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Impact of age and obstacles on navigation precision and reaction time during blind navigation in dual-task conditions☆☆

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ABSTRACT

Navigation without vision is a skill that is often employed in our daily lives, such as walking in the dark at night. Navigating without vision to a remembered target has previously been studied. However, little is known about the impact of age or obstacles on the attentional demands of a blind navigation task. This study examined the impacts of age and obstacles on reaction time (RT) and navigation precision during blind navigation in dual-task conditions. The aims were to determine the effects of age, obstacles, and auditory stimulus location on RT and navigation precision in a blind navigation task. Ten healthy young adults (24.5 ± 2.5 years) and ten healthy older adults (69.5 ± 2.9 years) participated in the study. Participants were asked to walk to a target located 8 m ahead. In half the trials, the path was obstructed with hanging obstacles. Participants performed this task in the absence of vision, while executing a discrete RT task. Results demonstrated that older adults presented increased RT, linear distance travelled (LDT), and obstacle contact; that obstacle presence significantly increased RT compared to trials with no obstacles; and that an auditory stimulus emitted early versus late in the path increased LDT. Results suggest that the attentional demands of blind navigation are higher in older than young adults, as well as when obstacles are present. Furthermore, navigation precision is affected by age and when participants are distracted by the secondary task early in navigation, presumably because the secondary task interferes with path estimation.

1. Introduction

Attention is defined as the information processing capacity of an individual [1]. A typical method to evaluate the attentional demands needed to perform a primary task is the dual-task methodology. This methodology assumes that there is a limited central processing capacity and that performing a task requires part of this capacity. If two tasks share this capacity and it is exceeded, performance in one or both tasks will be affected [2].

Older individuals have more difficulty than young individuals with walking and concurrently performing a task, such as avoiding obstacles, watching for traffic, or talking [1,3]. The addition of a concurrent task while circumventing obstacles was found to decrease ability to avoid obstacles, particularly in older adults [4–6]. This may explain the high rate of falls in this population [4,5]. It has been demonstrated that ageing requires a greater proportion of attentional resources to be allocated to postural stability and balance [7]. Slower processing capacity has been associated with age [8] and older adults have shown a decline in attention capacity as well as the ability to allocate available resources between tasks [9]. The tendency to stop walking when talking in older individuals is an indicator of a limited attentional capacity, and is also a predictor of future falls in older nursing home residents [3]. Furthermore, studies have shown significant attentional demands related to postural control in older adults, even under relatively simple conditions [1,7,10,11].

In daily life, there are many instances of displacements with limited vision, such as walking in the dark at night. Older individuals also experience reduced vision that is characteristic of ageing, or have vision problems such as cataracts. Limited vision may further increase the risk of falls, since it has been found that walking without vision requires higher attentional demands [12,13]. Several studies have demonstrated that navigating without vision towards a remembered target is associated with distance and direction errors [12–19]. Higher

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Abbreviations: BR, Body rotation; DT, Distance to target; LDT, Linear distance travelled; OC, Obstacle contact; RT, Reaction time.

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attentional requirements have also been observed during navigation through obstacles with full vision, particularly in older adults [e.g. 20]. However, very little is known about whether age and obstacles have effects on navigation errors and the attentional demands of walking without vision towards a previously seen target.

The aims of this study were to determine the effects of age, obstacles and auditory stimulus location on reaction time (RT) and navigation precision in a blind navigation dual-task. We hypothesised that (1) RT would be longer in older adults than in young participants, since ageing is known to be associated with a slower processing capacity [8]; (2) Older participants will make larger navigation errors than the young ones, since it has been suggested that older adults rely more on vision due to the sensory losses related to ageing [e.g. 21] and are more affected by removal of vision [22]. Age also causes deterioration in the somatosensory and vestibular systems [22], which are important for navigation [23], therefore effects of vision removal on navigation errors would be more significant in older adults; (3) Obstacles would increase RT in the blind navigation task, as previous studies have demonstrated that increasing difficulty of a navigation task would increase RT [e.g. 24,25]; (4) RT would be longer near the start of the path and near the target, since studies have found increased RT at the beginning of walking trials due to gait initiation [24] and as participants neared the target [25]; (5) A stimulus emitted near the start of the path would impact navigation precision more than a stimulus emitted near the end of the path, since the secondary task interferes with necessary updating of the participants' position during navigation [26].

