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Aging in movement representations for sequential finger movements: A comparison between young-, middle-aged, and older adults

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ABSTRACT

Studies show that as we enter older adulthood (>64 years), our ability to mentally represent action in the form of using motor imagery declines. Using a chronometry paradigm to compare the movement duration of imagined and executed movements, we tested young-, middle-aged, and older adults on their ability to perform sequential finger (fine-motor) movements. The task required number recognition and ordering and was presented in three levels of complexity. Results for movement duration indicated no differences between young- and middle-aged adults, however both performed faster than the older group. In regard to the association between imagined and executed actions, correlation analyses indicated that values for all groups were positive and moderate (r's .80,.76,.70). In summary, whereas the older adults were significantly slower in processing actions than their younger counterparts, the ability to mentally represent their actions was similar.

1. Introduction

In order to perform skilled motor actions, it is necessary to create an appropriate and effective movement representation used to plan and execute motions. The nature of mental (movement) representation is a central issue for understanding cognitive and motor development across the lifespan. The concept of mental representation has been cast from several perspectives. One of the more common views is that mental representation is an internal cognitive construct that represents external reality. This interpretation contends that action representation is a key feature of an internal forward model, a neural system that simulates the dynamic behavior of the body in relation to the environment (Wolpert, 1997). These representations are hypothesized to be an integral part of action planning (Caeyenberghs, Tsoupas, Wilson, & Smits-Engelsman, 2009; Molina, Tijus, & Jouen, 2008).

Central to the present paper is the notion that motor imagery is part of an internal forward model and is equivalent to a 'plan' of the action to follow; that is, it reflects an internal action representation (Jeannerod, 2001; Munzert & Zentgraf, 2009). The basis for much of the discussion related to the role of motor imagery in action representation and planning is the so-called equivalence hypothesis (e.g., Jeannerod, 2001); suggesting that motor simulation and motor control processes are functionally equivalent (Kunz, Creem-Regehr, & Thompson, 2009; Lorey et al., 2010; Munzert & Zentgraf, 2009; Ramsey, Cummings, Eastough, & Edwards, 2010).

Using the general motor imagery paradigm, studies have shown that advanced age (>64 years) is associated with functional decrements in the ability to mentally represent action (e.g., Gabbard, Caçola, & Cordova, 2011b; Mulder, Hochstenbach, Heuvelena, & Otter, 2008; Personnier, Bally, & Papaxanthis, 2010a; Saimpont, Mourey, Manckoundia, Pfitzenmeyer, & Pozzo, 2010; Skoura, Personnier, Vinter, Pozzo, & Papaxanthis, 2008). According to Gabbard, Caçola, and Bobbio (2011a), the vast majority of previous work used tasks requiring the simulation and execution of gross-motor movements; namely the trunk, shoulders and limbs, with the exception of their investigation using a chronometry paradigm (described later) to compare the movement duration of imagined and executed sequential finger movements between children and young adults. The underlying intent, as with the present study, was to gain a better understanding of the age-related ability to create internal models for action requiring fine-motor movements. The researchers found that 7-year-olds and adults were significantly different from 9- and 11-year-olds. Our goal with the present study, using the same paradigm, was to examine possible aging effects by comparing young-, middle-aged, and older adults.

Behaviorally, one of the most common tactics used to examine movement representation via motor simulation is chronometry. Specifically, chronometry paradigms measure the correspondence between the time-course of the participant's imagined (I) and executed (E) actions (Gabbard et al., 2011a). This tactic follows

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the premise that there is a functional relationship between motor imagery and execution. Theoretically, the closer the relationship between I and E movement time-course, the more refined the action representation (internal model). This method has proven to give reliable and replicable results (e.g., see review by Malouin, Richards, Durand, & Doyon, 2008; Sirigu et al., 1996). With adults, durations of imagined movements have been reported not to differ significantly from executed movements (e.g., Calmels, Holmes, Lopez, & Naman, 2006; Carrillo, Galdo-Alvarez, & Lastra-Barreira, 2008; Louis, Guillot, & Maton, 2008; Sabate, Gonzalez, & Rodriguez, 2007).

For example, Personnier, Kubicki, Laroche, and Papaxanthis (2010b) used a chronometry paradigm with imagined and executed arm pointing (gross-motor) actions in young and older adults and found that whereas older adults displayed the ability to mentally represent action, the quality (i.e., isochrony between executed and imagined movements) declined with advancing age. From another perspective, those findings indicate that there is likelihood of weakness in internal models of action in the elderly. In that study and a subsequent investigation (Personnier et al., 2010b), the researchers concluded that the decline in motor imagery might reflect functional changes in the aging brain; for example, the parietal cortex. Complementing those reports, Saimpont et al. (2010) reported a significant age effect regarding the ability to mentally simulate a complex sequential action involving the whole body (rising from the floor). That is, compared to younger adults, older persons displayed a significant level of difficulty.

