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AVOIDING VIRTUAL OBSTACLES DURING WALKING: TESTING RESPONSE INHIBITON

[1, 7]Zrinka Potocanac, [2]Ellen Smulders, [3]Felipe Carpes, [1]Wouter Hoogkamer,
[4]Mirjam Pijnappels, [5]Sabine Verschueren and [1, 6]Jacques Duysens
[1]KU Leuven, Dept. of Kinesiology, Belgium
[2]Tolbrug Specialized Rehabilitation, ‘s-Hertogenbosch, The Netherlands
[3]Laboratory of Neuromechanics, Universidade Federal do Pampa, Uruguaiana, RS, Brazil
[4]Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
[5]KU Leuven, Dept. of Rehabilitation Sciences, Belgium
[6]Sint Maartenskliniek Nijmegen, Department of Research, Development, and Education, Nijmegen, The Netherlands
[7]Corresponding author, e-mail: zrinka.potocanac@faber.kuleuven.be

INTRODUCTION

During locomotion motor inhibition plays an important role in adjusting or inhibiting a planned step, which is important in case of perturbations. Still, motor inhibition is seldom evaluated in lower limbs. Recently, several groups attempted to introduce testing of response inhibition during quiet stance [1] or step initiation [2–4]. Although motor inhibition performance on a computer task was not correlated to postural sway during quiet stance in healthy population, it is hypothesized that it might play a role in tasks requiring active motor response [1]. In a study on step initiation [4], subjects had to step to the left or right in response to congruent or incongruent visual stimuli. Those unable to perform a correct initial postural adjustment had a delayed step onset [4]. In other words, motor inhibition (required for an accurate response to incongruent stimuli) is essential for timely onset of a voluntary stepping reaction. This is important because impaired voluntary step initiation might lead to falls [2,3]. Lord et al. [2] have shown that the choice stepping reaction time test, evaluating the ability to modify a movement during step initiation, is a strong predictor of falls. Tseng et al. [3] compared the ability of healthy young and older adults to change their foot trajectory during step initiation in response to a change in desired landing position. Healthy older adults were unable to rapidly adjust foot landing locations and the authors assume this might lead to falls [3]. These studies indicate that motor inhibition, as a prerequisite for successful modification of movement, might play a role in avoidance of falls. They also stress the importance of testing this in demanding, real life resembling situations. Walking is one of such situations, because it is more demanding than step initiation and most falls occur during walking [5].

Therefore, the aim of this paper was to develop a test protocol to study the ability to modify ongoing movements during walking. This protocol needs to be feasible in elderly adults (EA, population most susceptible to falls) and young adults (YA). The proposed test is based on an obstacle avoidance (OA) task, because OA is typically encountered during walking and it requires fast adjustments, preceded by suppression of an ongoing motor activity [6]. We evaluated the developed test in single and dual task conditions, for both EA and YA. We hypothesized that inclusion of an additional cognitive task (also requiring inhibition) would make the new walking task even more demanding, and result in diminished performance on both tasks.

METHODS

Eleven healthy EA (mean age 72 years, SD 3.97 years) and twelve healthy YA (mean age 22.58 years, SD 2.5 years) walked on the C Mill (ForceLink, Culemborg, the Netherlands) at a speed of 3 km/h. This system, comprising a software package and an instrumented treadmill, is able to project gray patches of light onto the treadmill relative to the subjects’ foot placement. These projected patches of light served as stepping stones. The subjects were instructed to walk by stepping on the stones, unless a stepping stone changed color from gray to purple. In the latter case the instruction was to avoid stepping on the stone by either shortening or prolonging the step. Stepping on or beside the purple stepping stone was considered a failure. Task difficulty was manipulated by changing the time available to respond to the change in color (available response time, ART). As ART increases the task gets easier because more time is available to inhibit a previously initiated step aimed at the stone, and to find an alternative. ART was calculated by dividing available response distance (distance between the subjects’ center of pressure and stepping stone at the instant of color change, as provided by the C Mill system) with treadmill speed. The experimental setup is illustrated in figure 1.

