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Time reproduction during high and low attentional tasks in Alzheimer's Disease "A watched kettle never boils"

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ABSTRACT

A wealth of empirical evidence suggests that directing attention to temporal processing increases perceived duration, whereas drawing attention away from it has the opposite effect. Our work investigates this phenomenon by comparing perceived duration during a high attentional and a low attentional task in Alzheimer's Disease (AD) patients since these participants tend to show attentional deficits. In the high attentional task, AD patients and older adults were asked to perform the interference condition of the Stroop test for 15 s while in the low attentional task, they had to fixate on a cross for the same length of time. In both conditions, participants were not aware they would be questioned about timing until the end of the task when they had to reproduce the duration of the previously-viewed stimulus. AD patients under-reproduced the duration of previously-exposed stimulus in the high attentional relative to the low attentional task, and the same pattern was observed in older adults. Due to their attentional deficits, AD patients might be overwhelmed by the demand of the high attentional task, leaving very few, if any, attentional resources for temporal processing.

1. Introduction

"A watched kettle never boils" and "Time flies when you're having fun" are just two well-known adages that allude to the intimate relationship between attention and timing. Further evidence of this link is provided by experimental data showing that temporal intervals during low attentional tasks are perceived longer than those during high attentional tasks (for a review, see, Grondin, 2010; Phillips, 2012). With regard to the latter, it has been suggested that duration judgments decrease as task complexity increases because the greater attentional resources demanded by a task leave fewer attentional resources available for time processing (Zakay & Block, 1996).

To explain the link between attention and timing, Zakay and Block (1996) in which a pacemaker that generates pulses and an accumulator that counts them are separated by an attentional gate. They suggested that when an organism pays attention to time the gate opens wider, allowing the passage of more pulses to the accumulator per unit time, and therefore leading to an overestimation of time. Analogously, in situations where attention is not focused on the elapsing time, the number of accumulated pulses decreases, and consequently, time duration will be underestimated. Also arguing that duration over-estimation occurs when attentional resources are focused on timing, Dutke (2005) went so far as to suggest that the target of attentional resources may be one of the most important cognitive factors influencing duration judgments.

Attention is remarkably attenuated by aging (for a review, see, Verhaeghen & Cerella, 2002) and therefore how the duration of low and high attentional tasks is perceived and estimated by older adults is a question of great interest. Several authors (Craik & Hay, 1999; Gruber, Wagner, & Block, 2004) have suggested that a decline in attentional resources will contribute to acceleration of subjective time with aging. Specifically, it has been suggested that because older adults have diminished attentional resources, their sense of prospective time should shorten, particularly in intervals characterized by high attentional demands (Gruber et al., 2004).

Those with Alzheimer's Disease (AD) also present an interesting group to study as they often present with disorders of temporal processing whereby they tend to show significant alterations in the judgment of time (Carrasco, Guillem, & Redolat, 2000; Caselli,

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Iaboli, & Nichelli, 2009; El Haj, Moroni, Samson, Fasotti, & Allain, 2013; Nichelli, Venneri, Molinari, Tavani, & Grafman, 1993; Papagno, Allegra, & Cardaci, 2004; Rueda & Schmitter-Edgecombe, 2009). In one study (Carrasco et al., 2000), AD patients were asked to produce three prospective empty intervals, lasting 5 s, 10 s, or 25 s. Results showed that in all three conditions, they produced intervals that were not only greater than those produced by control participants but also that differed significantly from real intervals. In another study, Papagno et al. (2004) asked AD patients to prospectively estimate the duration of one low attentional and two high attentional tasks. In the low attentional task, participants had to pronounce syllables. In the high attentional tasks, they had to (1) press a key each time a ball entered a specific target square, and (2) repeat back sequences of digits. Here, as well, the AD patients overestimated time durations during all the three tasks, particularly the high attentional ones.

Critically, while results reporting overestimation of duration of low attentional tasks in AD patients like those from Carrasco et al. (2000) and Papagno et al. (2004) might be expected, those from Papagno et al. (2004), also reporting overestimation of high attentional ones may be considered unexpected. Indeed, while the overestimation of the 'empty' intervals such as used in the study of Carrasco et al. (2000) may be explained as the participants deploying their attentional processes on timing (Zakay & Block, 1996), in light of the previously described attentional theories (Dutke, 2005; Zakay & Block, 1996), high attentional tasks would be expected to be underestimated not overestimated as was found by Papagno et al. (2004).

