

EFFECTS OF THE PRESENCE OF OBSTACLES ON THE ATTENTIONAL DEMAND
OF BLIND NAVIGATION IN YOUNG AND ELDERLY SUBJECTS

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Abstract

The ability to navigate with limited vision is a skill that is often employed in our daily lives. Navigating without vision to a remembered target has previously been studied. However, not much is known about the attention required to perform blind navigation. We examined the effect of aging and presence of obstacles on the attentional demands of blind navigation. We evaluated reaction time, navigation errors and average walking speed in an 8 meter walking path, with or without obstacles, in the absence of vision. Results showed that older participants had increased reaction time and increased linear distance travelled as opposed to young participants, that obstacles increased reaction time and decreased average walking speed in all participants, and that emitting the reaction time stimulus early in the trial increased the linear distance travelled. Interpretation of the results suggests that aging and presence of obstacles augments the attentional demands of blind navigation.

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Abbreviations

LDT – Linear Distance Travelled

DTT – Distance to Target

BR – Body Rotation

AD – Angular Deviation from Direct Path

AWS – Average Walking Speed

RT – Reaction Time

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Chapter I

Introduction

Falls are a very serious concern for the health and quality of life of the elderly population. Forty percent of adults aged 65 and older living at home fall at least once a year (Rubenstein, 2006), and 50% of the elderly living in nursing homes fall annually (Lipsitz Johnson, Kelley & Koestner, 1991). Unintentional injuries are the fifth leading cause of death in older adults and falls correspond to two-thirds of these deaths (Rubenstein, 2006). There are many causes for this high prevalence of falls. With aging there is a decline in motor coordination, postural control, reflexes and muscle strength (Rubenstein, 2006). In addition, there are impairments in sensory systems, for instance vision and hearing (Rubenstein, 2006). A combination of these elements makes this population more prone to falls, which may lead to a loss of independence.

If we look at a basic daily task, for example walking in the dark at night and following a usual path in a house or apartment, it is implied that a normal young adult would have no difficulty getting from point A to point B without vision (i.e. without having to turn on the lights) (Mittelstaedt & Mittelstaedt, 2001; Loomis, Da Silva, Fujita & Fukusima, 1992; and Reiser, Ashmead, Talor & Youngquist, 1990). However, if we were to look at this task in an older person, in whom the sensory, motor and cognitive systems may slightly be impaired, it is possible they would accidentally hit an obstacle on their way to the destination. There are many possible examples of displacements with limited vision, especially in this older group; of course there is walking in the dark at night, but also dealing with reduced vision that normally comes with age, or with vision problems such as cataracts. Is the task of walking without vision in a remembered environment too difficult for this older

population? Is such difficulty due to deficiencies in the sensory-motor or the cognitive systems, or both? Our study aims to examine the cognitive aspect of this question. Previous studies have suggested there is a high attentional demand associated to walking without vision (Paquet, Lajoie, Rainville & Sabagh-Yazdi, 2008; Glasauer, Stein, Günther, Flanagin, Jahn, & Brandt, 2009; Lafleur, 2011). Other studies have shown the impact of walking without vision on navigation errors (Thomson, 1983; Reiser *et al.*, 1990; Paquet, Rainville, Lajoie & Tremblay, 2007; Paquet *et al.*, 2008; Mittelstaedt & Mittelstaedt, 2001; Loomis *et al.*, 1992; Gallagher, Lajoie & Guay, 2001). And finally, studies have also demonstrated the attentional requirements associated to walking through obstacles (Chen, Schultz, Ashton-Miller, Giordani, Alexander & Guire, 1996; Gérin-Lajoie, Richards & McFayden, 2006). However, no study did investigate the attentional demands of walking without vision towards a previously seen target, in a path clustered with obstacles. Furthermore, very little is known on the impact of aging on this ability. This thesis presents a scientific study aimed at answering these questions.

Chapter II

Review of Literature

1.0 Navigation

For the purpose of this study, we will be referring to navigation as the local navigation process, in which the individual is moving around in the immediate environment. All objects are within the range of perception and there is no need for internal representation of objects and places outside the immediate environment (Trullier, Wiener, Berthoz & Meyer, 1997). Navigation involves the integration of sensory, motor and cognitive functions (Trullier *et al.*, 1997). Vision is usually used to navigate and successfully avoid obstacles during walking. However, there are cases where vision may not be available or accurate. Walking in darkness or with low visual acuity are perfect examples of this. Therefore when we refer to blind navigation in this article, we are relating to navigation with the absence of visual information.

2.0 Role of Visual Information in Navigation

There have been debates on the necessity of continuous visual information during navigation. A study by Thomson in 1983 addressed this issue. He wanted to determine if locomotion can be controlled adequately when vision is excluded and to find the controlling mechanisms. It was demonstrated that locomotion can, in fact, be controlled adequately even without vision, meaning that subjects could accurately reach a target and navigate through obstacles without vision as long as target and obstacles have previously been seen. These results depended more on the time required to do the task than the distance to the target or the obstacles in the way (Thomson, 1983). The results suggested that there are two mechanisms by which this locomotion towards a target without vision is achieved. First, for

short distances (under 5 meters), subjects could program the necessary motor activities in advance. These accurate programs are independent of time and additional vision. However, they are inflexible and cannot be readjusted without vision. The second mechanism involves internalization of information in short-term memory in a more general form, which allows activities to be controlled over greater distances, and also allows for reorganization of the activity without having to reconsult vision directly. However, this internalization of information has a drawback, as after 8 seconds it starts fading out of short-term memory whether it was used or not (Thomson, 1983). These mechanisms of locomotion relate to open and closed loop types of limb control. Similarly to short distances, the open loop type of control involves the use of centrally determined, prestructured commands sent to the effector system which carries off the action. This type of limb control is done without feedback. It is used to control rapid, discrete movements, and is inflexible in the face of unexpected changes (Schmidt & Wrisberg, 2004). For the longer distances, we see a link to the closed loop type of limb control, which involves the use of feedback, and error detection and correction, to maintain the desired goal. It is to control slow, deliberate movements and is inadequate for fast movements (Schmidt & Wrisberg, 2004).

Previous studies (Mittelstaedt & Mittelstaedt, 2001; Loomis *et al.*, 1992; and Reiser *et al.*, 1990) have supported the one by Thomson by demonstrating that young, healthy individuals can accurately reach a previously seen target while walking forward without vision. Individuals seem to be accurate when the target is located 2 to 24 meters ahead. However, there are often small errors made in blind navigation, as subjects rarely stop at the exact location of the target, especially in distances over 10 meters. Variability of results seems to increase with distance, with a small and constant variability in distances between 3 and 9 meters, and much larger variability with larger distances (Loomis *et al.*, 1992). A study

by Rieser *et al.* (1990) looked at blindfolded walking to various distances ranging between 2 and 22 meters in 3 different conditions: standard walking, walking with a delay of 8 seconds at the start of the task and fast walking. Results showed that variable error increased as a linear function of distance.

3.0 Navigation and Aging

First of all, to give a proper definition to “older adults”, we will be using this term to refer to individuals aged 65 years or older, as this is the age group used in most studies found in the literature.

As previously mentioned, to maintain an upright posture, we resort to sensory information provided by vision, kinesthetic information (proprioceptive and cutaneous) and the vestibular system (Diener & Dichgans, 1988). The information provided by these systems is processed centrally in diverse areas of the brain including the cerebellum, brainstem, basal ganglia, and sensorimotor cortex. The control of posture is then done by musculoskeletal elements, which receive commands via the spinal cord and peripheral nerves (Downton, 1990). With age comes a deterioration of both the input, with a loss of sensitivity of the visual, proprioceptive and vestibular systems, and the output, with a slowing of nerve conduction velocity and reduction of muscle size (Lord, Clark & Webster, 1991; Woollacott, Shumway-Cook & Nashner, 1982). Studies such as the one by Manchester, Woollacott, Zederbauer-Hylton and Marin (1989) have shown significant deterioration in the somatosensory, vestibular and visual systems in accordance with age. Manchester *et al.* (1989) evaluated the visual, vestibular and somatosensory contributions to balance control. By using platform perturbations and comparing a young group to an older one, the authors determined that more losses of balance occurred in the older adults when ankle

proprioception was made incongruent with postural sway and when only foveal vision (where peripheral vision is occluded by goggles) was available. Skinner, Barrack and Cook (1984) have evaluated the effect of age on proprioception, referred in their article as joint-position sense. They found that aging is associated with a decline in joint-position sense. A study by Deshpande and Patla (2007) has shown the impact of aging on the visual-vestibular interaction during goal-directed navigation. They evaluated the impact of galvanic vestibular stimulation (GVS), which perturb vestibular information, and distorting vision on balance control in navigation, in young and elderly individuals. Participants had to walk a distance of 6 meters with various intensities of GVS and either normal or blurred vision. They found that increasing the intensity of the GVS would increase path deviations more in the older participants and that blurred vision conditions would decrease walking speed and increase step width variability. Results of their study suggest that vestibular input reweighting was less effective in older participants, as shown by their inability to converge efficiently towards the target with the GVS.

It has also been shown that older adults have a slower walking pace than young adults (Gabel, Johnston & Crowinshield, 1979). Furthermore, many studies by Murray and colleagues (Murray, Drought & Kory, 1964; Murray, Kory, Clarkson & Sepic, 1966; Murray, Kory and Clarkson, 1969) have demonstrated in adults 65 years of age and older, compared to young subjects, a shorter stride length (defined as the linear distance in the plane of progression between successive points of foot-to-floor contact of the same foot (Murray *et al.*, 1964)) and broader stride width (defined as the transverse distance between points approximating the ankle joint centers (Murray *et al.*, 1964)), a slower cadence and a lower swing-to-stance time ratio, in which subjects spent a longer period in the stance phase and a shorter period in the swing phase.

Many studies have been done on the impact of aging on navigation. For example a study by Gallagher *et al.* in 2001 compared young and elderly participants in an 8 meter blind walking task. There were 2 conditions: predictive, where participants had access to an emergency vision button, and received vision if they stepped out of the pathway borders, and the reactive condition, where vision was automatically given halfway through the path and in case of deviation from path. They found the elderly had shorter stride length, had slower walking speed, made more deviations from the pathway, and needed more access to visual cues to reach the target when compared to the young participants. Another study by Lafleur in 2009 demonstrated that in a similar 8 meter blind walking task, older subjects made more navigation errors, such as a larger body rotation at target and a larger angular deviation from the path, and they also made more distance errors by overshooting the target versus the young subjects, who had a tendency to undershoot and be closer to the target.

4.0 Attention

As we have evaluated the attentional demands of different blind navigation tasks, it is important to define attention. For this context, attention is defined as the information processing capacity of an individual (Woollacott & Shumway-Cook, 2002). A typical method to evaluate the attentional demands needed to perform a primary task is the dual-task methodology. This methodology has 3 basic underlying assumptions: Firstly that there is a limited central processing capacity, secondly that performing a task requires part of the limited processing capacity within the central nervous system, and thirdly, if two tasks share the processing capacity, and the capacity is exceeded, performance in one or both tasks can be disturbed (Kahneman, 1973; Parasuraman, 1981).

