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Aging effects on event and emergent timing in bimanual coordination

Jeffery J. Summers *, James Lewis, Hakuei Fujiyama

Human Motor Control Laboratory, School of Psychology, University of Tasmania, Hobart Campus, Private Bag 30, Hobart 7001, Tasmania, Australia

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ABSTRACT

There is growing evidence that normal aging may produce declines in some motor tasks but not others. One account of the task-specific aging effects suggests that age-related differences will be evident in tasks that demand high-level processing but not in tasks that can be performed relatively automatically. To test this hypothesis we compared the performance of young and older adults on two bimanual circle drawing tasks that utilize either low-level emergent timing processes (continuous circle drawing) or higher-level event-based timing mechanisms (intermittent circle drawing). The circle drawing tasks were performed with the hands coupled in either a symmetrical or asymmetrical coordination mode and at two individually-determined movement frequencies (comfortable and fast). Older participants were able to match the performance of young adults under both coordination modes and movement frequencies in the bimanual continuous circling task, but showed significantly greater temporal variability when performing the intermittent circling task. The results of the study are in accordance with the view that age-related effects will be observed in tasks in which movement timing is guided by high-level representations but not in tasks involving relatively automatic low-level timing processes.

* Corresponding author. Address: School of Psychology, Private Bag 30, Hobart 7001, Tasmania, Australia. Tel.: +613 6226 2884; fax: +613 6226 2883.
E-mail address: Jeff.Summers@utas.edu.au (J.J. Summers).

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1. Introduction

Normal aging is associated with progressive decline in cognitive and motor functions. The ubiquity of evidence for these negative age-related changes has led to a view of a common cause in terms of a general slowing with age in central cognitive processes (Cerella, 1985; Salthouse, 1996). Numerous studies have reported a general age-related motor slowing in tasks that emphasize speed, such as simple and choice reaction time (e.g., Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994), as well as in simple motor tasks involving postural responses to perturbation, spatial coordination, and manual dexterity (e.g., Greene & Williams, 1996; Inglin & Woollacott, 1988; Spirduso & Choi, 1993). Not all motor skills, however, decline with increasing age. The temporal coordination of the legs during walking and stair climbing show no age-related decline (Williams & Bird, 1992) and studies of bimanual coordination have reported similar performance levels for young and old participants when symmetrical (in-phase) movements are executed with homologous muscles (Greene & Williams, 1996; Serrien, Swinnen, & Stelmach, 2000; Wishart, Lee, Murdoch, & Hodges, 2000). Thus, normal aging may have different effects across a range of motor tasks. One account for the absence of age-related differences on certain tasks relates to the notion of attentional resource allocation. That is, older adults who perform as well as younger adults allocate more attention to the performance of even relatively simple movements to compensate for age-related physiological changes. Consistent with this view is the recent finding that during performance of coordinated ipsilateral hand and foot movements higher performing older adults exhibited more elaborate brain activation than young individuals, particularly in frontal regions (Heuninckx, Wenderoth, & Swinnen, 2008). However, a possible limitation of this postulated age-related compensatory mechanism is that performance deterioration may be expected in more challenging task conditions which place greater demands on limited available resources (Reuter-Lorenz & Cappell, 2008).

A related hypothesis regarding task differences suggests that age effects will not be observed in the performance of highly over-learned or "automatic" movements. Such movements can be performed without attention being directed towards the details of the movement. Age-related differences will be evident, however, in tasks requiring effortful processing by both young and older adults. There is considerable evidence that the in-phase bimanual coordination pattern is automatic for younger adults. Studies using a dual-task paradigm have shown no detriment in in-phase upper arm movements when concurrently performed with an attention-demanding task (Summers, Byblow, Bysouth-Young, & Semjen, 1998; Temprado, Chardenon, & Laurent, 2001; Temprado, Zanone, Monno, & Laurent, 1999). Anti-phase coordination, in contrast, has consistently been shown to demand attentional resources, particularly at higher movement frequencies. Some support for the automatic vs. effortful processing account of task-specific age differences has come from the finding that older adults are able to perform bimanual in-phase movements to the same level as young adults, but show performance decrements when anti-phase coupling between the hands is required (Lee, Wishart, & Murdoch, 2002; Wishart et al., 2000).

Age-related dissociation between tasks has also been observed in the temporal control of movement. Timing variability in isochronous tapping tasks appears to remain stable across age groups, whereas the production of rhythmic patterns shows age-specific deterioration (see Krampe, 2002, for review). Thus, low-level (automatic) timing mechanisms may remain intact in normal aging, but the higher-level timing processes required when multiple target durations have to be sequenced, as in rhythmic patterns, decline with age. Recently, a similar distinction between cognitively controlled and automatic timing processes has been proposed for tasks involving discontinuous and continuous movements (Lewis & Miall, 2003; Schaal, Sternad, Osu, & Kawato, 2004). Specifically, repetitive movements with distinct pauses between repetitions (i.e., discrete movements) are controlled by an internal clock-like mechanism. In these tasks explicit temporal goals are set for successive discrete events, such as the onset of each movement cycle, with an internal timing process being used to control movements between target intervals. This type of timing has been referred to as event timing and the cerebellum has been implicated in the control of discrete movements (Spencer, Zelaznik, Diedrichsen, & Ivry, 2003; Zelaznik, Spencer, & Ivry, 2002). It has also been argued that cognitively controlled