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Distinct mechanisms for the impact of distraction and interruption on working memory in aging

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Abstract

Interference is known to negatively impact the ability to maintain information in working memory (WM), an effect that is exacerbated with aging. Here, we explore how distinct sources of interference, i.e., *distraction* (stimuli to-be-ignored) and *interruption* (stimuli requiring attention), differentially influence WM in younger and older adults. EEG was recorded while participants engaged in three versions of a delayed-recognition task: no interference, a distracting stimulus, and an interrupting stimulus presented during WM maintenance. Behaviorally, both types of interference negatively impacted WM accuracy in older adults significantly more than younger adults (with a larger deficit for interruptions). N170 latency measures revealed that the degree of processing both distractors and interruptors predicted WM accuracy in both populations. However, while WM impairments could be explained by excessive attention to distractors by older adults (a suppression deficit), impairment induced by interruption were not clearly mediated by age-related increases in attention to interruptors. These results suggest that distinct underlying mechanisms mediate the impact of different types of external interference on WM in normal aging.

Keywords: EEG; Aging; Working memory; Distraction; Human

1. Introduction

Working memory (WM) involves the ability to store and manipulate information in mind over brief periods of time (Baddeley, 2003).[1] WM involves multiple cognitive subsystems responsible for functions such as storage, rehearsal and executive functions (Miyake and Shah, 1999). While the rehearsal of information is a fundamental aspect of WM, executive control processes are necessary for optimal performance. This includes the ability to inhibit interference from information that intervenes during the period of memory maintenance (Sakai et al., 2002). Such interference has a negative impact on WM performance, likely due to disruption of active top-down control processes required to maintain relevant information (Baddeley, 1986; Sakai, 2003; Sakai and Passingham, 2004; Sreenivasan and Jha, 2007; Yoon et al., 2006), as well as bottom-up disruption of stimulus representations in sensory cortices (Miller et al., 1996).

Here we present a framework in which interference of WM maintenance may be caused by both internal (i.e., intrusions and diversions- internally generated thoughts/images (Forster and Lavie, 2009)) and external factors (i.e., distraction and interruption (Clapp et al., 2009)) (Fig. 1); the latter of which is the focus of the current study. *Distraction* involves encountered stimuli that are irrelevant and intended to be ignored (e.g., radio playing while attempting to rehearse a phone number). This filtering of irrelevant sensory input is thought to be dependent on top-down suppression signals from the prefrontal cortex (PFC) (Chao and Knight, 1995, 1998). *Interruption* by external interference involves intervening stimuli that are purposefully attended to as an aspect of a secondary task (e.g., a phone call while holding something in mind). An

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[1] While some cognitive psychologists use the term šhort-term memoryẗo refer to tasks requiring only maintenance processes and reserve the term ẅorking memoryf̈or tasks requiring maintenance plus processing (e.g., manipulation, selection, updating), in the current manuscript the term working memory refers to the brief retention of information, with and without manipulation, when it is used to guide subsequent behavior.

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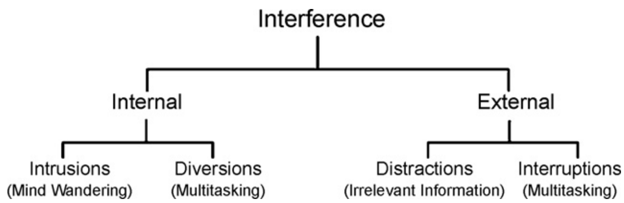

Fig. 1. Interference conceptual framework.

interruption requires a reallocation of cognitive resources, as well as processes involved in reactivating the disrupted representation afterwards, which is reliant on medial temporal lobe structures and the PFC (Sakai and Passingham, 2004; Sakai et al., 2002). For conceptual purposes, WM maintenance in the face of interruptions can be placed under the broader category of multitasking, which involves concurrently executed goal-directed operations (Salvucci and Taatgen, 2008; Salvucci et al., 2009). Recent network characterization with fMRI functional connectivity analysis revealed distinct mechanisms of influence by these two types of interference on WM maintenance (Clapp et al., 2009). Encoded information is retained throughout a maintenance period even in the presence of distraction via connectivity between the PFC and sensory cortex, while interruption results in a disruption of this connectivity, and reactivation in the post-interruption maintenance period. Given such distinct mechanisms, the impact of distraction and interruption on WM in older adults, as well as the underlying etiology of a negative influence by these two types of interference, may be different.

