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Making sense of age-related distractibility: The critical role of sensory modality

Maria J.S. Guerreiro [a,*], Dana R. Murphy [b], Pascal W.M. Van Gerven [a]

[a] Department of Neuropsychology and Psychopharmacology, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands
[b] Department of Psychology, Nipissing University, North Bay, Ontario, Canada

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ABSTRACT

Older adults are known to have reduced inhibitory control and therefore to be more distractible than young adults. Recently, we have proposed that sensory modality plays a crucial role in age-related distractibility. In this study, we examined age differences in vulnerability to unimodal and cross-modal visual and auditory distraction. A group of 24 younger (mean age = 21.7 years) and 22 older adults (mean age = 65.4 years) performed visual and auditory *n*-back tasks while ignoring visual and auditory distraction. Whereas reaction time data indicated that both young and older adults are particularly affected by unimodal distraction, accuracy data revealed that older adults, but not younger adults, are vulnerable to cross-modal visual distraction. These results support the notion that age-related distractibility is modality dependent.

1. Introduction

According to one of the most influential theories of cognitive aging, advancing age is accompanied by inhibitory decline (Hasher & Zacks, 1988), such that older adults have – among other inhibitory deficits – a reduced ability to ignore distracting stimuli (Lustig, Hasher, & Zacks, 2007). Evidence for this theory is based on experimental paradigms in which participants attend to some stimuli (or stimulus dimensions) while ignoring other stimuli (or other stimulus dimensions), and which have thus far been mostly conducted within the same sensory modality. For example, older adults have been shown to be more distractible than younger adults in both visual and auditory Stroop tasks (e.g., West & Alain, 2000; Wurm, Labouvie-Vief, Aycock, Rebucal, & Koch, 2004), in both visual and auditory Simon tasks (e.g., Pick & Proctor, 1999; Van der Lubbe & Verleger, 2002), and in both reading-with-distraction (e.g., Connelly, Hasher, & Zacks, 1991) and listening-in-noise tasks (e.g., Helfer & Freyman, 2008; Tun, O'Kane, & Wingfield, 2002; but see e.g. Murphy, McDowd, & Wilcox, 1999; Schneider, Daneman, Murphy, & Kwong See, 2000).

Experimental paradigms in which relevant and irrelevant information are presented in different sensory modalities have been considerably less investigated. Nevertheless, the few existing studies have yielded mixed results. In fact, studies of cross-modal visual attention – in which participants are required to attend to information presented in the visual modality and to ignore information presented in the auditory modality – have provided evidence for both age-dependent and age-independent cross-modal auditory distractibility. For example, age-equivalent cross-modal auditory distraction has been demonstrated in studies using cross-modal visual Simon tasks (Guerreiro, Adam, & Van Gerven, submitted for publication; Proctor, Pick, Vu, & Anderson, 2005; Simon & Pouraghabagher, 1978), cross-modal visual spatial cueing tasks (Guerreiro, Adam, & Van Gerven, 2012), and irrelevant speech paradigms (e.g., Beaman, 2005; Bell & Buchner, 2007; Enmaker, 2004; Rouleau & Belleville, 1996; Van Gerven & Murphy, 2010; but see Bell, Buchner, & Mund, 2008; Molander & Bäckman, 1990), whereas age-related cross-modal auditory distraction has been shown in studies using cross-modal oddball tasks (Andrés, Parmentier, & Escera, 2006; Parmentier & Andrés, 2010).

Studies of cross-modal auditory attention – in which participants must attend to information presented in the auditory modality and ignore information presented in the visual modality – have likewise yielded contradictory results. In fact, in the only four such studies that have been conducted to date, older adults were shown to be as distracted as young adults by visual irrelevant stimuli during an auditory verbal memory task (Einstein, Earles, & Collins, 2002), a cross-modal auditory Simon task (Guerreiro et al., submitted for publication) and a cross-modal auditory spatial cueing task

* Corresponding author at: Department of Neuropsychology and Psychopharmacology, Faculty of Psychology and Neuroscience, Maastricht University, P.O. Box 616, 6200 MD Maastricht, The Netherlands. Tel.: +31 43 3884255; fax: +31 43 3884560.
E-mail address: M.deSousaGuerreiro@maastrichtuniversity.nl (M.J.S. Guerreiro).