Even though functional decrements with aging have been well established in the literature, it is still unknown when declines associated with movement representation begin; which is especially relevant in regard to the representation of fine-motor movements. To that end, we compared imagined (I) and executed (E) movements of young adults (18–32 years), middle-aged adults (40–63 years), and older adults (65–93 years) using a chronometry paradigm with a task involving sequential finger (fine-motor) movements. We predicted that the ability to mentally represent action would decrease gradually with advancing age. That is, there would be a larger difference between I and E conditions as age increased. We also anticipated that movement duration would slow as age increased. As noted earlier, our goal was to gain a better understanding of advancing age during adulthood on the ability to mentally represent action requiring fine-motor movements.

2. Method

2.1. Participants

The study involved a convenience sample of 99 participants with ages ranging between 18 and 93 years of age. Participants were divided in three age groups: Young adults ($n = 33$, $M = 22.30$, $SD = 2.72$, range 18–32 years, 16 females, 17 males), middle-aged adults ($n = 33$, $M = 49.76$, $SD = 6.09$, range 40–63 years, 19 females, 14 males), and older adults ($n = 33$, $M = 74.52$, $SD = 6.69$, range 65–93 years, 18 females, 15 males). All participants completed an eligibility questionnaire and were excluded from the study if they had any of the following: known visual conditions or impairments affecting daily function (e.g. reading, driving, etc.); neurological disorders, diagnosed cognitive decline and low endurance or inability to maintain stance while seated. The experimental protocol and consent form were approved by the Institutional Review Board (IRB) for the ethical treatment of human subjects at the University of Texas at Arlington. Participants received written and verbal descriptions of the experimental procedures and voluntarily signed a consent form before participating in this study.

2.2. Task and procedure

Participants were tested individually in an isolated testing room. The setup included the use of a dual monitor computer with two 20-in. screens positioned back-to-back 6 in. from each other so that each of the monitors faced either the participant or the experimenter. This set-up allowed the experimenter to control what the participant viewed each time a trial was presented. Participants were seated comfortably in an upright position facing the computer monitor that was approximately 12 in. away with their dominant hand placed palm down on the table in front of them at midline and the opposite hand resting on the thigh on the same side. Height of the chair was adjusted in order to match the participant's head height to the top of the computer screen. Movement duration was programmed via computer to begin after the 'Get Ready' cue and completed by an experimenter via keypad (sitting adjacent to the participant) timed with the participant's 'Stop' response. Programming was created using MatLab software. The test was modified from adult work by Sabate, Gonzalez, and Rodriguez (2004) and the experimental paradigm has been reported elsewhere with children and young adults (Gabbard et al., 2011a).

The task involved producing sequential finger movements through imagined (I) and actual executed (E) movements. Numbered stickers were placed on the proximal segment of the fingers, numbered 1 through 5 on each finger, from their little finger through to their thumb. Movement sequences of 3, 4, and then 5 numbers (representing number load) appeared on the screen, and the participant was asked to either imagine lifting and tapping (I condition) or actually executing the task; corresponding numbered finger to match the numbers that appeared on the screen (example, Fig. 1). Participants used the dominant hand with the palm down and the wrist and the fingertips resting on the table surface. All fingers were slightly flexed as if they were prepared to begin typing on a keyboard. During testing, participants sat upright and remained relaxed. Movements of each finger began with a dorsal extension separating the fingertip from the table surface and were followed by a ventral flexion that returned the finger to its original position on the table. Each trial was composed of repetitive movements performed by different fingers. Once the sequence of taps was completed, the participant said 'Stop'. This was repeated 5 times each for both E and I conditions at each of the three load levels. Prior to the imagery condition, participants were trained to use motor (kinesthetic) imagery, meaning that they were trained to focus on and feel the individual effector (finger), thereby being more sensitive to the biomechanical constraints of the task (Johnson, Corballis, & Gazzaniga, 2001; Sirigu & Duhamel, 2001; Stevens, 2005).

Participants were randomly assigned to I or E condition to start the task which was then reversed for the start of the next level of complexity. Before the series of numbers appeared on the monitor, the participant was prompted with a "Get Ready" visual cue lasting 2 s. Participants were allowed breaks every block of 5 trials to

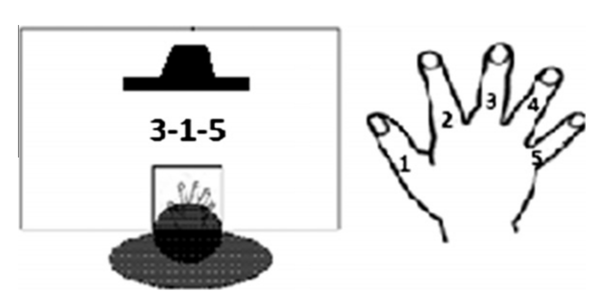

Fig. 1. Illustration of the general experimental setup.