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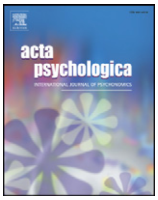

Visuomotor adaptability in older adults with mild cognitive decline

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ABSTRACT

The current study examined the augmentation of error feedback on visuomotor adaptability in older adults with varying degrees of cognitive decline (assessed by the Montreal Cognitive Assessment; MoCA). Twenty-three participants performed a center-out computerized visuomotor adaptation task when the visual feedback of their hand movement error was presented in a regular (ratio = 1:1) or enhanced (ratio = 1:2) error feedback schedule. Results showed that older adults with lower scores on the MoCA had less adaptability than those with higher MoCA scores during the regular feedback schedule. However, participants demonstrated similar adaptability during the enhanced feedback schedule, regardless of their cognitive ability. Furthermore, individuals with lower MoCA scores showed larger after-effects in spatial control during the enhanced schedule compared to the regular schedule, whereas individuals with higher MoCA scores displayed the opposite pattern. Additional neuro-cognitive assessments revealed that spatial working memory and processing speed were positively related to motor adaptability during the regular scheduled but negatively related to adaptability during the enhanced schedule. We argue that individuals with mild cognitive decline employed different adaptation strategies when encountering enhanced visual feedback, suggesting older adults with mild cognitive impairment (MCI) may benefit from enhanced visual error feedback during sensorimotor adaptation.

1. Introduction

The term “mild cognitive impairment (MCI)” has been conceptualized as a cognitive impairment representing a transitional phase between normal aging and dementia (Petersen et al., 2001). It has been suggested that individuals with MCI regularly display memory impairments but are otherwise cognitively and functionally intact (e.g., Rivas-Vazquez, Mendez, Rey, & Carrazana, 2004). Other studies have showed that individuals with MCI can exhibit subtle, yet specific deficits in a range of executive-related cognitive tasks, including perceptual speed (Bennett et al., 2002), response inhibition (Balota et al., 2010; Traykov et al., 2007), planning/problem-solving (Brandt et al., 2009; Takeda et al., 2010); working memory (Brandt et al., 2009; Rivas-Vazquez et al., 2004), and explicit memory (Petersen et al., 1999). Longitudinal investigations of elderly community-based samples indicate that MCI may appear 5 to 10 years prior to reaching the diagnostic criteria for dementia (Almkvist et al., 1998; Palmer, Bäckman, Winblad, & Fratiglioni, 2003; Small, Fratiglioni, Viitanen, Winblad, & Bäckman, 2000). Cognitive decline may be a non-reversible process but understanding the early functional declines among individuals with MCI could identify those who need support and lead to specific interventions.

Previous studies have discovered that participants with mild or probable dementia had general deficits in acquiring motor tasks (Moussard, Bigand, Belleville, & Peretz, 2014a; Tippett & Sergio, 2006). For example, Moussard et al. (2014a); Moussard, Bigand, Belleville, and Peretz (2014b) reported a study where patients with mild Alzheimer's disease (AD) and healthy controls learned sequences of gestures with either music or a metronome. All of the participants in the AD group were in the mild stages of the disease with Mini-Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975) scores between 23 and 27. Results showed that participants with AD demonstrated less motor learning compared to normal controls in both conditions. In another study (van Tilborg, Kessels, & Hulstijn, 2011), participants with mild-to-moderate dementia (average MMSE score was 20.6) were taught to use household appliances through either observational learning or instructional learning. Observational learning was not effective for any of the participants with mild-to-moderate dementia. While improvement was found through instructional learning,

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the overall performance of the participants with cognitive impairment was still well below the performance of the controls.

Acquiring and maintaining motor skills is critical for functional independence with advancing age. The current study focused on visuomotor adaptation, the ability to adjust movements in response to visual feedback. Experimentally, a typical center-out adaptation task requires participants to move a cursor on a screen from a center position to targets with a mouse or a joystick in three phases: (1) baseline phase with normal visual feedback of hand movements, (2) adaptation phase where the visual feedback of hand movement has rotated a certain degree (e.g., if a clockwise 45° rotation is implemented, a straight-up hand movement results in an up-right cursor movement on the computer screen); and (3) post-adaptation phase where the visual feedback of hand movement reverts to normal visual feedback. Successful adaptation is measured by “after-effect”, defined as movement in the opposite direction of the rotation in the post-adaptation phase (Buch, Young, & Contreras-Vidal, 2003; Criscimagna-Hemminger, Bastian, & Shadmehr, 2009).

It has been reported that cognitive processes, such as working memory, play a significant role in visuomotor adaptation (Anguera, Reuter-Lorenz, Willingham, & Seidler, 2011). In one visuomotor adaptation study, Anguera et al. (2011) found that age-related differences in spatial working memory correlated with learning differences in adaptation between young and older adults. Brain imaging data showed that younger adults had overlapping brain activation (i.e., right dorsolateral prefrontal cortex) when performing the working memory and adaptation tasks, whereas older adults did not. Additionally, the rate of learning correlated with the amount of activation within the right dorsolateral prefrontal cortex in young participants. These findings suggested that young adults effectively engaged spatial working memory processes during adaptation while older adults did not. The authors argued that individual differences in cognitive functions, especially spatial working memory, significantly impacted visuomotor adaptability. Working memory impairments can occur in individuals with MCI (Rivas-Vazquez et al., 2004; Brandt et al., 2009), but a link between cognitive impairments and visuomotor adaptation deficits in this population has not been examined empirically.

