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The relationship between executive function and fine motor control in young and older adults

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ABSTRACT

The present study examined the relationship between executive function (EF) and fine motor control in young and older healthy adults. Participants completed 3 measures of executive function; a spatial working memory (SWM) task, the Stockings of Cambridge task (planning), and the Intra-Dimensional Extra-Dimensional Set-Shift task (set-shifting). Fine motor control was assessed using 3 subtests of the Purdue Pegboard (unimanual, bimanual, sequencing). For the younger adults, there were no significant correlations between measures of EF and fine motor control. For the older adults, all EFs significantly correlated with all measures of fine motor control. Three separate regressions examined whether planning, SWM and set-shifting independently predicted unimanual, bimanual, and sequencing scores for the older adults. Planning was the primary predictor of performance on all three Purdue subtests. A multiple-groups mediation model examined whether planning predicted fine motor control scores independent of participants' age, suggesting that preservation of planning ability may support fine motor control in older adults. Planning remained a significant predictor of unimanual performance in the older age group, but not bimanual or sequencing performance. The findings are discussed in terms of compensation theory, whereby planning is a key compensatory resource for fine motor control in older adults.

1. Introduction

The decline of motor control with aging is particularly pronounced for dextrous hand movements (Ranganathan, Siemionow, Sahgal, & Yue, 2001; Shiffman, 1992; Vielut, Mahmoodi, Godde, Reuter, & Voelcker-Rehage, 2012). Compared to younger adults, older adults demonstrate poorer performance on tasks requiring fine motor control, which impacts significantly on their ability to complete functional activities such as tying shoelaces and fastening clothing (Clarke, Loftus, & Hammond, 2011; Ranganathan et al., 2001; Vielut et al., 2012). Such age-related declines are considered multi-factorial (for a review see Ward, 2006) and are often attributed to peripheral changes (e.g., nerve conduction), changes in proprioception (Kaplan, Nixon, Reitz, Rindfleish, & Tucker, 1985), grey and white-matter atrophy in movement-related cortical areas (Mattay et al., 2002), changes in motor networks (Heuninchx, Wenderoth, & Swinnen, 2008; Mattay et al., 2002), and changes in corticospinal excitability and inhibition (Fujiyama, Hinder, Schmidt, Garry, & Summers, 2012)

A number of studies have also reported age-related declines in executive functioning (EF) – the ability to plan, organise, and perform goal-directed behaviours (Lezak, 1995). Executive functions are particularly important when faced with novel

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situations requiring problem-solving and cognitive flexibility (Ashendorf & McCaffrey, 2008; Huizinga, Dolan, & Van Der Molen, 2006), and EF deficits have a profound impact upon the functional living skills of older people (Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000). Those EFs most susceptible to age-related decline are spatial working memory (SWM), set-shifting, and planning (Fisk & Sharp, 2004; Huppert, Bravne, Paykel, & Beardsall, 1995). It has been proposed that SWM, set-shifting, and planning rely substantially on prefrontal areas and that declines in these EFs reflect age-related loss of frontal functioning (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Fisk & Sharp, 2004).

SWM is the ability to attain, hold, and manipulate information about the location of objects in the environment (Smith, Jonides, & Koeppe, 1996). Of all the EFs, working memory is potentially the most sensitive to age-related neurological changes (Kane et al., 2004; Salthouse, 1994; Salthouse & Babcock, 1991). A number of studies have found that, compared to younger adults, older adults demonstrate poorer performance on SWM tasks (Myerson, Hale, Rhee, & Jenkins, 1999; Robbins et al., 1998; Tubi & Calev, 1989). Robbins et al. (1998) assessed SWM in healthy adults aged 21–79 years old, using a task requiring participants to locate a token hidden within one of a number of boxes presented on a computer screen. Participants aged over 60 demonstrated significantly more SWM errors than those aged under 60, leading the authors to conclude that significant declines in SWM occur at approximately 60 years of age.