There are different models capable of explaining the decrease in performance that happens in a dual-task, as described in an article by Lacour *et al.* (2008). First, the cross-domain competition model postulates that posture control and cognitive activity compete for attentional resources. This would mean that in a dual-task condition, postural performance should be altered. This has been disproved in many studies therefore this model has serious limitations. Second, there is the U-shaped non-linear interaction model, which states that body balance can either be improved or diminished depending on the difficulty of the cognitive demand of the secondary task. In this theory there are limitations as well since studies used did not employ similar parameters to evaluate postural performance. More studies need to be done to confirm its functional relevance. Finally, there is the task prioritization model. This model proposes that dynamics of balance control could be achieved differently among subjects. It is similar to Baltes' model of selection, optimization, and compensation which is based on three principals: the selection of the goals that are crucial for the individual, the optimization of the performance level of the goal is done by all relevant means, and compensation is made by using alternative strategies for maintaining performance level (Baltes, 1997). It seems that older individuals will prioritize posture in divided attention situations, as a way of avoiding falls. This theory also has some disapproval, with certain reports contradicting the model.

There are several theories concerning attention that explain the reason why doing two tasks concurrently is difficult; the fixed capacity theory, the central-resource capacity theory, and the multiple resource theory. The fixed capacity, or bottleneck, theory proposes that a person has difficulty doing several things at once, since the human information processing system executes each of its functions in serial order, and some of these functions can process only one element at a time. The bottleneck theory suggests that a bottleneck exists

somewhere along the stages of information processing, which filters out information which is not selected for further processing (Magill, 2004). Various authors have debated on the location of the filter, some saying it was early in the processing sequence, at the stage of detection of environmental information (Welford, 1952; Broadbent, 1958), and others arguing it was later, after information was perceived or after it had been processed cognitively (Norman, 1968; Deutsch & Deutsch, 1963; Keele, 1973). Alternatively, there is the central-resource capacity theory, which proposes there is one central source of attention resources for which all activities requiring attention compete (Magill, 2004). Kahneman (1973) stated that capacity limits of the central pool of resources are flexible. The amount of available attention may vary depending on certain personal characteristics (i.e. arousal level), on the task being performed (i.e. attentional demand required) and on the situation. Finally, the multiple-resource theory suggests there are several attention resource mechanisms, each of which is related to a specific information-processing activity, and is limited in how much information it can process simultaneously (Magill, 2004). Wickens (1980, 1992) proposed that resources for processing information are available from 3 sources: the input and output modalities (i.e. vision, limbs and speech system), the stages of information processing (i.e. perception, memory encoding and response output) and the codes of processing information (i.e. verbal codes and spatial codes). When concurrent tasks compete for the same resources, they will be performed less well than if they used different resources.

5.0 Attentional Demands in Balance Control, Walking and Navigation

It has been demonstrated that balance control, both in static and dynamic conditions, is attentionally demanding. This was first demonstrated by Bardy and Laurent (1991). Their study proved that reaction times increased as difficulty of the task increased. In their

experiment, young subjects had to walk towards a target surface and stop in front of it. Two target sizes were used (large and small) and the trials were either done using a single-task or dual-task situation, in which reaction time was evaluated using the response to an auditory stimulus. Reaction times were longer during the walking task with targets than during unconstrained walking and sitting. It was shown that the participant's reaction time increased as they approached the target, with considerably shorter reaction times during the early stages of the approach. Studies by Lajoie *et al.*, in 1993, and Paquet *et al.*, in 2008, similarly demonstrate an increase in reaction time associated with the difficulty of the task. Lajoie *et al.* (1993) proposed that if higher cognitive processes are needed to control and regulate gait, a less stable postural position (i.e. walking) would require more attention than a stable position (i.e. sitting). Their study compared reaction time to an auditory stimulus in 4 conditions: sitting, standing with a broad base of support, standing with a narrow base of support, and walking along an 8 meter path. Results from their study showed that reaction times were fastest for sitting, slower for standing, and slowest for walking. Reaction time slowed proportionally to the increased difficulty of the postural/locomotor task. This indicates that balance control and gait are attentionally demanding, and demonstrates that these demands increase with the difficulty of the task (Lajoie *et al.*, 1993). Therefore, they state that the walking task cannot be considered an automated task requiring no cognitive processing. As for the study by Paquet and colleagues in 2008, they similarly examined attentional demands by testing participants on an 8 meter path. However, subjects had to walk without vision in four separate directions (forward, backward, and sideway right and left) until they believed to have reached the target. In addition to this task, participants had to count backwards in increments of 3. Results demonstrated that the dual task had a significant effect on gait velocity, and that the rate of correct responses to the counting task was

significantly reduced in the dual-task. Therefore, they suggested that their dual-task exceeded the attention capacity in subjects. They noted that performance of their primary task was not affected in their dual-task. They attribute this to the task prioritization effect; the subjects were told that the primary task (navigation without vision towards a previously seen target) was more important than the secondary task (counting backwards by steps of 3). It was proposed that if subjects are instructed to place priority on the navigation task, the impact would be the variation of the secondary task (the reaction time).

A study by Sparrow *et al.*, (2002) confirmed that increasing difficulty of the task would increase reaction time. The authors also confirmed the attentional cost associated with walking. In their study, they compared 12 young to 12 older participants in both an unconstrained walking and a targeting task. Participants also had to respond to either an auditory or a visual reaction time task. They found that the unconstrained walking task was associated to a longer reaction time than the baseline, and the targeting task was associated to a longer reaction time than the unconstrained walking task. The researchers effectively supported previous findings, corroborating that increasing the difficulty of the task lengthens reaction time. This was later supported by Lafleur (2009), who demonstrated similar results in her walking task. Participants were asked to walk along an 8 meter path and stop when they believed they had reached the target. Concurrently, they were asked to respond to auditory signals, to measure reaction time. There was a significant effect of condition on reaction time: the baseline, sitting reaction time was shorter than during navigation.

Literature demonstrates that performing a secondary or multiple tasks during a relatively automatic activity such as walking does not present a significant threat to stability in healthy young adults. This was demonstrated in a study by Ebersbach and Dimitrijevic (1995) in which the effect of concurrent tasks on the control of gait was investigated.

Participants had to walk along a 10 meter pathway while doing 4 different tasks: a digit span memory task, a fine motor task, a combination of both digit span and fine motor tasks, and a fast finger tapping task. They found that the concurrent tasks had impacts on gait, by reducing stride time and increasing the double-support time. These significant changes in gait parameters were however fairly small, suggesting that multiple tasks during a task such as unperturbed gait does not pose an important threat to stability in young adults. However the effects in older individuals or people suffering from neurological conditions could be more severe.

Attentional requirements of navigation seem to vary in a walking task. As previously mentioned, Bardy and Laurent's study in 1991 demonstrated that reaction time increased as participants neared the target in a walking task. However, according to Sparrow *et al.* (2002), there also seems to be an effect of gait initiation. This group demonstrated elevated reaction times at the beginning of the trials, which they associate to the attentional cost of gait initiation. This seems to be more present in older adults. The data from Sparrow's study (2002) combined with the data from Bardy and Laurent's study (1991) seem to suggest that in a navigation task there is an attentional cost of gait initiation followed by a reduced demand during the steady-state of walking, followed by an increase in proximity of an obstacle or target.

6.0 Attentional Demands in Navigation and Aging

Studies have suggested a significant difference in attentional demands between young and older individuals. In 2002, Sparrow *et al.* compared young participants to older ones in different walking tasks, and found that reaction times were longer for the older participants, which they associate with a higher risk of increased falls in this population. Similarly, in

2006, Gérin-Lajoie *et al* took a look at attentional demands of a walking task with obstacles. They examined the effect of stationary or moving obstacles on gait combined with an attention task of listening to a recorded message and answering questions at the end of each trial regarding the message. Results showed that older adults made more errors in answering the questions related to the messages than young participants, which suggests they had greater problems dividing attention between both tasks.

Furthermore, it has also been shown that dividing attention in a walking task had a bigger impact on older individuals than younger ones. Chen *et al.* (1996) examined the effect of dividing attention on the ability to avoid obstacles, comparing young versus older subjects. Subjects had to step over a virtual band of light, and in some trials had to respond to vocal reaction time tests while walking. Obstacle contact was increased when attention was divided, and this change was larger in the older subjects. Results from this research lead the authors to suggest that this diminished ability to respond to hazards may contribute to the high rates of falls in the elderly. They propose that in a demanding gait task, a secondary stimulus could cause a decline in the gait task performance, which would increase the risk of falls, or that allocating increased attentional resources to the gait task could reduce the response time to a hazard.

At this point, we know there is a higher attentional cost associated to walking without vision (Paquet *et al.*, 2008; Glasauer, *et al.*, 2009; Lafleur, 2011), that navigating without vision towards a remembered target is possible however it will be associated to navigation errors (Thomson, 1983; Reiser *et al.*, 1990; Paquet *et al.*, 2007; Paquet *et al.*, 2008; Mittelstaedt & Mittelstaedt, 2001; Loomis *et al.*, 1992; Gallagher *et al.*, 2001) and that walking through obstacles is associated to higher attentional requirements (Chen *et al.*, 1996; Gérin-Lajoie *et al.*, 2006). No previous study examines whether aging has an effect on the

navigation errors and the attentional demands of walking without vision towards a previously seen target, in a path including obstacles. For this reason, we decided to take a look at navigation errors and reaction time in a blind navigation task with and without obstacles, in young and older participants.

7.0 Objectives and Hypotheses

The general objective of this study is to determine the effects of aging on the attentional demands of blind navigation with or without obstacles. More specifically, our aims are to 1) determine the effects of age on reaction time and on navigation errors in a blind walking task; 2) determine the effects of obstacles on reaction time and on navigation errors in a blind walking task; 3) determine the impact of location of auditory stimulus on reaction time and navigation errors in a blind walking task; and 4) determine the effects of age and presence of obstacles on mean walking speed.

We hypothesise that 1) reaction time and navigation errors increase in accordance to age. As the sensory losses related to aging normally push older adults to rely more on vision, we believe the effects of the removal of vision on navigation errors are more significant. Aging is also known to be associated with a slower processing capacity (Welford, 1988), therefore we expect a slower reaction time in the older participants; 2) obstacles increase reaction time in the blind walking task but not navigation errors because the length of the path is short; 3) There is an increase in reaction time at the beginning of the task and near the target, and when the auditory stimulus is given early in the path, navigation errors are larger than when it is given later; and 4) speed is decreased with age as it is found in the literature as being a normal consequence of aging, and speed decreases with the complexity of the task (therefore is slower in trials with obstacles).

