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Age-related changes in duration reproduction: Involvement of working memory processes

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Abstract

The aim of the present research was to study age-related changes in duration reproduction by differentiating the working memory processes underlying this time estimation task. We compared performances of young and elderly adults in a duration reproduction task performed in simple and concurrent task conditions. Participants were also administered working memory tests to measure storage and central executive functions. Findings indicated a differential involvement of working memory storage and central executive functions in age-related differences in temporal tasks. The limited storage capacities explained age-related changes in the simple task of duration reproduction, and the dysfunctioning of central executive functions accounted for age-related changes in duration reproduction performed in a concurrent task condition, which involves greater attentional resources.

Keywords: Aging; Estimation of time; Central executive; Working memory

1. Introduction

Time is crucial for our everyday activities. The estimation of how much time it will take is often a key element for our decisions: for example, in a conversation we take our speaking turn after having judged that a pause was long enough. Time estimation is a complex process, involving an internal time base and several processes such as attention, memory and decision-making (Gibbon, Church, & Meck, 1984). According to the scalar expectancy theory (SET) (Gibbon et al., 1984), during the time interval to be estimated and under attentional supervision, a time base emits pulses which are stored in an accumulator (working memory) and compared with previously memorized durations stored in long-term memory to decide on the adequate temporal response. Processes underlying time processing undergo age-related effects, several studies demonstrating that older participants asked to finger tap at their preferred rate spontaneously choose a slower motor tempo than younger adults, indicating that the time base rate slows down with age (Baudouin, Vanneste, & Isingrini, 2004; Vanneste, Pouthas, & Wearden, 2001). Moreover, memory deficits and decreases in attentional resources are classically observed in aging (Mc Dowd & Shaw, 2000; Zacks, Hasher, & Li, 2000). Thus, modifications in time estimation can be explained by age-related slowing of the internal clock rate and/or deficits of memory capacities or attentional resources (Block, Zakay, & Hancock, 1998; Craik & Hay, 1999; Perbal, Droit-Vollet, Isingrini, & Pouthas, 2002; Vanneste & Pouthas, 1999).

Several studies have shown that a duration reproduction task is closely dependent on working memory capacities (Baudouin, Vanneste, Isingrini, & Pouthas, 2006; Fortin & Couture, 2002; Perbal et al., 2002). This task consists of two phases: in the first, a duration is estimated and memorized, and in the second it is reproduced after a short delay. This

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involves storing the accumulated pulses according to the duration to be reproduced (first phase), followed by reproduction proper (second phase) in which the currently accumulated pulses are compared with those previously stored in working memory. Relationships between working memory, attention, and duration reproduction in aging have been studied by Perbal et al. (2002). While the authors did not observe age-related difference in the control counting condition, they found that older participants reproduced durations less accurately than younger adults when attention was divided between temporal and non-temporal information processing tasks (dual-task paradigm with a concurrent digits reading condition). This age-related deficit was primarily related to working memory deficits (Perbal et al., 2002).

According to Baddeley's model, working memory is responsible for the processing and temporary storage of information (Baddeley, 1986). This model is a three-unit system with a central executive acting as supervisor directing attention and coordinating the activities of the other two storage components, called peripheral slave systems, i.e. the phonological loop system and the visuo-spatial sketchpad (Baddeley, 1986). Experimental evidence supports the existence of these different components in working memory, notably that of the central executive (Baddeley, 1996; Doiseau & Isingrini, 2005; Van der Linden, Coyette, & Seron, 1992). With regard to Norman and Shallice's supervisory attentional system (SAS) (see Shallice, 1988), Baddeley (1986) suggested that the SAS and the central executive component of the working memory system are essentially the same structure located in the prefrontal cortex areas of the brain (for review, see Smith & Jonides, 1997, & D'Esposito, 2001). Division of attention has also generally been attributed to the central executive component of working memory (Baddeley, 1986, 1996). In a dual-task paradigm, participants have to simultaneously perform two different tasks, requiring attention to be divided between two types of information, thus involving the working memory central executive component (Baddeley, 1986). With aging, attentional resources, the central executive and storage capacities of working memory decrease (Van der Linden, Brédart, & Beerten, 1994; for review see Verhaeghen, Marcoen, & Goossens, 1993).

Previous results have suggested that the ability to reproduce duration is closely related to working memory capacities (Baudouin et al., 2006; Fortin & Couture, 2002; Perbal et al., 2002). It can therefore be assumed that temporal processing requires differential involvement of working memory components depending on the attentional resource demands. However, none of these studies considered working memory as a multi-system, and used multiple measures to examine concurrently the involvement of storage and central executive components of working memory. Accordingly, the aim of the present study was to provide a better explanation of age-related modifications in time estimation, looking in greater depth at the differentiation of the working memory processes underlying duration reproduction. Participants were asked to perform a duration reproduction task in two experimental conditions: simple task and concurrent task. The concurrent task can be viewed as an experimental condition similar to everyday life situations in which temporal information is rarely evaluated alone; generally, we are confronted with a wide range of durations to which we have to adjust. Participants also performed working memory tests measuring storage and central executive components. We hypothesized that older participants would be significantly less accurate in the duration reproduction task than younger ones, particularly in the concurrent task condition. To investigate the differential roles of working memory components in the two conditions, we computed correlations between the reproduced durations and working memory scores. Because reproduction is a time estimation task traditionally associated with working memory capacities, we hypothesized that age-related deficits in working memory would explain changes in temporal information processing. More precisely, we assumed that duration reproduction performed in the simple task condition would be closely related to the working memory storage measure, whereas in the concurrent task condition it would be related to both the storage component measure and the more specific central executive component measure. The simple reproduction task consisted in storing and maintaining pulses, closely involving working memory storage capacities, whereas reproduction with a concurrent task involved the working memory functions of both storage (as in the simple reproduction task) and coordination of divided attention and information attributed to the central executive. These putative relationships were investigated by hierarchical regressions, to determine the respective weights of the two factors assumed to explain age-related differences in duration reproduction, i.e. decrease of storage and dysfunctioning of the working memory central executive with aging.

2. Method

2.1. Participants

Forty-four volunteers took part in this study: 23 young adults, aged 20–35 (12 females and 11 males, mean age = 27.745, $SD = 3.69$), 21 elderly adults, aged 60–81 (15 females and 6 males, mean age = 71.71, $SD = 5.09$). All participants reported being in good physical and mental health, and free from medication known to affect the central nervous system. The older participants had scores within normal limits ($\geqslant 27$) on the Mini-Mental Status Examination (MMSE, Folstein, Folstein, & McHugh, 1975). All participants had received at least eight years of schooling. The young adults had more years of education than the elderly (15.30 [1.79] and 10.14 [1.59], respectively, $p < .001$). However, the age groups did not differ on vocabulary scores (assessed by the Mill Hill Test, Raven, 1982) (27.48 [2.94] and 27.14 [3.91], respectively, $p < 1$). Participants were also within normal limits (11 points) on the