Set-shifting is the ability to demonstrate flexible problem solving in the face of varying schedules of reinforcement (Reurter-Lorenz, Ridderinkhof, Span, & van der Molen, 2002). This skill is of increasing importance in the modern world, as it enables one to deal with rapidly changing circumstances. Set-shifting involves shifting from previously successful behavioural schemas to new schemas, often while reconfiguring and redefining tasks to make them more manageable (Liens, Ruthruff, & Kuhns, 2008). A lack of such flexibility can result in perseverative behaviour, which is where a person persists with an inappropriate response which is ineffective for the new situation (Reurter-Lorenz et al., 2002). A number of studies have found that older adults demonstrate significant age-related deterioration in set-shifting and cognitive flexibility (Ashendorf & McCaffrey, 2008; Reurter-Lorenz et al., 2002; Robbins et al., 1998). Ashendorf and McCaffrey (2008) examined the cognitive processes underlying age-related decline on the Wisconsin Card Sorting Test (WCST). Older adults (63–89 years) demonstrated significantly more perseverative errors than younger adults (18–22 years), which the authors attributed to a less effective use of feedback by the older adults.

Planning involves identifying goals and developing strategies to achieve desired goals (Craik & Bialystok, 2006; Jurado & Rosselli, 2007). Intact planning abilities are particularly important for tasks comprising a number of different components (e.g., making breakfast; Craik & Bialystok, 2006). Older adults demonstrate significant age-related deterioration in planning ability (Robbins et al., 1998; Salthouse, Atkinson, & Berish, 2003). Robbins et al. (1998) examined planning ability in a group of healthy adults aged 21–79 years old, using a computerised version of the Tower of London task. Participants aged 60 and over took longer and made more errors than those younger, leading the authors to suggest that planning abilities significantly declines from the age of 60.

Studies of the neural correlates of EF indicate prefrontal involvement (Carpenter, Just, & Reichle, 2000). Movement in older adults is associated with increased recruitment of the prefrontal, traditionally cognitive, cortex (Heuninchx et al., 2008; Seidler et al., 2010). This prefrontal recruitment is thought to reflect a shift from automatic movement control to conscious, more cognitively involved movement control. For example, older adults are more reliant upon planning and attention when performing a basic balancing task (Woollacott & Shumway-Cook, 2002) Planning ability has been shown to be important in gross motor control, such as posture and gait. Research in older adults and neurodegenerative disease has shown that reduced planning ability is associated with a higher incidence of falls, reduced gait speed, and balance impairment (Kearney, Harwood, Gladman, Lincoln, & Masud, 2013). In comparison, those with intact planning ability were able to effectively plan movements to regain balance which resulted in decreased incidence of falls.

Furthermore, older adults have more difficulty performing cognitive and motor tasks simultaneously compared to younger adults (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). Shumway-Cook et al. (1997) found that older adults were unable to perform a language-processing task while maintaining their posture in a changing environment. Fraser, Li, and Penhune (2010) found that older adults performed poorly on a sequential finger tapping task, when a high-cognitive load task was introduced. Fraser et al. (2010) concluded that changes in general executive processes may be the root behind differences in fine motor control in healthy aging. It has recently been suggested that the increased reliance on cognition to perform basic motor tasks by older adults may be indicative of some form of compensatory cerebral reorganisation (Heuninchx et al., 2008; Mattay et al., 2002), whereby cognitive networks and resources offer compensatory support for declining motor control.

It is increasingly apparent that EFs and motor control are linked in aging. The age-related decline in both EF and motor control raises the question of whether specific aspects of EF (SWM, set-shifting, planning) differentially support fine motor control in older adults. The first aim of the present study was to examine differences in the relationships between EF and fine motor control in younger and older adults. It is hypothesized that significant relationships between EFs and fine motor control for older, but not younger, adults will be observed, indicating that EFs may provide compensatory support for fine motor control in aging. The second aim of the study was to explore the independent contributions of SWM, set-shifting, and planning to fine motor control in older adults. If one component of EF contributes more than the others to fine motor control, then maintenance of that particular aspect of EF may be beneficial to movement for older people.