Chapter III

The Effect of Obstacles on the Attentional Demand of Blind Navigation in Young and Older Participants

1.0 Methods

1.1 Participants

In this study, we tested 20 participants; 10 young adults, aged between 21 and 29 years (average age of 24.5 years), and 10 older adults, aged between 67 and 76 years (average age of 69.6 years). We used a convenience sample to select participants. Participants had no recent history of musculoskeletal injury to the lower limb and no history of falls in the past 6 months, which was determined through a health questionnaire (Appendix III), and no neurological condition that could impair performance in the study, which was evaluated with the mini-mental state evaluation (Folstein, Folstein & McHugh, 1975) (Appendix IV).

1.2 Material

In the study, participants were in a large room (18 x 9 meters) which included an 8 meter walking path. The starting point and target at 8 meters were clearly identified with masking tape lines on the floor, and obstacles were placed at specific intervals along the path. Obstacle 1 consisted of two foam cylinders which were hung from the ceiling (Figure 1). Both obstacles had reflective markers attached to the lower extremity, to ensure their representation in the Vicon recording, and were 1m81 in length and 7cm in diameter. Foam cylinders were only fixed to the ceiling, so if a participant were to hit one, it would move. Obstacle 1 represented a door frame, with a width of approximately 80 cm, placed 1m30 after the starting point. Obstacle 2 consisted of a foam cylinder (1m77 in length and 12cm in

diameter) placed in the middle of the path, approximately 4m30 through the path. Figures 1 and 2 illustrate this layout.



Figure 1 – Setup of the Experiment. The obstacles consisted of foam cylinders which were hung from the ceiling. Obstacle 1 consisted of two obstacles (1m81 in length, 7 cm in diameter) representing a door frame, with a width of approximately 80 cm, placed 1m30 after the starting point. Obstacle 2 consisted of a foam cylinder (1m77 in length, 12 cm in diameter) placed in the middle of the path, approximately 4m30 through the path.

A Vicon512TM three-dimensional motion analysis system (Oxford Metrics, Tustin, CA, USA) with 8 infrared high-resolution cameras was used to collect body displacement along the walking path (but only start and end positions were analysed). A model was obtained from 20 reflective markers placed on both sides of participant, on shoulders, upper arms, elbows, hands, hips (anterior and posterior), knees, ankles, heels and toes. Sampling frequency was set at 200 Hz.

In addition to the reflective markers, participants were also equipped with a speaker, to emit the auditory stimulus, and an mp3 player, to record the stimulus and verbal response to the stimulus. Finally, participants wore opaque goggles to eliminate vision.

Photoelectric cells were placed at specific intervals along the path, to trigger the emission of the auditory stimulus when a participant's body crossed the beam of light emitted by the cell. Figure 2 illustrates the position of the cells.

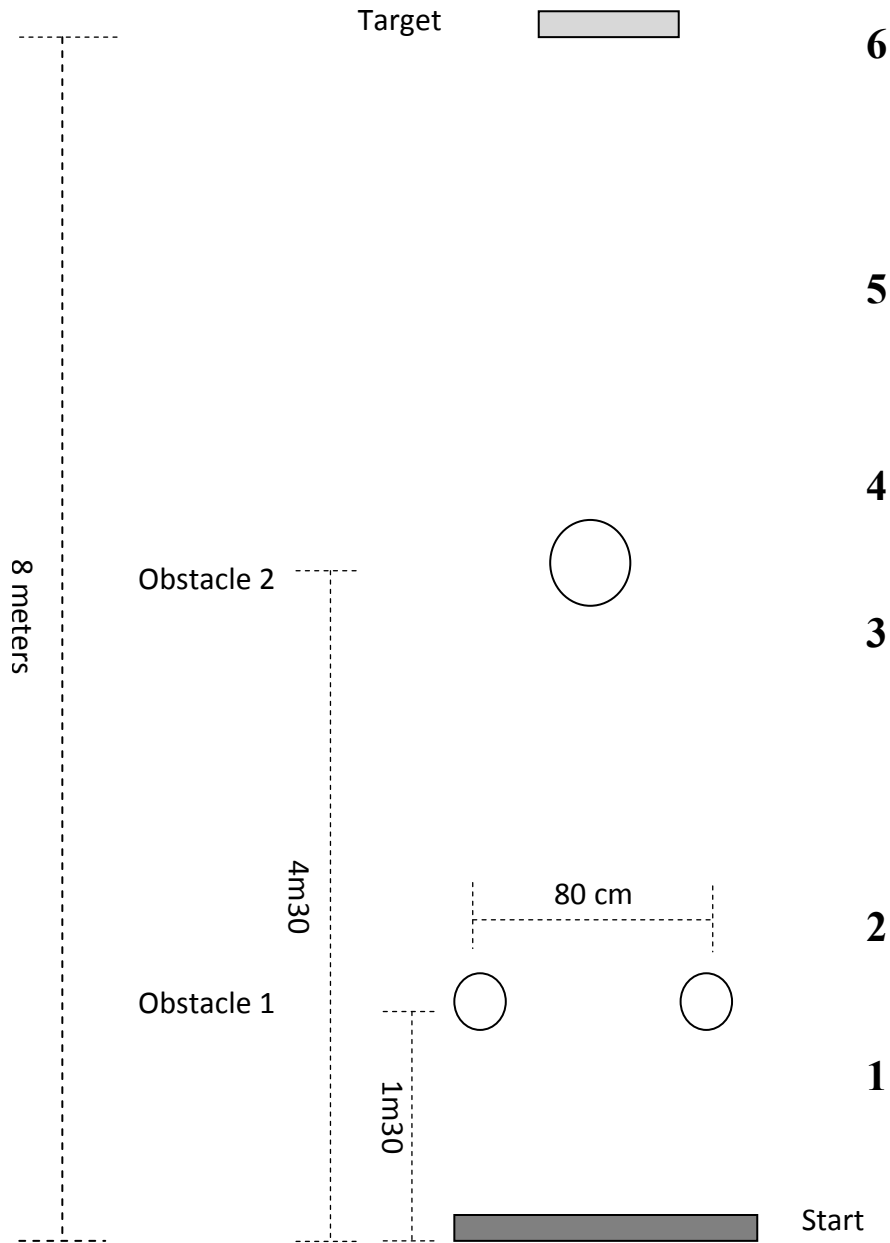


Figure 2 – Setup of the Experiment: 8 meter path including starting line, target line and obstacles 1 and 2. Obstacle 1 was located 1m30 after the starting line, and the distance between both foam cylinders in obstacle 1 was of 80 cm. Obstacle 2 was located 4m30 after the starting line. Location 1 corresponds to the auditory stimulus emitted near obstacle 1. Location 3 corresponds to the auditory stimulus emitted near obstacle 2. Location 6 corresponds to the auditory stimulus emitted at the last step. Locations 2, 4 and 5 correspond to the auditory stimuli which were used as supplementary trials to counteract consistency of stimuli.

1.3 Procedure

There were two conditions in this experiment. The first condition was a single blind navigation task, and the second condition was a dual-task involving a primary navigation task with a secondary reaction time task performed concurrently.

Single-task

The main task in this experiment was blind navigation. Participants were placed at the starting line and had 5 seconds to look at the path and target. After these 5 seconds, they put on their opaque goggles. We waited 8 seconds before giving them the starting signal to eliminate the internalization of the path information (Thomson, 1983). The participants' task was to depart at the starting line, and walk the 8 meter path while wearing the opaque goggles until they believed they had arrived at the target line. After participants stopped, following each trial, the experimenter would roll them back to the starting line with a computer chair while they kept wearing the goggles.

In half the trials, obstacles 1 and 2 were added to the main blind navigation task, as described in the material section. 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 hit an obstacle. We alternated between trials with and without obstacles but kept them in blocks of 4-8 trials, simply because of the manipulation of the obstacles which was time consuming. In the event that a participant would walk too close to a fixed obstacle (such as a wall), they were told to stop walking immediately, to avoid injuries that could occur, and the experimenter would roll them back to the starting point using the computer chair, while the participant kept wearing the goggles. A computer chair was used to roll the participant back to the start line to avoid feedback of results. Participants

never knew where they had stopped, and therefore performance improvement due to feedback was avoided.

Dual-task

In addition to the navigation task, done either with or without obstacles, we added a reaction time task. An auditory stimulus (“beep”) was emitted at 6 different places in the path. Participants had to respond “top” as quickly as possible, while continuing the primary task of navigating without vision towards the target. There were either 0 or 1 stimuli emitted per trial, at alternating places on the path. As illustrated in Figure 2, there could be a stimulus emitted near obstacle 1, another near obstacle 2 and another triggered manually at the last step made by participants (locations 1, 3 and 6). Locations 2, 4 and 5 correspond to stimuli which were used as supplementary trials to counteract consistency of auditory stimuli. This was done to reduce risk of any association that may be done or any sequence that may be noticed by participants. The location of auditory stimuli was randomly presented to avoid anticipation. This task was done either without obstacles, or with obstacles 1 and 2. We were interested in finding reaction time at the moment where the participant was wondering whether he or she is nearing the target, not necessarily at the target itself because participants make distance and direction errors. Therefore the last stimulus (location 6) was emitted manually by the experimenter, who used judgement through observation to trigger that stimulus during the last walking cycle of the participant in the trial. In addition, for three participants out of the 20, all the auditory stimuli had to be triggered manually, since the automatic triggering was not working.

Trials

Eight trials per auditory stimulus locations 1, 3 and 6 were done in each condition (no obstacle or 2 obstacles) for a total of 48 trials. In addition, 8 trials with no stimulus were done in each condition (no obstacle or 2 obstacles) to bring the total up to 64. Finally, we included 6 supplementary trials at auditory stimulus locations 2, 4 and 5, which gave us a total of 70 trials. The order of the trials was randomly presented, and we alternated through conditions.

At the end of all 70 trials, participants were asked to walk the path twice with vision, to gather their comfortable walking speed.

1.4 Outcome Measures

From the collected kinematic data, we extracted only the starting and final positions. Therefore, only two moments from each trial were taken, using the shoulder markers. If the shoulder marker data was unavailable, we would use the knees, or the ankles. With this extracted data, we were able to calculate the following navigation errors:

Linear Distance Travelled (LDT): LDT corresponds to the average linear distance travelled between the start and final position of each task (Figure 3).

Distance to Target (DTT): DTT corresponds to the average linear distance between the final position and the target (Figure 4).

Body Rotation (BR): BR corresponds to the participant's shoulder angle at the final position. It was calculated by comparing the shoulder angle between the starting line and the final position (Figure 5).

Angular Deviation from Direct Path: Angular deviation (AD) is the angle of deviation from the straight trajectory towards the target (Figure 6).

Average Walking Speed (AWS): AWS corresponds to the average gait velocity in each trial and was measured in meters by seconds. It was calculated by dividing the linear distance travelled by the duration of the trial. AWS in the navigation task without obstacles served as the reference to which other speeds were compared.

