Memory and memory time: Backward and forward telescoping in Alzheimer’s disease

Mohamad El Haj\textsuperscript{a,b,⁎}, Steve M.J. Janss\textsuperscript{c}, Pascal Antoine\textsuperscript{a}

\textsuperscript{a} Univ. Lille, CNRS, CHU Lille, UMR 9193 – SCALab – Sciences Cognitives et Sciences Affectives, F-59000 Lille, France
\textsuperscript{b} CHU de Lille, Unité de Psychogériatrie, Pôle de gérontologie, 59037 Lille, France
\textsuperscript{c} The University of Nottingham-Malaysia Campus, Semenyth, Malaysia

**Abstract**

Backward and forward telescoping are opposite timing biases. The former refers to misattributing events to earlier dates, whereas the latter refers to misattributing events to later dates. The present study investigated both biases in participants with Alzheimer’s Disease (AD) and healthy older adults, matched on age, sex, and education level. Participants were asked to recall the years when five remote and five recent public events had occurred. They were also assessed with a cognitive and clinical battery that included a context memory task on which they had to associate letters and locations. Results showed backward telescoping for recent events and forward telescoping for remote events in AD participants and older adults. Furthermore, poorer context recall was observed in AD participants and older adults displaying backward telescoping than in those displaying forward telescoping. These findings suggest an association between the amount of contextual information recalled and the direction of the timing bias. Backward telescoping can be associated with deficiencies in retrieving context characteristics of events, which have been associated with retrograde amnesia and pathological changes to the hippocampus in AD.

**Keywords:** Alzheimer’s disease, Context memory, Hippocampus, Subjective timing

**1. Introduction**

**1.1. Memory and timing in Alzheimer’s disease**

The relation between time and memory has been subject to substantive theoretical and empirical speculations as the natural course of forgetting has been considered to be the result of the passage of time. As time goes on, memory retrieval decreases and the ability to remember forgetting has been considered to be the result of the passage of time. As such, it is important to understand the nature of memory and timing in Alzheimer’s disease (AD).

The hippocampus plays a crucial role in memory and timing, particularly in tasks that require the retrieval of specific events. It has been extensively studied since the work of Ebbinghaus (1885–1964). Time not only influences memory recall, it is also a part of memory. According to Tulving (2002), episodic memory allows storage of information about temporally dated events and temporal-spatial relations among these events. Tulving (2002) also argued that episodic recall triggers mental time travel (i.e., the ability to mentally project oneself in time to re-experience specific events), suggesting a strong association between memory and time.

In regard to Alzheimer’s disease (AD), clinical assessment usually opens with evaluation of timing ability. For instance, the Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975), a cognitive screening instrument that is widely used in AD, begins with questions about memory for time (i.e., “what is the date today?”, “what is the season?” “what day of the week is it?”). The clinical interest in timing ability is reflected by a substantial body of empirical research assessing timing errors in AD (El Haj & Kapogiannis, 2016). For instance, Rueda and Schmitter-Edgecombe (2009) asked individuals with AD to read aloud series of numbers that appeared on a computer screen during four time intervals: 10 s, 25 s, 45 s or 60 s. At the end of each interval, participants answered how long the trial had lasted by providing a verbal estimation in seconds. These procedures showed deviations from objective time in individuals with AD, consistent with a large body of literature on this topic (Carrasco, Guillem, & Redolat, 2000; Caselli, Iaboli, & Nichelli, 2009; El Haj, Moroni, Samson, Gasotti, & Allain, 2013; El Haj, Omigie, & Moroni, 2014). Although this literature has shown distortions in timing in individuals with AD, it has dealt with short intervals in laboratory settings. The aim of the present study was therefore to replicate these findings on memory for everyday life by asking individuals with AD to estimate the dates of public events.

Broadly speaking, memory for public events in AD has been subject to extensive evaluation. Meeter, Eijsackers, and Mulder (2006) presented open-ended questions to AD participants about remote events that had occurred during the 1970s, 80s and 90s (e.g., “Who became the first black president of South Africa in the 1990s?”). Results showed AD-related decline in memory for public events, reflecting a body of empirical evidence in this area (Beatty, Salmon, Butters, Heindel, & Granholm, 1988; Dorrego et al., 1999; El Haj, Gandolphe, ...
In regard to memory for the dates of public events, Sagar, Cohen, Sullivan, Corkin, and Growdon (1988) assessed this ability by asking AD participants to estimate the dates when pictures of public events were taken, such as a picture depicting the shooting of Lee Harvey Oswald after his arrest for the assassination of President John F. Kennedy in 1963. Results showed AD-related difficulties in retrieving the dates of public events, a finding that was replicated by Muller et al. (2014) who asked AD participants to provide the years when public events have occurred (from 1954 to 1999) and also found low dating accuracy in AD. These two studies suggest poor memory for the dates of public events in AD, but they did not investigate the direction of the timing bias. In other words, they did not evaluate whether individuals with AD tend to judge public events to occur farther back in time (i.e., backward telescoping) or more recently than is actually the case (i.e., forward telescoping).

1.2. Direction of dating errors

Backward telescoping and forward telescoping for dates of public events has been assessed by Janssen, Chessa, and Murre (2006) who asked a large population of 1579 participants (M age = 44.29 years, SD = 14.53) to answer questions, such as “When did Princess Diana die in Paris?”. This study showed a tendency to judge recent events to have occurred farther back in time (i.e., backward telescoping) and remote events to have occurred more recently than was actually the case (i.e., forward telescoping).

