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Working memory decline in normal aging: Memory load and representational demands affect performance

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ABSTRACT

Normal aging is associated with numerous changes in cognitive capacities, including an overall decline in working memory performance. Nevertheless, whereas some neuropsychological evaluations have suggested that visuo-spatial working memory may exhibit a greater age-related decline than verbal working memory, other assessments made in real-world tasks, or in tasks with higher memory loads, have suggested that age-related declines in working memory performance may be similar for spatial, visual and verbal information. Here, we tested young (20–30 years) and older (64–73 years) healthy adults in real-world laboratory memory tasks designed to assess the impact of memory load (one, two or three items to remember) on age-related changes in working memory performance for color and allocentric spatial information. We used several measures to characterize working memory performance: the total number of choices to find the goal(s), a measure of overall task performance; the number of correct choices before erring, an estimate of memory capacity; and the number of errorless trials, a measure of perfect memory. All measures revealed: (1) an overall decline of working memory performance with age; (2) a greater age-related decline of working memory performance with higher memory loads, regardless of the type of information; (3) no evidence that spatial working memory was more affected by age than color working memory. We discuss how age-related declines in working memory performance may be most influenced by memory load, the representational demands of the task and its dependence on hippocampal function, and not by the type of information to be remembered.

1. Introduction

Age-related changes in cognitive capacities are observed across the lifespan of otherwise healthy human individuals (Salthouse, 2004, 2009). Nevertheless, the beginning of "old age" is frequently considered to be around 65 years of age, and often coincides with retirement from paid employement (Wang & Shi, 2016). Normal cognitive aging is difficult to characterize and is essentially defined by exclusion as the absence of evidence of mild cognitive impairment (MCI) or dementia, such as Alzheimer's disease (Fabiani, 2012; Jagust, 2013; Rowe & Kahn, 1987). Normal aging is associated with a variety of changes in cognitive capacities, one of which is an overall decline in working memory performance (Fabiani, 2012; Jagust, 2013). Working memory refers to a brain system that enables temporary storage and manipulation of the information necessary for language comprehension and production, learning, and reasoning (Baddeley, 1992). Working memory can be evaluated by testing the ability of individuals to remember and use trial-unique information that must be distinguished from information acquired on previous trials, a process that requires the ability to resist interference and distraction (Banta Lavenex, Colombo, Ribordy Lambert, & Lavenex, 2014; Bizon, Foster, Alexander, & Glisky, 2012;

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Engle, Tuholski, Laughlin, & Conway, 1999; Spellman et al., 2015). Classical models suggest that working memory may be separated into distinct components for verbal, visual and spatial information, and, over the years, a number of experimental findings have supported the view that different types of information may be processed by different temporary storage systems (Baddeley, 2007; Baddeley, 2012; Logie and Marchetti, 1991).

Accordingly, a number of studies evaluated whether age-related changes in working memory performance may differ based on the type of information to be remembered, and a number of studies have reported that visuo-spatial working memory may exhibit a greater age-related decline than verbal working memory (Chen, Hale, & Myerson, 2003; Jenkins, Myerson, Joerding, & Hale, 2000; Myerson, Hale, Rhee, & Jenkins, 1999; Salthouse, 1995; Shelton, Parsons, & Leber, 1982). In these studies, both verbal and spatial information were displayed on a computer screen placed in front of the participants, and verbal stimuli consisted of both alphabetic (Jenkins et al., 2000) and numeric (Chen et al., 2003; Myerson, Emery, White, & Hale, 2003) stimuli. For example, Jenkins et al. (2000) tested young (18–24 years) and older (62–77 years) adults on letter and location span tasks (with and without concurrent secondary tasks). They reported that older adults remembered 61% of the number of locations remembered by young adults and 67% of the number of letters remembered by young adults. Similarly, Myerson et al. (1999) tested young (18–22 years) and older (63–69 years) adults on digit and location span tasks (with and without concurrent secondary tasks). They reported that older adults remembered 62% of the number of locations remembered by young adults and 87% of the number of digits remembered by young adults. Interestingly, Chen et al. (2003) tested young (18–22 years) and older (65–75 years) adults on object/visual-feature working memory tasks with 2 or 3 shapes and spatial working memory tasks with 5 or 6 locations, in order to test the effect of memory load on working memory performance. They reported that with low memory loads (2 shapes or 5 locations) older adults' performance differed based on the type of information. Older adults remembered 81% of the number of shapes remembered by young adults and 60% of the number of locations remembered by young adults. In contrast, with higher memory loads (3 shapes or 6 locations), the age-related decline in working memory performance was similar for the two types of information. Older adults remembered 49% of the number of shapes remembered by young adults and 46% of the number of locations remembered by young adults. Chen et al. (2003) concluded that age affects working memory performance for both spatial and object information. They also concluded that increasing memory load led to greater age-related declines in working memory performance, regardless of the type of information.