When all trials were calculated, we calculated an average for each condition: Auditory stimulus locations 1, 3, 6 or no stimulus, either with or without obstacles. This was done for each participant. These averages were then used for analysis. We excluded the supplementary trials at locations 2, 4 and 5.

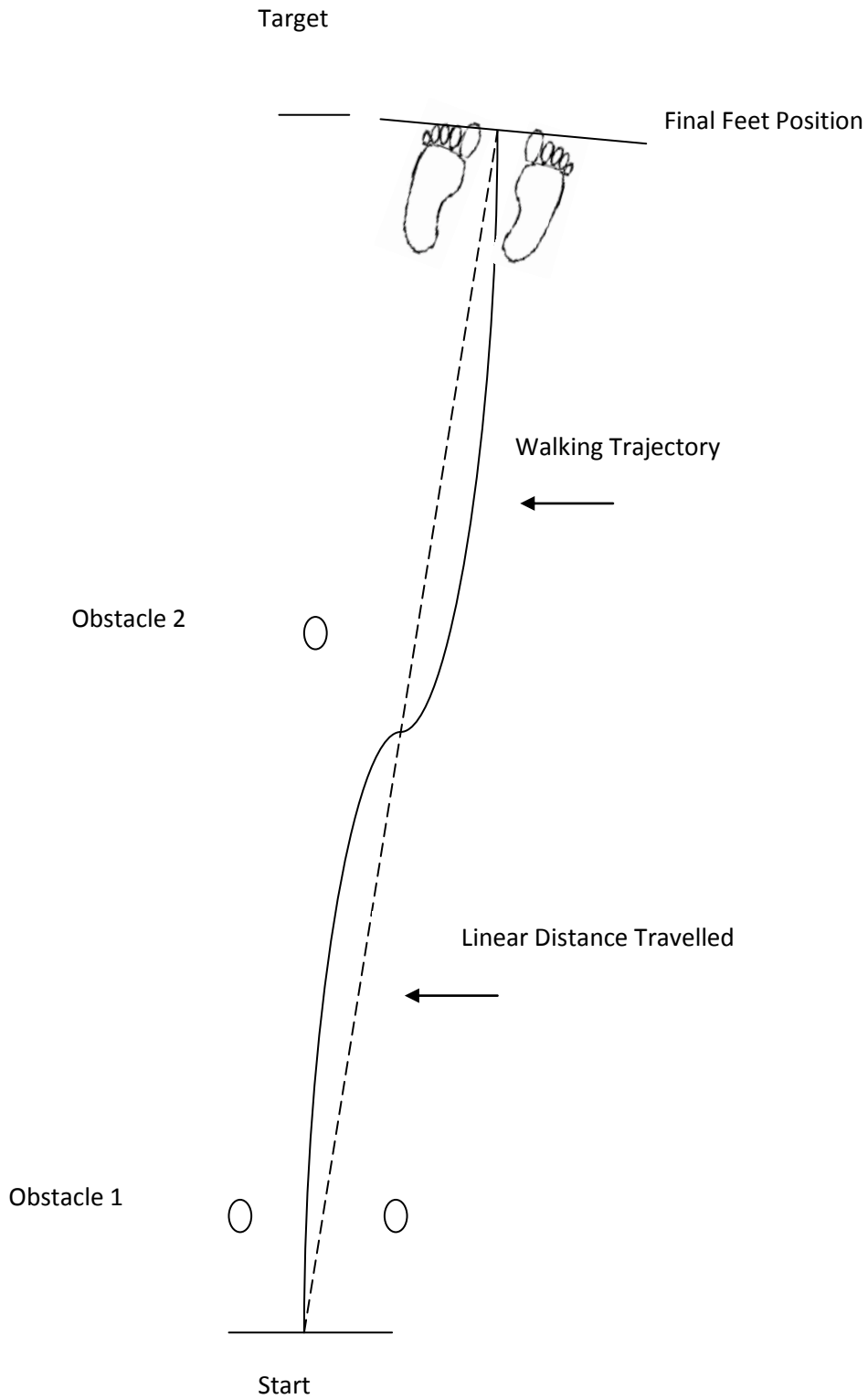


Figure 3 – The measure of Linear Distance Travelled (dashed line) shown from a theoretical walking trajectory (continuous line)

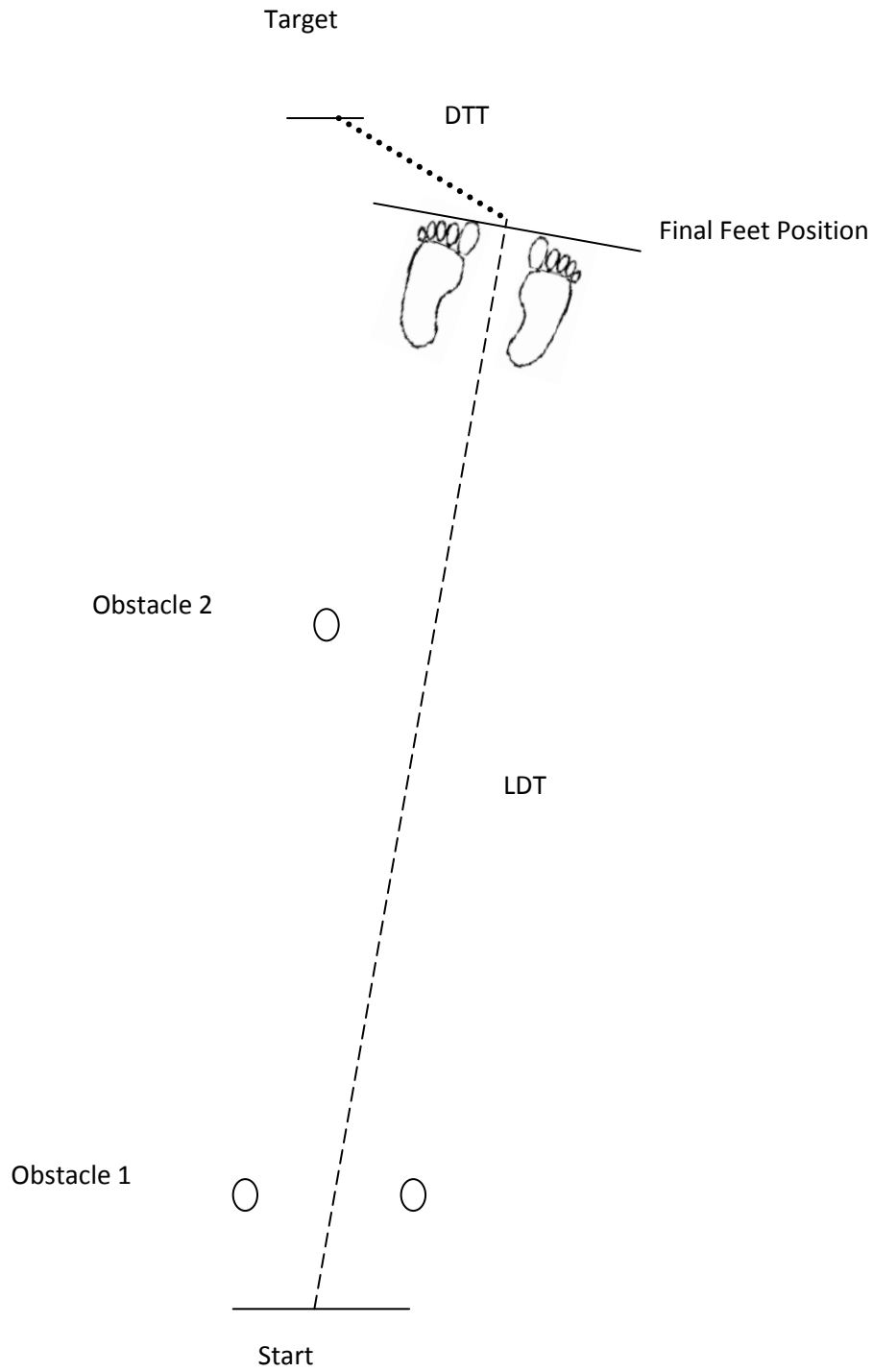


Figure 4 – The measure of Distance to Target (dotted line) shown from a theoretical LDT