It has been well demonstrated that WM performance declines with age (Dobbs and Rule, 1989; Foos and Wright, 1992; Salthouse et al., 1991). However, it is believed that rote maintenance abilities are relatively spared in healthy aging (Craik and Jennings, 1992), and WM deficits are largely observed when executive processes are taxed (e.g., in the setting of interference or high memory load) (Gazzaley et al., 2007). Previous research has demonstrated that older adults have significant impairment in WM performance when they encounter interference, beyond that experienced by younger adults, (Gazzaley et al., 2008, 2005b; Reuter-Lorenz and Sylvester, 2005). Internal interference, or intrusions, have been reported to disrupt an older adults' ability to maintain information, as in studies of proactive interference (Emery et al., 2008; Lustig et al., 2001) and internally generated thoughts (Borella et al., 2007). External interference by distraction disrupts WM performance in older individuals (Hasher et al., 1999) and is attributed to a deficit in top-down suppression of irrelevant information early in the visual processing stream (Gazzaley et al., 2008, 2005b). To our knowledge, no previous studies have directly addressed the impact of interruptions on WM in an older population. However, it has been shown that older adults are more disadvantaged than younger individuals when they divide their attention (Craik and Salthouse, 2000; Crossley and Hiscock, 1992; Kramer et al., 1995; Kramer and Larish, 1996; McDowd and Craik, 1988; Park et al., 1989; Tsang and Shaner, 1998). These differences persist even when controlled for age-related performance decrements on a single task (Crossley and Hiscock, 1992). Likewise, the ability to multitask diminishes in older adults, as assessed by driving simulations (Chaparro et al., 2005; Ponds et al., 1988), task management tests (Craik and Bialystok, 2006) and gait/posture experiments (Doumas et al., 2008; Faulkner et al., 2007).

The goal of this study was to explore the influence of these different types of external interference on WM in normal aging. To accomplish this, as well as to investigate the neural basis of any age-related behavioral effects, electroencephalography (EEG) was used to record neural activity as participants engaged in a cognitive paradigm assessing WM in the setting of distraction and interruption. Interference was introduced during the maintenance period of a simple delayed-recognition task. We performed this experiment in a group of healthy older participants and compared the data to those obtained from a population of younger adults who recently participated in the same experiment (Clapp et al., 2009). The inclusion of both types of external interference in the same experiment allows us to directly compare the consequences of age-related alterations in the suppression of irrelevant information and multitasking on WM performance. Neural analysis focused on early ERP measures associated with visual stimulus representation and attentional control

2. Methods

2.1. Participants

EEG was recorded from 24 healthy older participants (ages 61–82, mean 69.4 years) as they performed the experimental task. Participants had normal or corrected-to-normal vision, volunteered, gave consent, and were monetarily compensated to participate in the study. Participants were pre-screened, and none used any medication known to affect cognitive state. Three participant's neural and behavioral data were removed due to unacceptable noise in the EEG data.

In the experiment involving younger adults, EEG was recorded from 21 healthy younger participants (ages 18–30, mean 23.3, 14 males) as they performed the identical tasks (Clapp et al., 2009). One participant's neural and behavioral data were removed from analysis due to a failure to perform the task (no responses to probes), which was corroborated both behaviorally and neurally.

2.2. Neuropsychological testing

Participants in the older age group were screened to ensure intact executive and memory function. 11 neuropsychological tests were used, including: MMSE (Folstein et al., 1975), geriatric depression (Yesavage et al., 1982), visual-spatial function (copy of a modified Rey-Osterrieth figure), visual-episodic memory (memory for details of a modified Rey-Osterrieth figure), visual-motor sequencing (trail mak-