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(Guerreiro et al., 2012), but significantly more distracted than younger adults by visual irrelevant stimuli during an auditory *n*-back task (Guerreiro & Van Gerven, 2011).

Based on such differences in age-related vulnerability to distraction across sensory modality combinations, we have recently hypothesized that sensory modality plays a crucial role in age-related distractibility (Guerreiro, Murphy, & Van Gerven, 2010; Guerreiro & Van Gerven, 2011). According to this hypothesis, age-related distraction is more likely to occur with unimodal than with cross-modal distraction and if distraction is visual, regardless of the relevant sensory modality. This pattern of age-related differences in selective attention may be linked to distinct filtering mechanisms within the visual and auditory modalities, which might be differentially affected by age. Specifically, auditory distractors appear to be filtered out at both central (e.g., auditory cortex; Woldorff et al., 1993) and more peripheral (e.g., cochlea; Giard, Collet, Bouchet, & Pernier, 1994) neurocognitive levels, depending on task demands, with peripheral filtering posited to occur predominantly during cross-modal visual selective attention (Giard, Fort, Mouchetant-Rostaing, & Pernier, 2000). In contrast, visual distraction appears to be filtered out only at more central (e.g., visual cortex) processing levels (Kanwisher & Wojciulik, 2000), with the largest attentional modulations occurring at the highest levels of the visual processing hierarchy (Ciaramitaro, Buračas, & Boynton, 2007).

Arguably, the higher up distracting stimuli reach in the processing stream, the more distractible they become for older adults, which would especially be the case for visual distractors. In line with this assertion, recent evidence shows that older adults exhibit impaired suppression of unimodal visual distraction at the level of the visual cortex, and that those older adults with larger suppression deficits are also the ones that encode distracting stimuli to a greater extent (Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Schmitz, Cheng, & De Rosa, 2010).

The main goal of the present study was to assess the role of sensory modality in age-related distraction, across all combinations of visual and auditory relevant and irrelevant information. To this end, we used the same tasks and experimental design across sensory modalities: a visual *n*-back task with no distraction, visual distraction and auditory distraction (Experiment 1); and an auditory *n*-back task with no distraction, auditory distraction and visual distraction (Experiment 2).

A secondary goal of this study was to investigate the role of memory load on age-related distractibility. Research in younger adults has shown that, within visual selective attention, higher memory load results in greater interference effects on behavioral performance from the distractors. Also, measures of brain activity indicate that higher memory load results in increased activity in visual areas where distractors are processed (e.g., De Fockert, Rees, Frith, & Lavie, 2001). This effect appears to be due to a critical role of working memory in suppression of distraction by maintaining the prioritization of relevant stimuli. Given the age-related deficits observed in working memory (e.g., Rypma & D'Esposito, 2000), the toll imposed by increasing working memory load on selective attention would be especially high for older adults as compared to younger adults. Although we have recently shown that memory load does not modulate age-related distraction in the cross-modal domain (Guerreiro & Van Gerven, 2011), the possibility that memory load modulates age-related unimodal distractibility has not yet been explored. To address this question in the present study, we manipulated memory load between $n = 1$ and $n = 2$.

2. General method

2.1. Participants

Twenty-four younger adults and 24 older adults participated in this study. The young participants were recruited through advertisements posted on bulletin boards throughout the Maastricht University campus, as well as through advertisements posted on a participant recruitment website. The older adults were recruited from a participant pool of the Maastricht Aging Study (Jolles, Houx, Van Boxtel, & Ponds, 1995).