As described above, most studies assessing visuo-spatial working memory in aging have used neuropsychological paradigms in which stimuli are presented on computer screens. They were thus limited to the assessment of egocentric spatial representations, which differ from the allocentric spatial representations an individual may build when moving about in a real-world environment (Banta Lavenex & Lavenex, 2009; Burgess, 2006; O'Keefe & Nadel, 1978). To address this disparity, we recently expanded the investigation of age-related changes in working memory performance to compare age-related changes in allocentric spatial working memory and color working memory (Klencklen, Banta Lavenex, Brandner, & Lavenex, 2017). Specifically, we tested 20–30-year-old and 65–75-year-old adults on four memory tasks requiring participants to learn, on a repeated-trial basis (i.e., reference memory) or a trial-unique basis (i.e., working memory), the locations or colors of three pads among 18 pads distributed on the floor of a real-world laboratory environment. Older adults performed less well than young adults on all memory tasks, but especially on working memory tasks. Consistent with the previous findings described above, some measures including the number of correct choices before erring (CBE), an estimate of memory capacity, suggested that spatial working memory may be more affected by age than color working memory. Indeed, the CBE of older adults in the spatial working memory condition was 67% of the young adults', whereas the CBE of older adults in the color working memory condition was 76% of the young adults'. Similarly, the number of trials with the first or first two choices correct suggested a greater age-related decline in allocentric spatial working memory. In contrast, the number of errorless trials (NET), a measure of perfect memory performance, suggested that color and spatial working memory were equally affected by age. Indeed, the NET of older adults in the spatial working memory condition was 54% of the young adults', whereas older adults' NET in the color working memory condition was 56% of the young adults'. Similarly, the absolute difference in the number of correct choices before erring between young and older participants revealed no differential age-related impairment between the spatial and color conditions, since older adults remembered on average 0.66 fewer locations and 0.65 fewer colors than young adults (Klencklen et al., 2017). In sum, in light of the lack of unequivocal evidence that age-related declines in working memory performance are specific to the type of information to be remembered, we hypothesized that such declines may appear greater for spatial information than color information, depending on the measures used to evaluate memory performance, because spatial memory may have specific qualitative representational demands and thus depend on specific neural structures to be encoded, and have greater quantitative representational demands and thus require the encoding of more bits of information.

The current study aimed to test this hypothesis. Specifically, we tested 24 young (20–30 years) and 24 older (65–75 years) healthy adults to assess the impact of memory load (one, two or three items to remember) on age-related changes in working memory performance for color and allocentric spatial information. We used several measures to characterize working memory performance, which all revealed: (1) an overall decline of memory performance with age; (2) a greater age-related decline of memory performance with higher memory loads, irrespective of the type of information (color or spatial); (3) no evidence that spatial working memory was more affected by age than color working memory.

2. Methods

2.1. Participants

Twenty-four young adults (11 males) aged 20–30 years (M = 23.7, SD = 3.6) and twenty-four older adults (12 males) aged 64–73 years (M = 68.9, SD = 2.8) took part in the study. Participants were recruited via personal connections, email postings on