During pilot experiments with YA we observed a large variability in performance. The ARTs which our subjects considered “easy” and at which they could perform the task with a low failure rate, varied among the subjects although they all were of similar age and physical abilities. Therefore, in an attempt to develop a protocol that would cover a range from “easy” to “difficult” for all subjects, we determined ARTs considered “easy” individually. To determine the individual “easy” level, subjects were gradually introduced to the task. First they practiced walking on the treadmill without the stepping stones, then the stepping stones were introduced, and after introduction of the color change (serving as an obstacle) they had time to practice the full task. Once familiar with the task they performed short versions of the task that started from a universally very easy condition. (YA: ART = 720 ms, EA: ART = 840 ms). Three obstacles were presented, after which the difficulty was increased (by decreasing ART by 60 ms) until the subject's first failure. This was repeated and the mean value of ARTs at which the two failures occurred served as the limit of the "easy" level for the main experiment.

For the dual task an auditory Stroop task was used, consisting of the words 'high' and 'low' spoken in a high or a low pitch. The stimulus was either congruent (spoken word matched the pitch used) or incongruent (the word did not match the pitch) and subjects were to respond as fast as possible by verbalizing the pitch used. The stimulus was presented continuously and randomized; with the interstimulus interval set to approximately 1.2 s. Responses were recorded wirelessly.

Subjects were tested at their own individually determined "easy" ART level with 20 obstacles that could appear in front of left or right foot. The obstacles were randomly distributed among the stepping stones, with the frequency of the color change set to 7 stones per minute. Following a break the same condition was repeated with auditory dual tasking. Participants were instructed to perform both tasks (primary and secondary) to the best of their abilities.

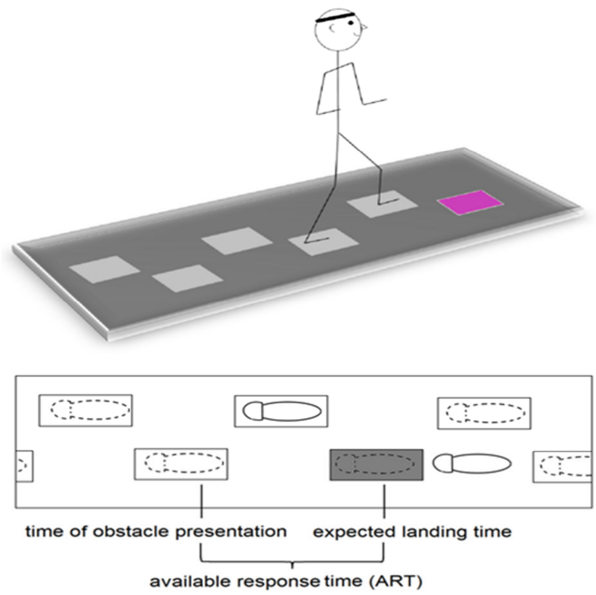

Figure 1: Illustration of the experimental setup and ART. Subjects should step onto projected patches of light unless a patch changes color to purple, in which case they should avoid it.

RESULTS AND DISCUSSION

Individually determined "easy" ART levels and associated failure rates for YA and EA are presented in table 1. Note that the "easy" level for the young was considerably shorter than for the elderly (625 ms compared to 785 ms), indicating that the elderly needed more time to be successful. On the other hand, variability in the individually determined ARTs was much lower for EA than for YA. Failure rates on the walking task were defined as percentage of the total number of presented obstacles. Although an attempt was made to have comparable difficulty level, it was found that failure rates were more than 2.5 times higher for the EA for the YA in the single task condition, using the "easy" task. In the dual task conditions, the failure rates were further increased by 11.12% and 4.55% for YA and EA respectively, confirming our hypothesis that an additional task requiring inhibition would increase error rates on the walking task. Mann Whitney U test showed a statistically significant difference in failure rates between EA and YA for both single ($p < 0.01$) and dual task ($p < 0.01$).

CONCLUSIONS

We have presented a novel task for testing the ability to modify ongoing movements during walking. Initial results of elderly and young adults indicate that this task is feasible for both populations of interest. At their individually determined starting levels of difficulty healthy elderly adults made more failures on the walking task than young adults did, even though they had more time to respond to the obstacle. Adding the dual task increased the failure rates even further. It is concluded that response inhibition during walking is especially challenging for elderly as compared to young adults and might be an underlying factor for increased fall risk in aging.

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Table 1: Individually determined starting level available response times and corresponding failure rates on the walking task, for elderly and young adults, single and dual task.

	Individual "easy" ART (ms)			Failure rate ST (%)			Failure rate DT (%)		
	mean	**SD**	**range**	**mean**	**SD**	**range**	**mean**	**SD**	**range**
Young	625	65	540-720	16	11	5-35	27	11	15-45
Elderly	785	18	780-840	40	22	15-80	45	12	30-60