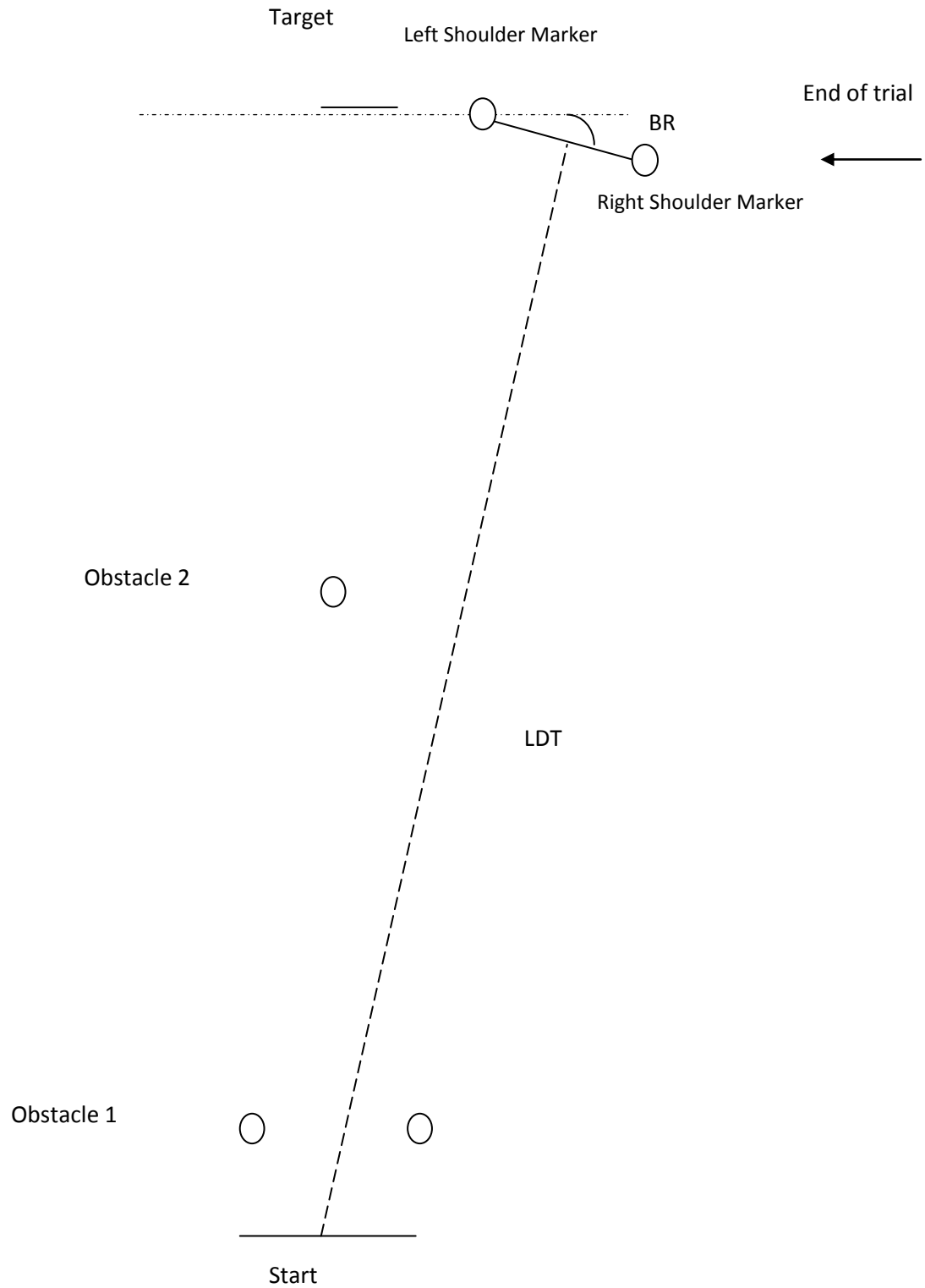


Figure 5 – The measure of Body Rotation (BR) shown from a theoretical LDT

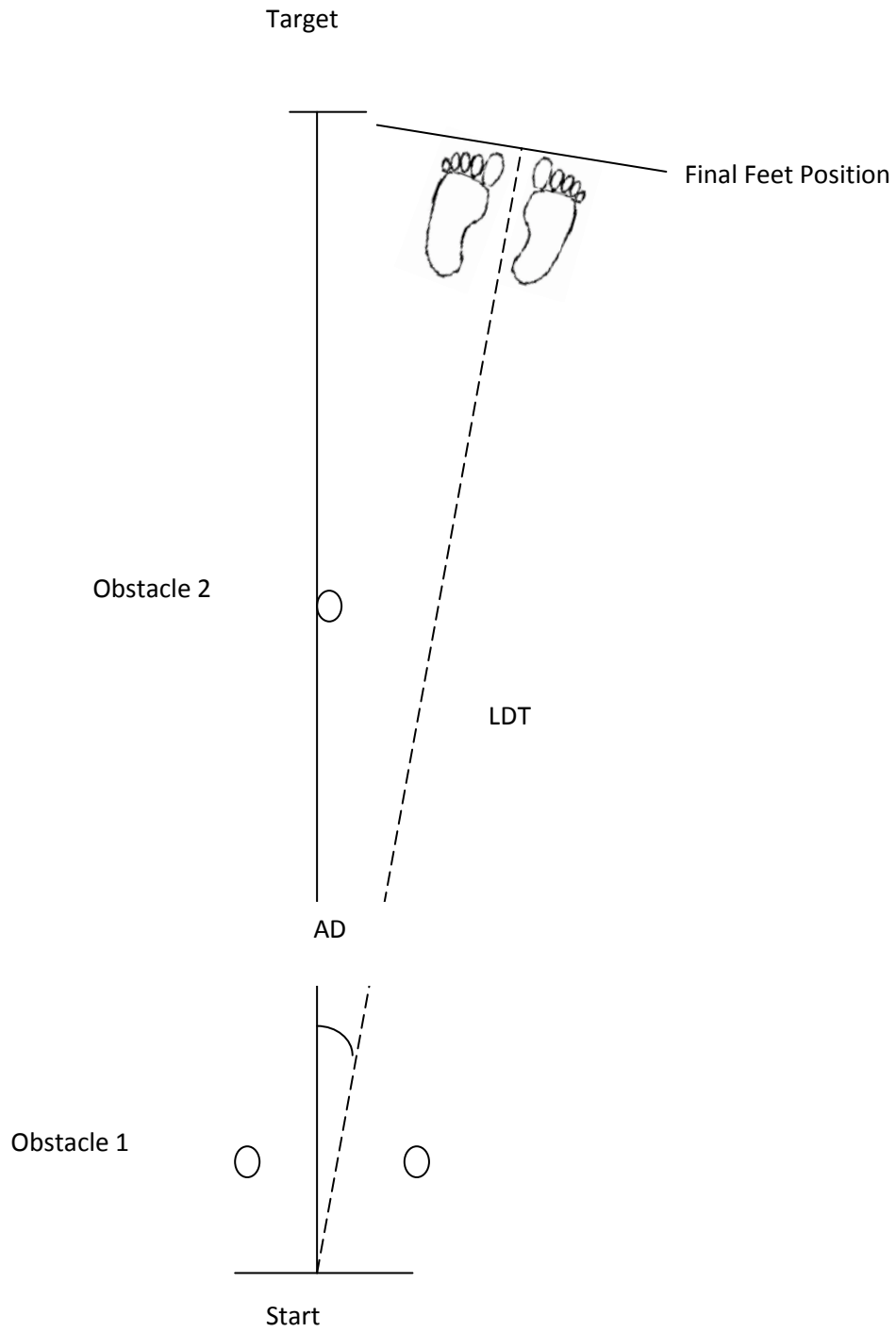


Figure 6 – The measure of Angular Deviation (AD) from the direct path shown from a theoretical LDT

Reaction time (RT) was established using the audio data we collected with the mp3 player. We used Audacity software for Windows XP to determine the time between the first deflection of the trace during the stimulus sound signal and the first deflection of the trace during the verbal response. The difference in time gave us the RT for each trial. For each participant we then calculated an average RT for each condition: Auditory stimulus locations 1, 3 or 6, either with or without obstacles. We did not include in the analysis the supplementary trials at locations 2, 4 and 5, and also excluded outliers (data that diverged from an average of ± 2 standard deviations).

2.0 Statistical Analyses

Data reduction was done before analysis, by calculating averages for each outcome measure within participants. Six three-way analysis of variance on group (young vs. older) x condition (obstacle vs. no obstacle) x location of stimulus (1, 3, 6 or no stimulus) with repeated measures on the last two factors were performed on RT, LDT, DTT, BR, AD and AWS. Post hoc comparisons were used to localize significant differences. Significant main effects and interactions were reported at 0.05. Data analysis was performed using Statistica for Windows (StatSoft, Tulsa, OK, USA).

3.0 Results

3.1 Reaction Time During Navigation

Statistical results of a three way ANOVA (Group X Condition X Location) with repeated measures on the last two factors revealed a significant effect of group on reaction time ($F_{(1, 18)} = 15.645, p = 0.001$), which is demonstrated in figure 7. Older participants proved to have a significantly longer average reaction time (640 ms) than the young participants (521 ms). In figure 8, we can observe a significant effect of condition on RT ($F_{(1, 18)} = 13.278, p = 0.002$). The average RT in conditions with obstacles (603 ms) is longer than in conditions without obstacles (558 ms). There was no significant effect of stimulus location (obstacle 1, obstacle 2 or last step) on RT ($F_{(2, 36)} = 1.302, p = 0.284$) with average RT of 582 ms, 571 ms and 587 ms respectively. There were no significant interactions between variables. Figure 9 below illustrates a summary of obtained RT data, showing average RT for trials with or without obstacles for the different auditory stimulus locations, in young and older participants.

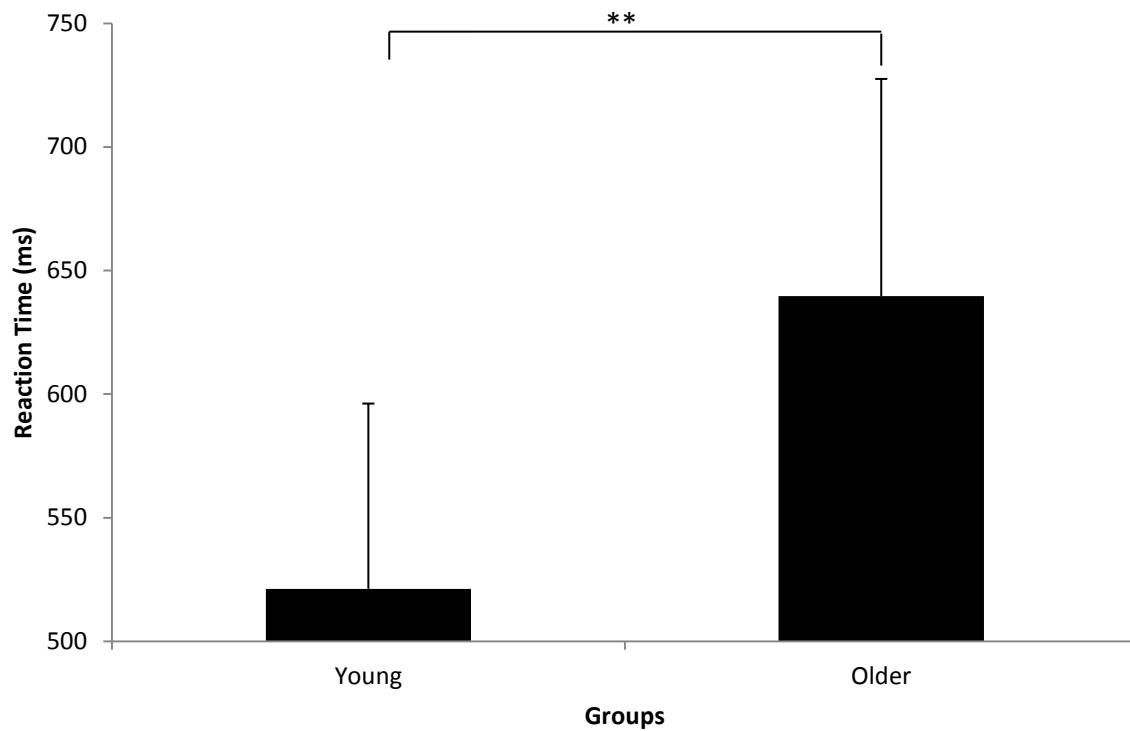


Figure 7 – Average (+1 SD) Reaction Time for Young vs. Older Participants (** $p < 0.01$)

