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Response inhibition and avoidance of virtual obstacles during gait in healthy young and older adults

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ABSTRACT

Adjustments of preplanned steps are essential for fall avoidance and require response inhibition. Still, inhibition is rarely tested under conditions resembling daily living. We evaluated the ability of young and older adults to modify ongoing walking movements using a novel precision step inhibition (PSI) task combined with an auditory Stroop task.

Healthy young (YA, $n = 12$) and older (OA, $n = 12$) adults performed the PSI task at 4 individualized difficulty levels, as a single and dual task (DT). Subjects walked on a treadmill by stepping on virtual stepping stones, unless these changed color during approach, forcing the subjects to avoid them. OA made more failures (40%) on the PSI task than YA (16%), but DT did not affect their performance. In combination with increased rates of omitted Stroop task responses, this indicates a "posture first" strategy. Yet, adding obstacles to the PSI task significantly

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deteriorated Stroop performance in both groups (the average Stroop composite score decreased by 13% in YA and 27% in OA). Largest deficit of OA was observed in rates of incorrect responses to incongruent Stroop stimuli (OA 35% and YA 12%), which require response inhibition. We concluded that the performance of OA suffered specifically when response inhibition was required.

1. Introduction

During gait, we plan swing limb trajectories for steps ahead using visual information about the environment in a feed forward manner (Patla & Vickers, 1997). If perturbed, one needs to adjust a planned step using feedback information both on whole body and limb motion (Patla & Vickers, 1997) and on the surrounding environment (Maki & McIlroy, 2007; Patla & Vickers, 1997). This requires inhibition, because the preplanned step needs to be stopped before finding an alternative foot landing position. Therefore, inhibition is an important skill, lack of which might lead to increased instability and risk of falling, especially given the age related deterioration of inhibitory abilities (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Verbruggen & Logan, 2008).

In the past, response inhibition ability was typically tested in the arms (Coxon, Stinear, & Byblow, 2007; Coxon, Van Impe, Wenderoth, & Swinnen, 2012). More recently however, several groups have attempted to assess response inhibition in the lower limbs in healthy older adults (OA), thereby attempting to bridge the gap with the field of arm motor control (Redfern, Jennings, Mendelson, & Nebes, 2009; Sparto et al., 2013; Tseng, Stanhope, & Morton, 2009; Uemura, Oya, & Uchiyama, 2013). These experiments have confirmed a link between inhibition and motor reactions, more specifically postural sway and step initiation.

With respect to gait it is interesting to relate these findings on response inhibition to falls. It is known that falls are associated with an impaired ability to execute a fast voluntary step (Lord & Fitzpatrick, 2001). This impairment might be due to inhibitory deficits as it has been shown that inhibition of inappropriate postural adjustments is required for a timely onset of a voluntary stepping reaction (Sparto et al., 2013; Uemura et al., 2013). Furthermore, the ability to modify an initiated step in response to desired foot landing position shifts declines with aging (Tseng et al., 2009). However, these experiments remain somewhat remote to circumstances of falling. They focused mainly on movement preparation (Lord & Fitzpatrick, 2001; Sparto et al., 2013; Uemura et al., 2013) and were limited to step initiation, while most falls occur during walking (Robinovitch et al., 2013; van Dieën & Pijnappels, 2008). Therefore, we aimed to measure the ability of OA to modify ongoing movements during walking. To this aim, we used an obstacle avoidance task (Moraes & Patla, 2006; Weerdesteyn, Nienhuis, & Duysens, 2005), as a common fall related situation, and included an element of inhibition in order to work in parallel with the arm movement experiments on response inhibition. Our specific walking task required stepping toward a precise target and then inhibiting that step following a sudden "stop" signal (Potocanac et al., 2014). This is a form of obstacle avoidance that stresses the need for inhibition and adjustment of preplanned steps as the obstacles initially represent targets for subjects to step on. Hence, this walking task requires inhibition of ongoing precise steps and we refer to it as precision step inhibition (PSI) task throughout this paper. Our previous work established a protocol that proved to be feasible, although demanding, in young adults (YA) (Potocanac et al., 2014). However, it remains to be seen whether this task is appropriate for use in OA, the population of interest with respect to falls.

To further test for response inhibition we added a cognitive dual task (DT) that also requires inhibition. Including a DT in our experiment is not only interesting from the inhibition point of view, but also adds ecological validity with respect to falls. During daily living one almost always performs multiple tasks while walking, and with advancing age even simple cognitive tasks can have a