictory findings, they highlight the implication of frontal areas in time perception. This assumption is further supported by several neuroimaging studies, showing activation of the frontal cortex, particularly the right prefrontal cortex, during the processing of suprasecond intervals (for a review, see, Grondin, 2010). The frontal lobes are not the only neuroanatomical regions associated with time perception. The medial temporal lobe also seems to play a key role in this ability. The classic case study of H.M., who underwent a bilateral medial temporal lobe resection, shows underestimation for durations of more than 20 s in this patient (Richards, 1973). More precisely, patients with left medial temporal lobe lesions tend to show impairments in retrospective and prospective timing, whereas those with right lesions show impairments only in prospective time perception (Noulhiane, Pouthas, Hasboun, Baulac, & Samson, 2007). Taken together, these studies suggest that the frontal and medial temporal lobes are the main cortical regions involved in time perception. Noteworthy is that medial temporal lobe lesions are considered as the neuroanatomical hallmark of AD (McKhann et al., 2011), suggesting how much timing ability can be affected by this disease.

As previously stated, our paper aims to investigate retrospective time perception in normal aging and AD. The slim body of existing literature suggests that retrospective time is subjectively perceived as shorter than prospective time (Zakay & Block, 2004). Therefore, we hypothesize that retrospective time should be perceived as shorter than prospective time. In view of the literature suggesting that past events are perceived as shorter by older adults than by younger adults (e.g., Friedman & Janssen, 2010), we suppose that prospective time will be more underestimated by AD patients than by older or younger adults. Because mental time travel seems to rely on subjective time estimation, we expect significant correlations between mental time travel and time perception. Significant correlations can also be expected between time perception end executive function. The latter ability is believed to reflect frontal functioning (e.g., Denckla, 1996), a region that is also strongly involved in time perception (Binkofski & Block, 1996; Grondin, 2010; Koch et al., 2002; Wiener & Coslett, 2008).

2. Method

2.1. Participants

Sixteen subjects with probable AD ((10 women and 6 men; *Mean* age = 71.94 years, *SD* = 6.74; *Mean* years of formal education = 8.81, *SD* = 2.51, *Mean* Mini Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975) = 21.44, *SD* = 1.78)), 16 healthy older adults (9 women and 7 men; *Mean* age = 68.50 years, *SD* = 7.63; *Mean* years of formal education = 10.50, *SD* = 3.22, *Mean* MMSE = 28.25, *SD* = 1.52), and 16 younger adults (10 women and 6 men; *Mean* age = 22.06 years, *SD* = 3.64; *Mean* years of formal education = 14.88, *SD* = 2.52) voluntarily participated in this study. AD participants, meeting NINCDS–ADRDA criteria (National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association McKhann et al., 1984) for probable AD, were recruited from local retirement homes. There were no significant differences in terms of age, $t(30) = 1.65$, $p > .10$, or sociocultural level, $t(30) = 1.35$, $p > .10$, between these participants and the healthy older adults. The older adults were often the spouses, relatives or friends of the AD participants. Their verbal ability ($M = 30.38$, $SD = 8.69$) was matched with the verbal skills of a group of younger adults ($M = 34.25$, $SD = 7.16$), as measured with the Mill Hill vocabulary test (French translation by Deltour, 1993). Although the years of education were significantly higher in the younger adult group than in the older adults, $t(30) = 4.27$, $p < .001$, no differences in verbal ability were found between both groups on the Mill Hill test, $t(30) = 1.37$, $p > .10$.

All participants were French native speakers and reported normal or corrected-to-normal visual and auditory acuity. The following exclusion criteria were applied: major linguistic impairments, alcohol or drug use, history of clinical depression significant psychiatric or neurological illness, cerebrovascular disease, or traumatic brain damage. All participants were administered a neuropsychological battery including five executive tasks and one episodic memory task. This battery is fully described elsewhere (El Haj & Allain, 2012; El Haj, Fasotti, & Allain, 2012a; El Haj, Fasotti, & Allain, 2012b; El Haj, Postal, & Allain, 2013). The neuropsychological test performance of each group is illustrated in Table 1.

2.2. Procedures

2.2.1. Time perception

Participants were tested individually in an area free from auditory and visual distractions. Experiments took place either in their retirement/own home (for the AD participants and older adults) or at the university (for the younger adults). We also tested participants at their respective age-optimal time of the day. AD participants and older adults were tested in the morning whereas younger adults were examined in the afternoon.

The experimental procedures included four retrospective and four prospective trials. Each trial was lasting 30 s, 60 s, 90 s, or 120 s. The interval of 30–120 s was chosen because estimating delay less than 30 s seems to be preserved in AD patients (Carrasco et al., 2000). On the other hand, Rueda et al. (2009) suggest evaluating estimation of intervals lasting more than 60 s, this to approximate activities of daily life with these patients. The retrospective and prospective trials were assessed in two sessions, spaced one week apart on average. Sessions and trials were counterbalanced across participants. For instance, in one session a participant fulfilled three retrospective (30 s, 90 s, and 120 s) and one prospective tasks (90 s), and in the second session she/he performed one prospective (60 s) and three prospective tasks (30 s, 60 s, and 120 s).