One possibility is that these results are reconcilable by the specific nature of the temporal task employed by Block (Block, Hancock, & Zakay, 2010; Grondin, 2008, 2010; Mioni, Mattalia, & Stablum, 2013) or by the prospective nature of the tasks used by Carrasco et al. (2000) and Papagno et al. (2004). In prospective tasks, participants, being aware of timing, deploy their attentional resources toward timing processes and consequently overestimate time. This assumption fits well with the model of Zakay and Block (1996). Following the assumption of Zakay and Block (1996), we suggest that the previous use of prospective tasks in papers dealing with time perception in AD has led to a bias of the usual observation that duration judgment decreases as task complexity increases. Our paper addresses this confound in the literature by comparing time estimation during low attentional and high attentional tasks using a retrospective approach.

Temporal discrimination tasks are held to activate the 'cortico-thalamic-basal ganglia timing circuit' – an extended network encompassing basal ganglia, and generally right lateralized prefrontal, superior temporal and inferior parietal cortices (Coull, Vidal, Nazarian, & Macar, 2004; Morillon, Kell, & Giraud, 2009; Rao, Mayer, & Harrington, 2001). The role of the frontal cortices is believed to be the 'reading out' of firing activity of the spiny neurons comprising the cortico-thalamic-basal ganglia timing circuit (for a review see Merchant, Harrington, & Meck, 2013). Impairments to the functioning of these frontal areas, due to for instance aging or AD, may be expected therefore to also compromise performance on temporal discrimination tasks.

In summary, it is well established that directing attention to temporal processing increases perceived duration, whereas distracting attention from time decreases perceived duration (Dutke, 2005; Zakay & Block, 1996). Research in AD (Papagno et al., 2004) may have failed to support such a pattern due to its use of prospective tasks that direct attention to time. We addressed this shortcoming by assessing perceived duration of low attentional and high attentional tasks using a retrospective approach. In line with the vast body of literature on this subject (Dutke, 2005; Graf & Grondin, 2006; Phillips, 2012; Zakay & Block, 1996), and especially aging research (Craik & Hay, 1999; Gruber et al., 2004), we predicted that AD patients would underestimate the duration of tasks associated with high attentional relative to low attentional load. Specifically, given that the frontal lobes are involved in governing attentional processing and timing mechanisms (Merchant et al., 2013) and further given that these areas become impaired in aging and AD (Raz, 2000), we predicted greater time deviations in high attentional relative to low attentional tasks in both normal aging and AD.

2. Method

2.1. Participants

Seventeen subjects with probable AD and 18 healthy older adults voluntarily participated in the present study. Details of participants' demographics and neuropsychological performance are given in Table 1. AD participants, meeting NINCDS-ADRDA (National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association McKhann et al., 1984) criteria for probable AD, were recruited from local retirement homes. Healthy older adults were often the spouses, relatives or friends of the AD participants. In order to assess their cognitive ability, all the participants were assessed with a neuropsychological battery including (1) general cognitive ability: the Mini Mental State Examination, the maximum score was 30 points (Folstein, Folstein, & McHugh, 1975), (2) spontaneous flexibility: participants were given 2 min to generate as many words beginning with the letter P, (3) working memory: participants repeated a series of numbers in the forward digit span task (in the reverse order for the backward digit task), and (4) episodic memory: on the 5-words test (Dubois et al., 2002), participants had to remember, on a 2 min-delayed task, five words in free recall and, if necessary, a categorical cued recall. In general, AD patients showed poorer neuropsychological performance than older adults, confirming their diagnosis.

All participants were French native speakers and reported normal or corrected-to-normal visual and auditory acuity. None of them had encountered the loss of a relative within 1 month before the assessment. Exclusion criteria were: traumatic brain damage, cerebrovascular disease, significant psychiatric or neurological illness, history of clinical depression and alcohol or drug use.

2.2. Apparatus

A laptop computer with a 15-inch LCD display was used for presenting the timing tasks. Stimuli presentation and response recording were controlled using the software package Psychopy (Peirce, 2007).

Table 1
Demographic and neuropsychological characteristics of Alzheimer's Disease patients and healthy older adults.

	Alzheimerer	Older
Number of participants	17	18
Gender (m/f)	$(11/6)^{n/s}$	(12/6)
Age in years	$71.65\ (6.53)^{n/s}$	68.28 (7.90)
Education in years	$9.00\ (2.55)^{n/s}$	10.28 (3.14)
MMSE (general cognitive ability)	$21.53\ (1.77)^{**}$	28.22 (1.59)
Fluency (spontaneous flexibility)	$17.47\ (5.85)^{*}$	23.89 (5.82)
Forward span (working memory)	$4.24\ (1.25)^{**}$	6.17 (1.42)
Backward span (working memory)	$3.53\ (1.23)^{n/s}$	4.17 (1.65)
Five-words (episodic memory)	$3.53\ (1.28)^{**}$	4.78 (0.43)

Note. MMSE = Mini Mental State Examination, Standard deviations given in parentheses; $^{n/s}$ the difference with the following group was non-significant; the difference between groups was significant at: $^{*}p < .01$, $^{**}p < .001$.