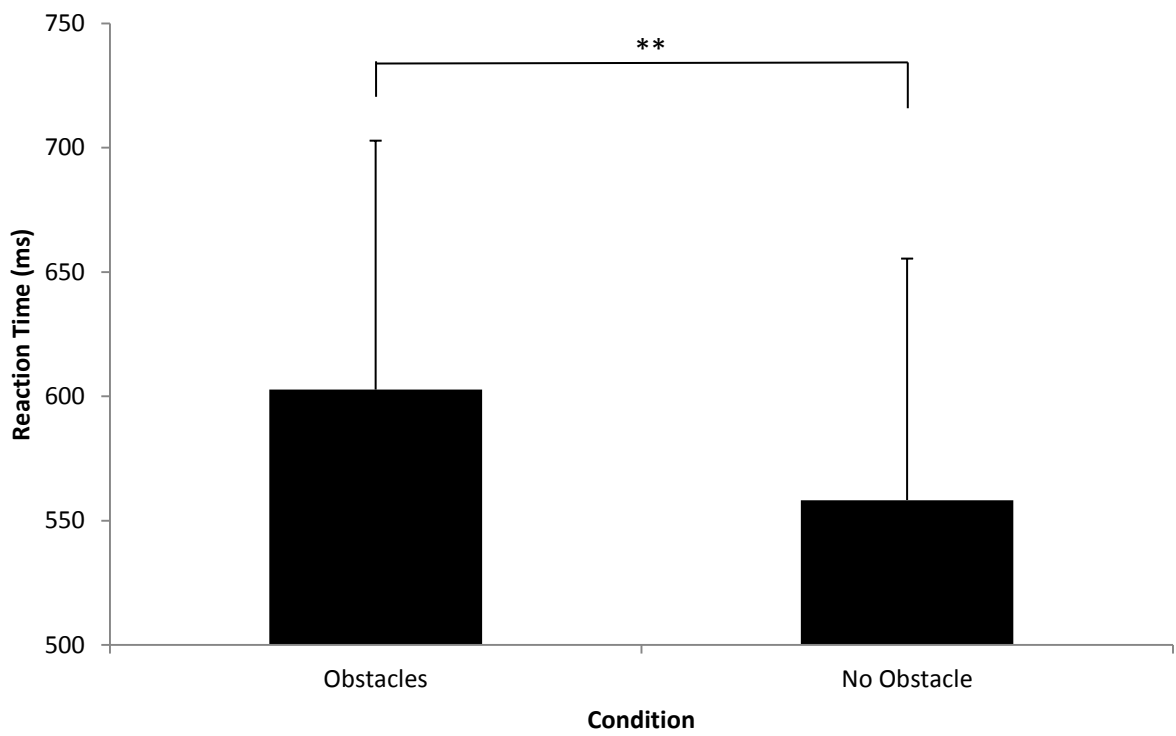


Figure 8 – Average (+1 SD) Reaction Time for Trials with Obstacles vs. with No Obstacles (** $p < 0.01$)

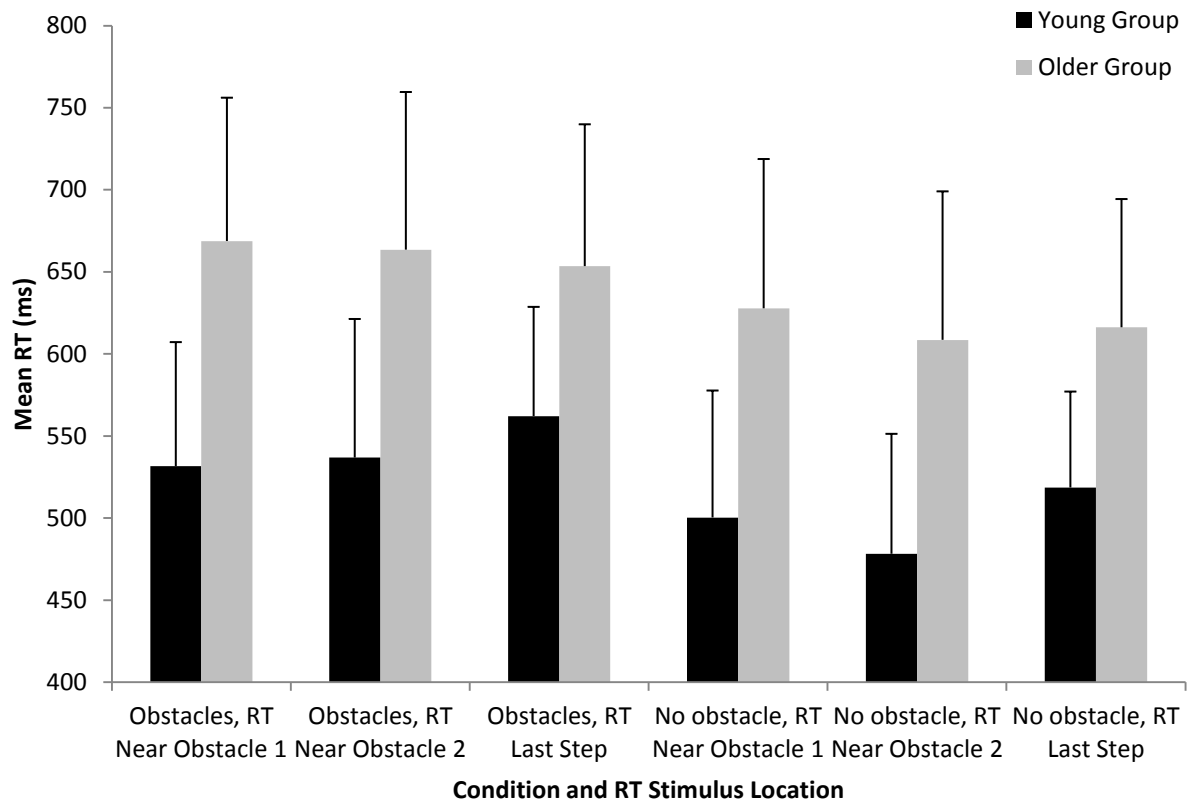


Figure 9 – Average (+1 SD) Reaction Time for Trials with Obstacles or with No Obstacles for Different Auditory Stimulus Locations, in Young and Older Participants. There is a significant effect of group on reaction time ($F_{(1, 18)} = 15.645, p = 0.001$), and a significant effect of condition on RT ($F_{1, 18} = 13.278, p = 0.002$). There was no significant effect of stimulus location (near obstacle 1, near obstacle 2 or last step) on RT ($F_{2, 36} = 1.302, p = 0.284$) and no significant interactions.

3.2 Navigation Errors

Linear Distance Travelled and Distance to Target

Results of a three way ANOVA (Group X Condition X Location) with repeated measures on the last two factors revealed a significant main effect of Group on the average linear distance travelled ($F_{1,18} = 4.620, p = 0.045$). Figure 10 illustrates a significantly larger LDT in older adults (9262 mm), compared to the young adults (8228 mm).

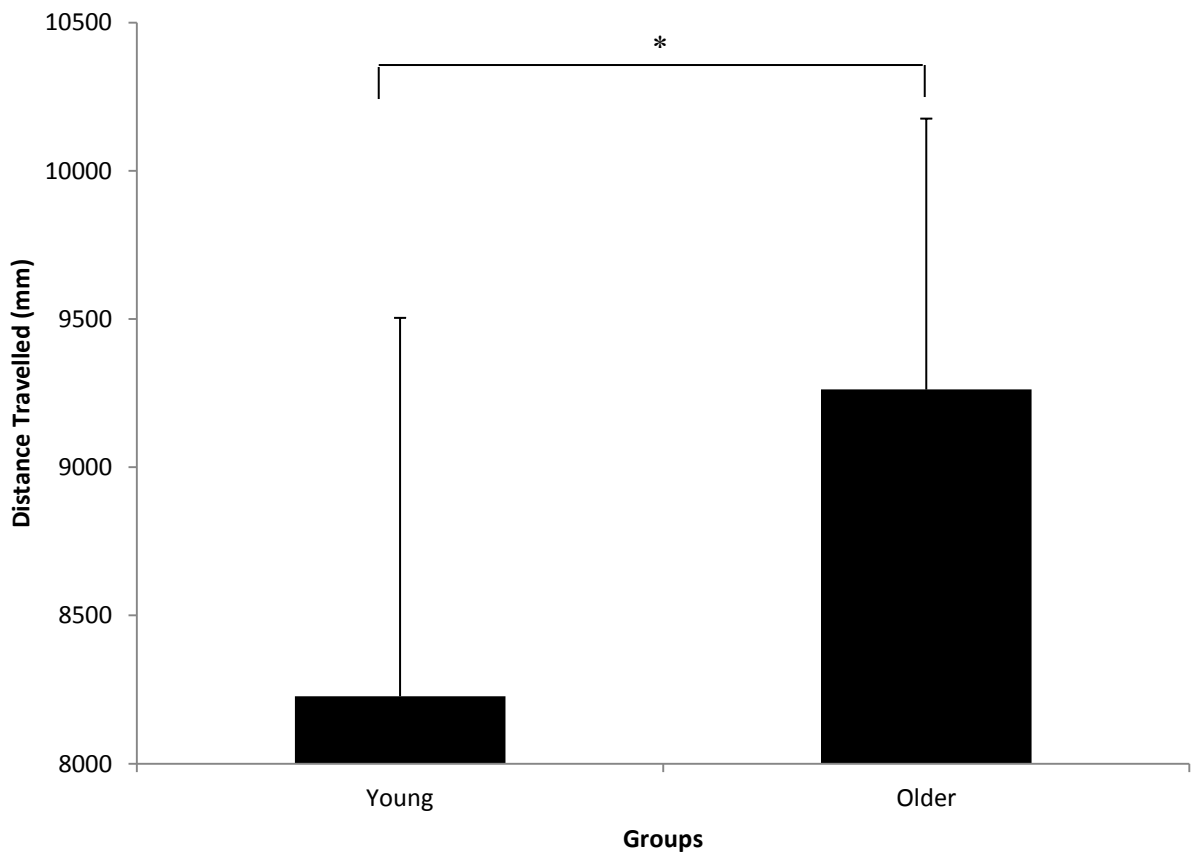


Figure 10 – Average (+1 SD) Linear Distance Travelled in Young and Older Participants (* $p < 0.05$)

Figure 11, below, illustrates a significant difference in the LDT by participants between start and finish when the auditory stimulus is emitted at the beginning of the walking task ($F_{3, 54} = 3.857, p = 0.014$), rather than later in the task. The LDT was longer when the auditory stimulus was emitted near obstacle 1 (8886 mm) rather than near obstacle 2 (8715 mm), at the last step (8675 mm) and when there was no stimulus (8704 mm).