Our study tested backward and forward telescoping in individuals with AD, because it would shed light on the mechanisms underlying these timing biases. According to Friedman (1993), memory for the times of events depends, among other factors, on contextual features (e.g., the event took place at university) that allow inferring when the event probably occurred (e.g., the event probably took place when I was undergraduate). In a similar vein, Batin, Van der Linden, Michel, and Friedman (2004) showed that reduced timing ability, as may be observed in normal aging, was due to difficulties using contextual information to infer when events have occurred.

The role of context memory can also account for the direction of bias (i.e., backward vs. forward telescoping). This assumption follows the accessibility principle, which states that the amount of knowledge about an event determines whether the event is perceived to be recent or old (Brown, Rips, & Shevell, 1985). People may infer that, if they recall few details about an event, the event must have happened a long time ago and, if they recall many details, the event must have happened recently. In accordance with this principle, Brown et al. (1985) found that people judge events they knew much about as occurring more recently than the events in fact had, and events they knew little about as occurring more remotely than actually was the case.

Besides the contextual account, timing deviations in AD can be attributed to hippocampal dysfunction. Studies suggest that lesions to the hippocampus can result in alterations in the accuracy and precision of timing of short and long intervals (for a review, see MacDonald, Fortin, Sakata, & Meck, 2014). More precisely, the discovery of ‘time cells’ in the hippocampus that provide a neural support for time processing has suggested the hippocampus is crucial for remembering the flow of continuous events and bridging the temporal gaps between discontinuous events (Eichenbaum, 2013; Howard & Eichenbaum, 2013; MacDonald, Carrow, Place, & Eichenbaum, 2013).

Similar to hippocampal ‘place cells’ that are activated when a spatial cue is processed, ‘time cells’ are implied in the formation and retrieval of temporal representations. The hippocampal neural ensembles process and segment temporal flow in much the same way that they process special features of memories (MacDonald et al., 2014). The hippocampal involvement in timing can also be illustrated with a lesion study that found that patients with left medial temporal lobe lesions, including the hippocampus, had deficits in verbal estimation and production of short time intervals (Noulhiane, Pouthas, Hasboun, Baulac, & Samson, 2007). Interestingly, medial temporal lobe, and especially the hippocampus, are among the first brain regions affected by the amyloid deposition in AD, and are therefore structurally and functionally compromised in the disease (El Haj, Antoine, Nandrino, & Kapogiannis, 2015; El Haj et al., 2016; Pennanen et al., 2004), which may provide a neuroanatomical explanation for timing deviation in AD.

1.3. The present study

To summarize, research suggested deviations in AD for the timing of short intervals (Carrasco et al., 2000; Caselli et al., 2009; El Haj, Moroni, et al., 2013; El Haj et al., 2014), and the dating of public events (Muller et al., 2014; Sagar et al., 1988). The present paper aimed at extending this literature by investigating whether AD participants would demonstrate forward telescoping (i.e., misattributing events to later date) or backward telescoping (i.e., misattributing events to previous date) when remembering the dates of remote and recent public events.

Another aim of this paper was to test relationship between context recall and forward telescoping. This second hypothesis is based on the work by Brown et al. (1985), who suggested forward telescoping for events about which participants know much and backward telescoping for events about which participants know less. To test this hypothesis, AD participants and control older adults were asked to provide the years when remote and recent public events had occurred. They were also assessed on context memory with a task in which they had to process associations between letters and their corresponding locations (i.e., encoding context). Besides its contextual feature, this associative task provides an appreciation of hippocampal function as this brain region is implied in associative mechanisms (Langton & Wood, 2010; Mayes, Montaldi, & Migo, 2007; Weniger, Bousein, & Irel, 2004). We expected poorer context recall in AD participants and older adults that displayed mostly backward telescoping than in those that displayed mostly forward telescoping.

2. Method

2.1. Participants

The study included 24 participants with a clinical diagnosis of probable mild AD (17 women and 7 men; M age = 73.71 years, SD = 6.49; M years of formal education = 8.92; SD = 2.78) and 26 control older adults (19 women and 7 men; M age = 71.38 years, SD = 7.40; M years of formal education = 9.85, SD = 2.71). The AD participants were recruited from local retirement homes. They were diagnosed with probable AD dementia by an experienced neurologist or geriatrician based on NINCDS-ADRDA clinical criteria (McKhann et al., 2011). The control older adults were often spouses or companions of AD participants. They were independent and living at home. These older adults were matched with the AD participants according to sex \[X^2 (1, N = 50) = 0.03, p > 0.10\], age \(t(48) = 1.16, p > 0.10\), and education level \(t(48) = 1.15, p > 0.10\).

All participants freely consented to participate and were allowed to withdraw whenever they wished. Exclusion criteria were: significant neurological or psychiatric illness, history of alcohol or drug use, and major visual or auditory acuity difficulties that could prevent assessment. Clinical and cognitive characteristics of all participants were assessed with a comprehensive battery, detailed below.

2.2. Procedure and materials

Participants were tested individually in a quiet room in their residency or home. They were briefed that the study concerned cognitive
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