Two older adults were excluded due to failure to understand the instructions. The final sample comprised 24 younger adults (aged 20–27 years, $M = 21.7$, $SD = 2.3$, 16 women) and 22 older adults (aged 60–73 years, $M = 65.4$, $SD = 3.7$, 12 women). Older adults had significantly less years of formal education ($M = 12.7$ years, $SD = 4.3$) than younger adults ($M = 17.2$ years, $SD = 2.0$), $t(28.9) = 4.47$, $p < .001$.

A battery of tests was administered in order to further characterize the younger and older samples with respect to neuropsychological and sensory functioning.

The Raven Standard Progressive Matrices (Raven, Court, & Raven, 1988) was used to assess fluid intelligence. In this test, scores range from 1 (*superior intellect*) to 5 (*limited intellect*). Older adults ($M = 2.8$, $SD = 0.8$) did not differ from younger adults ($M = 2.8$, $SD = 0.6$) with respect to fluid intelligence abilities, $t(44) = 0.07$, $p = .943$.

The Stroop Color-Word Test (Stroop, 1935) was used to assess inhibitory functioning. In this test, a measure of interference was calculated by subtracting the average time needed to complete the first two cards from the time needed to complete the third card (Interference = Stroop III − [(Stroop I + Stroop II)/2]) (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006). Oder adults showed significantly more Stroop interference ($M = 39.6$ s, $SD = 9.6$) than younger adults ($M = 26.0$ s, $SD = 8.9$), $t(44) = 5.02$, $p < .001$.

The Dutch reading chart (Medical Workshop, Groningen, The Netherlands) was used to measure visual acuity. In this test, participants read a text printed in varying font sizes. The visual acuity score is determined by the smaller text size that can be read without errors, ranging from 0.5 (*optimal*) to 1.25 (*poor*). This test was performed with corrective lenses in those participants who had corrected-to-normal vision. Older adults had significantly higher visual acuity scores ($M = 0.8$, $SD = 0.2$), that is, lower visual acuity, than younger adults ($M = 0.7$, $SD = 0.2$), $t(44) = 3.29$, $p = .002$.

A screening audiometer (Voyager 522, Madsen Electronics, Taastrup, Denmark) was used to measure hearing acuity. This test consisted of measuring pure-tone thresholds (in decibels hearing level — dB HL) in each ear at 0.5, 1, 2, and 4 kHz, and the hearing acuity score was expressed as the average hearing threshold at 1, 2, and 4 kHz for the best ear (Davis, 1995). Older adults had significantly higher hearing thresholds ($M = 22.2$ dB HL, $SD = 9.1$), that is, lower hearing acuity, than younger adults ($M = 6.3$ dB HL, $SD = 3.3$), $t(26.2) = 7.76$, $p < .001$, which can be considered as a normal pattern of age-related hearing loss (Fozard & Gordon-Salant, 2001).

2.2. Materials

2.2.1. n-back tasks

In two consecutive experiments, we used visual (Experiment 1) and auditory (Experiment 2) *n*-back tasks, in which memory load was manipulated between $n = 1$ and $n = 2$. Participants were thus required to judge whether every newly presented digit after the *n*th digit was the same or not as *n* positions back in the sequence. In each condition, a sequence of $n + 64$ digits between 1 and 9 was presented one at a time in a green (RGB: 0, 127, 0) or red (RGB: 255, 0, 0) color in the visual task, and spoken by a male or female voice in the auditory task. Each stimulus was presented for 500 ms and followed by a 1500-ms inter-stimulus interval. The tasks were programmed in E-Prime (Psychology Software Tools, Pittsburgh, PA) and presented in a 17 in. computer screen. The visual stimuli were presented in the center of the screen and their size on the display was approximately 3.6 cm × 2.7 cm. Participants were seated approximately 57 cm away from the computer screen. The auditory stimuli were recorded by a single speaker in a sound-attenuated chamber at