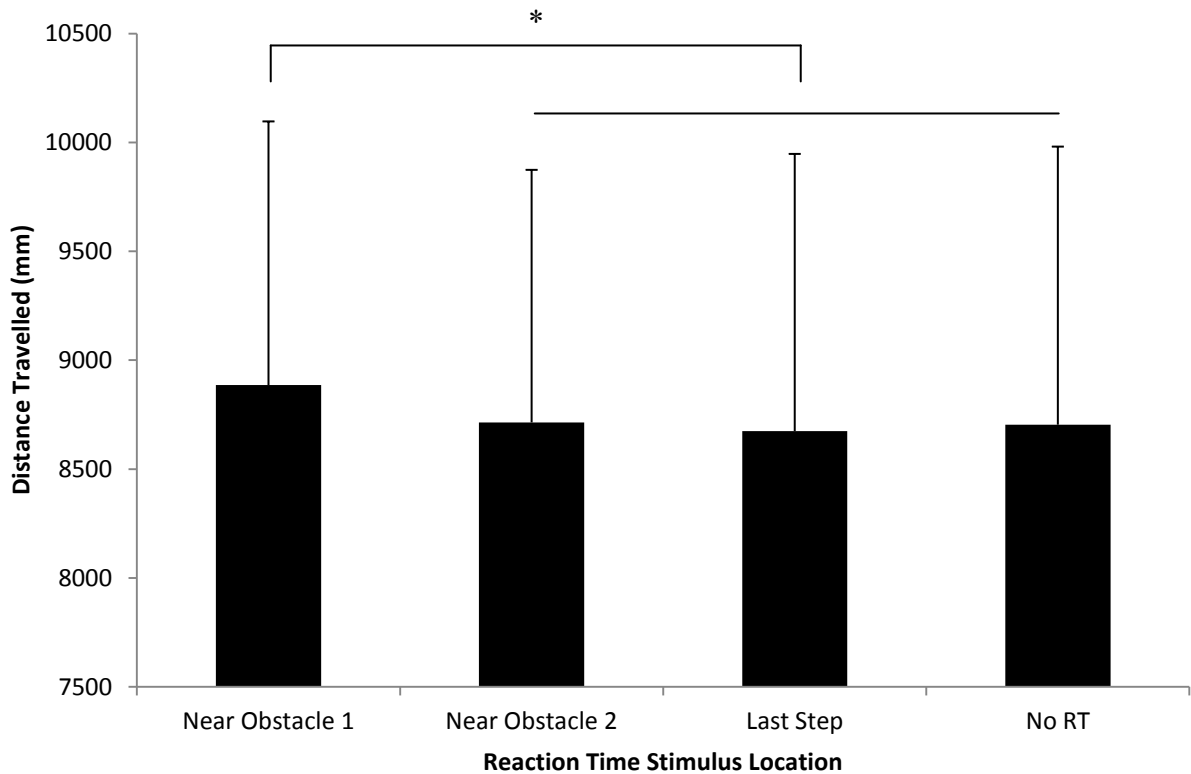


Figure 11 – Average (+1 SD) Linear Distance Travelled for Different Locations of Auditory Stimulus (Near obstacle 1, near obstacle 2, at the last step of the trial, or when there is no stimulus given) (* $p < 0.05$).

There was no significant effect of obstacle presence on average LDT ($F_{1, 18} = 0.017$, $p = 0.897$), with an average of 8735 mm for trials with obstacles and 8755 mm for trials without. For average distance to the target, there were no significant effects of group, obstacle presence or auditory stimulus location and no significant interactions between variables. For group, there was no significant effect ($F_{1, 18} = 2.633$, $p = 0.122$), with younger participants having an average DTT of 1440 mm and the older participants an average DDT of 1802 mm. Obstacle presence did not have a significant effect ($F_{1, 18} = 0.473$, $p = 0.500$), with an average DTT of 1582 mm with obstacles and 1660 mm without. As for auditory stimulus location, there was also no significant effect ($F_{3, 54} = 0.819$, $p = 0.489$), with an average DDT of 1674 mm with stimulus near obstacle 1, 1589 mm near obstacle 2, 1628 at last step, and 1593 with absence of stimulus.

Body Rotation and Angular Deviation from the Direct Path

Results of a three way ANOVA (Group X Condition X Location) with repeated measures on the last two factors revealed a significant main effect of condition on average body rotation ($F_{1, 18} = 7.250$, $p = 0.015$). Participants were less accurate in tasks with obstacles than without, with a significantly higher BR at the end of the task (11.743° with obstacles versus 10.080° without). However, the difference between obstacle and no obstacle is only of 1.6°. There was no significant effect of group on BR ($F_{1, 18} = 0.720$, $p = 0.407$), with average BR of 10.2° for young participants and 11.6° for older participants, or auditory stimulus location ($F_{3, 54} = 0.120$, $p = 0.948$), with an average BR of 10.9° with stimulus at obstacle 1, 10.8° at obstacle 2, 11.1° at last step, and 10.9° with no stimulus. For angular deviation from the direct path, there was no significant effect of group ($F_{1, 18} = 1.407$, $p = 0.251$), obstacle presence ($F_{1, 18} = 3.478$, $p = 0.079$), or auditory stimulus location ($F_{3, 54} =$

1.107, $p = 0.354$), although we see a tendency in the effect of obstacle presence in angular deviation. We can see that the presence of obstacles increases angular deviation from the direct path, with an average AD of 5.2° versus 4.5° when no obstacles are present, although this just failed to reach significance. Average AD for young participants was of 4.4° versus the older participant average of 5.3° , and averages for different locations of the auditory stimulus were of 4.9° with stimulus near obstacle 1, 4.9° near obstacle 2, 5.0° at last step and 4.6° when no stimulus was given.

Average Walking Speed

Results of a three way ANOVA (Group X Condition X Location) with repeated measures on the last two factors revealed a significant main effect of condition on average walking speed ($F_{1, 18} = 71.581, p < 0.0001$). In figure 12, we show the AWS in conditions with obstacles as opposed to conditions without obstacles, for young and older participants. AWS in conditions with obstacles (0.645 m/s) is significantly slower than AWS in conditions without obstacles (0.824 m/s). There is no effect of group ($F_{1, 18} = 0.737, p = 0.402$), with an AWS of 0.714 m/s for young participants and 0.756 m/s for older participants, or location of auditory stimulus ($F_{3, 54} = 1.546, p = 0.213$), with an AWS of 0.741 m/s with stimulus near obstacle 1, 0.731 m/s near obstacle 2, 0.730 m/s at last step and 0.737 m/s with no stimulus.

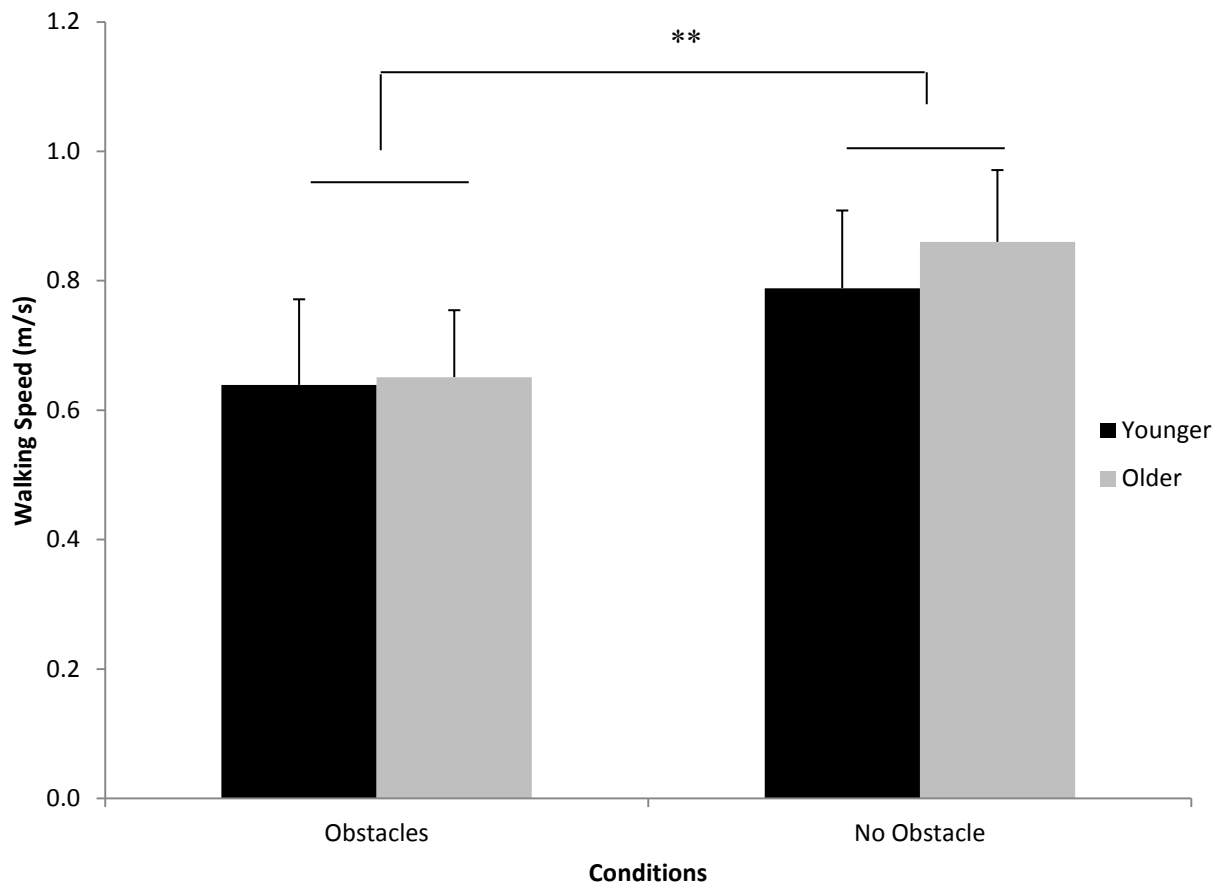


Figure 12 – Average (+1 SD) Walking Speed in Conditions with Obstacles vs. with No Obstacles, for Young and Older Participants (** $p < 0.01$)

4.0 Discussion

This experiment revealed four main findings: 1) aging increases RT and navigation errors during navigation without vision on a distance of 8 meters; 2) the presence of obstacles in the 8 meter path increases RT in both groups; 3) location of auditory stimulus has an impact on distance errors in both groups; and 4) the presence of obstacles slows down the AWS in both groups.

4.1 Aging and Blind Navigation

4.1A: Aging increases RT during blind navigation

In our study, we found a significant effect of age on RT in the blind navigation task. Older participants proved to have a significantly longer average RT than the young participants. Previous studies have shown the differences in RT between young and older participants. For example, a study by Lajoie, Teasdale, Bard and Fleury (1996) compared 8 young and 8 elderly participants in different tasks (sitting, standing with a broad support base, standing with a narrow support base and walking along an 8 meter path), with a secondary RT task. Results indicated that older participants had longer RT than the young participants. This supports the idea that age may affect RT during navigation. Another study was the one by Chen *et al.* (1996) which compared young vs. older participants walking along an 8 meter pathway. In their study, a virtual band of light was projected across participants' path while they walked and participants were instructed to step over this "obstacle". In addition, to divide attention, RT tests were conducted during the walking task, where participants had to verbally respond as soon as a red light would turn on. They found that the secondary mental task affected the older participants significantly more than the young ones, by making them do more errors or avoid less obstacles. This supports our findings, as aging affects the ability to perform a dual task during walking.

A study by Sparrow *et al.* (2002) was done on the effects of aging on the attentional demands of walking. They compared 12 young vs. 12 older participants on 8 meter walking tasks, one being unconstrained walking, the other being a targetting walking task, where participants had to place either foot between target strips 8 meters away from the starting point. Either auditory or visual RT tasks were emitted randomly between initiation and end of walkway. They found an effect of age on the visual RT task, but not in the auditory RT task. It is possible, as proposed by Wickens (1980, 1992) in accordance to the multiple-resource theory, that when participants had to use the same sensory modality (in this case vision) to navigate and respond to a stimulus, they found an effect of age, but when it was two different modalities, there was no age effect. It is important to note that this experiment was done with vision, which could result in a smaller attention demand than in blind navigation.