Differences in motor learning have also been observed within the elderly population. It has been proposed that individuals with dementia rely more on visual feedback when learning new tasks. In a series of studies, Dick et al. (2010) asked participants to track a rotating block with a handheld pointer under restricted vision and non-restricted vision conditions in a rotary pursuit task. Results showed that while both controls and individuals with dementia learned the task in the non-restricted vision condition, participants with AD had lower learning rates in the restricted vision condition. The authors argued that visual feedback is important for motor learning across older participants, but individuals with AD are especially reliant on visual feedback. Several motor learning models theorized visual feedback is an important factor that drives motor learning (Shadmehr, 1997; Wolpert, Diedrichsen, & Flanagan, 2011).

During visuomotor adaptation, an error signal, indicating a discrepancy between the planned movement and the movement outcome, is believed to be a critical component of learning (Wolpert & Ghahramani, 2000). It has been argued that providing augmented error signals (i.e., making errors more noticeable to the senses) can improve learning. More salient errors are hypothesized to force individuals to update their internal working model from the perturbed movements, increase motivation to learn by making small errors seem larger, and lead to larger signal-to-noise ratios for sensory feedback and self-evaluation (Israely & Carmeli, 2015). Several recent studies found increased motor adaptation when sensory feedback of error signals were augmented in healthy young adults (Patton, Wei, Bajaj, & Scheidt, 2013) and stroke patients (Patton, Stoykov, Kovic, & Mussa-Ivaldi, 2006). Furthermore, Patton et al. (2013) reported that a ratio of 1:2 between the original error signal and feedback optimized motor learning whereas a ratio of 1:3 or larger may result in an unstable adaptation process.

The potential benefits of increasing error feedback has not been studied in individuals with MCI and enhancing visual error feedback could provide an opportunity to increase motor learning in older individuals with cognitive decline. Thus, the purpose of current study was to investigate whether enhanced visual error feedback could improve motor learning in older adults with mild cognitive decline. First, we hypothesized that individuals with greater cognitive decline would show less adaptability compared to those with normal cognitive ability when presented with regular (i.e. 1:1 ratio) error-feedback. Second, based on a series of studies reported by Dick et al. (2010) indicating that older adults with cognitive impairment rely more on visual feedback, we hypothesized that individuals with cognitive decline may benefit from augmented visual feedback. In other words, we expected that individuals with greater cognitive decline could show similar adaptability compared to those with normal cognitive ability when presented with enhanced (i.e. 1:2 ratio) error-feedback. Lastly, previous studies demonstrated that individual differences in cognitive functions, especially spatial working memory, significantly impacted visuomotor adaptability in a classic adaptation task (Anguera et al., 2011). Therefore, we hypothesized that cognitive measures (e.g., working memory) would significantly relate to adaptability in a regular feedback (1:1 ratio) schedule. In an enhanced feedback schedule, we expected individuals with greater cognitive decline to rely on a different strategy (i.e., visual feedback) and the same relationship between cognitive measures would not be seen. The findings of this study not only provided preliminary information about visuomotor adaptation in older adults with MCI but also indicated possible approaches of intervention that could enhance motor performance in individuals with cognitive decline.

2. Methods

2.1. Participants

Thirty-two elderly participants (ranged from 65 to 80 years of age) were recruited from senior apartment complexes and community senior centers in the Ann Arbor-Detroit area. Participants were excluded if they reported a history of neurological disease (e.g., stroke, traumatic brain injury, Parkinson's disease, and multiple sclerosis). Participants were also excluded if their cognitive decline was more severe and their current cognitive functioning potentially met the criteria for dementia, screened by the Mattis Dementia Rating Scale (DRS, scores lower than 123 were excluded, Mattis, 1988) and the Montreal Cognitive Assessment (MoCA, scores lower than 19). Participants were also excluded if they reported significant depression, assessed by the Beck Depression Inventory-II (i.e., scores higher than 28). As a result, four participants were excluded due to a history of neurological disease. Three were excluded because their MoCA scores were lower than 19. In addition, two more were excluded because of their guardianship status. Overall, twenty-three elderly participants (ranged from 65 to 78 years of age, mean = 70.04; 19 females and 4 males) were included in the sample. All participants independently signed the informed consent before testing began.

2.2. Procedure

General health history questionnaires and neuropsychological tests were administered after the participants signed the informed consent. The Mattis Dementia Rating Scale (DRS, Mattis, 1988) was used to examine dementia symptoms. A minimum score of 123 was required for participation in the current study. The *Montreal Cognitive Assessment* (MoCA; Nasreddine et al., 2005) was administered to assess levels of global cognition. The MoCA is a screening tool for cognitive impairment and dementia, assessing cognitive domains in short-term memory, visuospatial ability, executive functions, attention and working memory, language, and orientation to time and place. The total score of the MoCA can range from 0 to 30. Individual with scores below 26 are