2. Methods

2.1. Participants

Ten young adults (1 male, 9 female, 24.5 ± 2.46 years) and 10 older adults (8 male, 2 female, 69.5 ± 2.88 years) participated in this study. All were healthy, with no recent history of musculoskeletal injury to the lower limb, no history of falls in the past 6 months, and no uncorrectable problems with vision, as was determined through a health questionnaire. Participants also had no cognitive condition that could impair performance in the study, as was evaluated with the mini-mental state evaluation [27]. All participants signed a consent form approved by the University of Ottawa's Ethics Committee before participation.

2.2. Apparatus

Two obstacles were placed at specific intervals along an 8 m walking path. Obstacles were made of light Styrofoam cylinders hung from the ceiling. Obstacle 1 consisted of two beams hanging side by side, 80 cm apart, and represented a door frame. Both beams were 1.8 m in length and 7 cm in diameter. Obstacle 2 was 1.8 m in length and 12 cm in diameter and was placed in the middle of the path. Figs. 1 and 2 represent this layout. A Vicon512^{TM} three-dimensional motion analysis system (Oxford Metrics, Oxford, UK) with 8 infrared high-resolution cameras was used to collect reflection from markers. A model was obtained from 20 reflective markers placed on the participant. Sampling frequency was set to 200 Hz. Participants were also equipped with a speaker that emitted the auditory stimulus and an mp3 player to record the stimulus and verbal response. The speaker and mp3 player were both attached to a fabric loop placed around the participant's neck, at the level of the sternum. Participants wore opaque goggles that completely excluded vision during the trials.

Fig. 1. Setup of the experiment. The obstacles consisted of Styrofoam cylinders which were hung from the ceiling. Obstacle 1 consisted of two obstacles representing a door frame placed 1m30 after the starting point. Obstacle 2 consisted of a foam cylinder placed in the middle of the path, approximately 4m30 through the path.

2.3. Procedure

2.3.1. Single-task

The main task in this experiment was blind navigation. Participants were placed at the starting line and had 5 s to look at the path and the target located 8 m away, after which they put on opaque goggles. There was an 8-s delay before giving participants the starting signal to eliminate the internalisation of path information [15]. The participants' task was to depart at the starting line, walk the 8-m path while wearing the opaque goggles until they believed they had arrived at the target line, and stop. Following each trial, the participants were wheeled back to the starting line with a wheelchair while still wearing opaque goggles in order to avoid knowledge of results which may have affected performance.

In half the trials, obstacles 1 and 2 were installed in the path, as shown in Figs. 1 and 2. We randomly presented blocs of 4 trials with or without obstacles in order to reduce time spent manipulating obstacles. During the blind navigation task, participants were asked to avoid obstacles while executing the previously described goal of reaching the target without vision. Participants were instructed to keep walking even if they touched an obstacle.

2.3.2. Dual-task

In addition to the navigation task, either with or without obstacles, an auditory-verbal RT task was added. This type of RT task was used since it is an easy, portable technique and is the standard secondary task used in similar studies from our research team [e.g. 7,13]. An auditory stimulus ("beep") was emitted at any one of the 6 different locations of the path. Participants were asked to respond "top" as quickly as possible to this stimulus, while continuing the primary task of navigating without vision towards the target. There was either one or no stimulus emitted per trial, with the stimulus randomly alternating among 6 locations of the path, as demonstrated in Fig. 2. RTs were collected when the stimulus was emitted near obstacle 1, near obstacle 2 or triggered manually at the participants' last step (Fig. 2: Locations 1, 3 and 6). No RTs were collected at locations 2, 4 and 5 as these correspond to stimuli used as supplementary trials to counteract consistency of auditory stimuli. The supplementary trials were used to reduce risk of any association or sequence pattern that may be noticed by participants. The location of auditory stimuli was randomly presented to avoid anticipation.