Results from a study by Lafleur (2009) are different than ours. They used a very similar protocol to the one used in the present study, comparing 14 young to 10 older participants in an 8 meter blind walking task, which included a RT task. The main difference was that they did not use obstacles. They found no significant effect of age on RT. We know that complexity of the task can affect RT. By adding obstacles to our study, we increased complexity of the task. This would cause subjects whose processing capacity was already close to being exceeded (such as the older adults) to show an increase in RT. Therefore, this could be a reason why we saw a significant effect of age on RT, and not Lafleur.

Most of these findings suggest that attentional demand during a dual task involving walking is greater in older than in young participants. More specifically, the attentional demand is particularly increased in the absence of vision during walking.

These results were expected, since aging is known to be associated with a slower processing capacity (Welford, 1988), reduced attentional resources, and a deficit in the capability to divide attention and/or to correctly allocate the resources between simultaneous tasks (Baron, Myerson, & Hale, 1988; Craik & Byrd, 1982)

Furthermore, as stated previously, attention is likely limited in every individual and any task that is not reflex or fully automated requires a portion of this limited processing capacity. If two tasks performed simultaneously exceed this processing capacity, performance should deteriorate, either on the primary task or both tasks (Kahneman, 1973; Parasuraman, 1981). A previous study by our group similarly demonstrates this (Paquet *et al.*, 2008). They used a blind navigation task combined with the dual-task of counting backward by steps of 3 during navigation. They found that subjects counted slower and made more mistakes during the dual-task (navigation and counting) than when counting while sitting. Studies by Lajoie *et al.* in 1993 and 1996 presented similar conclusions. In the 1993 study they compared RT in 6 subjects in the following tasks: sitting, standing with broad base of support, standing with narrow base of support and walking on an 8 meter pathway. In the 1996 study, the protocol was the same; however they compared 8 young participants to 8 older ones. Both studies demonstrated that the RT for the sitting task was shorter than in the standing tasks, and similarly the RT for the standing tasks were shorter than the walking task. Therefore, they showed that by increasing complexity of the task, RT was longer. This brings us back to Kahneman (1973) and Parasuraman's (1981) suggestion that performance deteriorates when processing capacity is exceeded. Hence, this idea supports our proposal that attentional requirements were exceeded in the present task of navigating through obstacles without vision. It seems that the capacity was more exceeded in our older participants than in the young ones.

We can suggest that our results support the task prioritization model, or similarly Balte's model of selection. The older participants seem to have prioritized navigation control at the expense of cognitive performance, as seen by a slower RT than in the young group. Furthermore, in one subject in particular, we were able to observe a clear example of prioritizing postural stability, since the participant often stopped whenever the auditory stimulus would be emitted, answer the verbal response and then keep walking. Of course, we worked with a younger category of older individuals; therefore these differences between young and old will not have been as noticeable as if we had worked with an older group.

4.1B: Aging increases navigation errors during blind navigation

The literature states that it is possible for young, healthy individuals to reach a previously seen target without vision (Mittelstaedt & Mittelstaedt, 2001; Loomis *et al.*, 1992; and Reiser *et al.*, 1990; Thomson, 1983). This has also been demonstrated in older adults, although they make more mistakes than young individuals (Gallagher *et al.*, 2001; Lafleur 2009). Thomson's study (1983) demonstrated that for distances over 5 meters, individuals seem to internalize the visual information in their short-term memory in a more general form, which allows for reorganization of the activity without having to reconsult vision directly. However, after 8 seconds this internalization of information starts to fade out of short-term memory whether it was used or not. In the case of our study, since participants walk at different speeds and take different strategies to circumvent the obstacles, time to complete the trial varies amongst participants. To control for this, we waited 8 seconds after participants put on their opaque glasses to give the start signal, to eliminate the impact of this internalization of visual information.

Our study supports literary findings that young and older participants can successfully navigate to a previously seen target without vision. It also supports the idea that aging increases navigation errors during blind navigation, more specifically LDT. Lafleur (2009) similarly found a significant effect of group on travelled distance, where travelled distance was shorter in young participants than older participants, which supports our present findings. In the study from Gallagher *et al.* (2001), young and older participants had to walk an 8 meter pathway, blindfolded, without stepping out of bounds. They found the older participants had a tendency to deviate more from the path, although these results did not achieve significance. The study may suggest that aging could cause an increase in navigation errors, in their case demonstrated by more deviations from the path.

Thus, in blind navigation studies, aging was found to impact navigation precision by increasing navigation errors. This is an expected result, as somatosensory and vestibular systems are known to deteriorate with age (Manchester *et al.*, 1989). Altogether, the previously mentioned results support the idea that the cognitivo-sensori-motor control of older adults is impaired compared to young adults. Older participants may have difficulties with perception of their own displacement (Böök & Gärling, 1981) or in updating the current position during navigation (Potegal, 1982). This impairment could also be due to a difficulty in estimating the target distance and location (however Reiser *et al.* (1990) have shown that this contributes very little to navigation errors) or an insufficient working memory to remember the target's position while updating one's own position (Reiser *et al.*, 1990).

We found significant differences in LDT, however no significant difference in DTT or AD. This combination of DTT and AD, two non-significant measures, seems to cause enough impact to make a significant difference in the LDT value. Possibly with a bigger sample size we would have achieved significance in all measures.

4.2 Presence of Obstacles in Blind Navigation

We found a significantly longer RT associated to trials with obstacles, as opposed to trials without obstacles. Previous studies support this finding. The study by Sparrow *et al.* (2002) compared RT in two different dual-task conditions: unconstrained walking, and targeting (placing the foot between target strips). They found that RT was longer in the targeting task. It suggests that the targeting task was more complex than the unconstrained walking task and required more attentional resources. In a study by Bardy and Laurent (1991), 11 subjects were asked to walk to randomly positioned targets along a path, which ranged from 13.5 to 15 meters from the starting point. Targets varied between small and large, and this was done either in a single- or dual-task situation, which involved a RT task. Results from this study demonstrated that RT was longer in the case of a small target. It could be that the task with a small target was more difficult to execute and required more attention. These findings relate to Posner and Keele's study in 1969, which demonstrated a similar finding for wrist movements made to small and large targets. These studies bring us back to Fitts's Law, which suggests that the time needed to quickly move to a target area is function of the distance to the target and the size of the target. Targets that are smaller and/or further away require more time to acquire. The law demonstrates a speed-accuracy trade off, which is a tendency to substitute accuracy for speed, or vice versa, depending on the task requirements (Fitts, 1954).

These findings suggest that attentional demands are higher during a more complex walking task involving navigation. More specifically, in the case of the present study, we added to the actual knowledge that attentional demands are increased during walking through obstacles in the absence of vision, in both young and older participants.

4.3 Location of Auditory Stimulus on Distance Errors and RT

As the novel finding of this study, we found it very interesting to discover that the location of the auditory stimulus has an impact on the distance errors. We found that when the auditory stimulus was emitted near obstacle 1 it significantly increased the distance travelled rather than when given later. We cannot support this finding with what is found in the literature as it is a new finding, since no previous study compares the impact of different auditory stimulus locations on distance errors in blind navigation through obstacles. We propose that the emission of the auditory stimulus acted as a distraction to the participant. An explanation for this could be that the stimulus likely interferes with the necessary updating of the participant's position during navigation (Potegal, 1982), which is to keep mentally calculating the distance to be covered to reach the target. Thus, when the auditory stimulus is given early, participants undergo disorientation early during the trial, which makes them make a larger error than when they get distracted later in the trial. Further studies would need to be made on the subject to confirm this finding and to support our theory.

We were expecting to see a difference in RT for different auditory stimulus locations. However, we found no significant difference. Literature demonstrated that reaction time increased at gait initiation (Sparrow *et al.*, 2002) and as participants neared the target in a walking task (Bardy and Laurent, 1991). Of course, in those studies, participants had full vision. Since our participants did not have vision, the complexity of the task is greatly increased. Possibly, this would render the entire task too complex, resulting in high RTs everywhere. To confirm this, and the impact on distance errors, more research would need to be done.

4.4 Obstacles Decrease Average Walking Speed

The present study demonstrates that by adding obstacles to the blind walking task, there is a significant decrease in average walking speed across participants. A study by Gérin-Lajoie *et al.*, (2006) directly supports these findings. They researched the effect of stationary or moving obstacles on gait combined with an attention task of listening to a recorded message and answering questions at the end of each trial in young and older participants. They found that participant's gait speed decreased with the presence of obstacles.

Walking Speed in Dual-Task Conditions

We only found one study that examines the impact of obstacles on walking speed (Gérin-Lajoie *et al.*, 2006). However, we took a look at several other studies that show that gait velocity is slowed in dual-task conditions. In their 2008 blind navigation study, Paquet *et al.* demonstrated that mean gait velocity was significantly slower during concurrent navigation and backward counting than in navigation only.

Glasauer *et al.* (2009) did a set of experiments on blindfolded walking. They looked at blindfolded walking with or without a combined mental task of counting backwards in steps of 7. They found that average walking velocity was slower in dual-task than in walking alone.

Similarly, a study by Gallagher *et al.* in 2001, demonstrated comparable findings. In their study, participants had to walk without vision along an 8 meter pathway. There were 2 conditions. The first was a predictive condition, in which subjects had to walk without vision. They were only given vision if they stepped out of bounds, and also had a button for emergency vision, which they were told to avoid using if possible. The second was a reactive

condition, in which vision was automatically given halfway through the path, and which also included vision if they stepped out of bounds. The study demonstrated that there was a faster cadence rate associated to the reactive condition. The researchers attribute this to the fact that participants automatically received vision in this condition, which resulted in participants being more confident. Therefore, since there was an increase in visual cues in that condition, we might consider it an easier task. This would reinforce the fact that by increasing complexity of the walking task, walking speed slows down.

In contrast, a study done by Sparrow *et al.* (2002) did not find a significant effect on walking speed. They compared a simple walking task to a targeting task coupled with an auditory or visual RT task. They found that there was no effect of dual-task on walking speed. This could be explained by the fact that in study, participants had full vision. Similarly, the study by Bardy and Laurent in 1991 demonstrated that having a difference in target size, or having a single- or dual-task, did not have an impact on walking speed. However, participants once again had full vision in this study, which makes the primary walking task easier than walking without vision, as in our study.

Therefore, we can then suggest from these findings that an increase in the difficulty of a blind walking task would decrease the walking speed of the participant. More specifically, the present study demonstrates that by adding obstacles to a blind walking task, the walking speed is significantly affected.

Walking Speed in Young and Older Adults

The surprise in the present study is that the impact of obstacles on walking speed was the same in young and older participants. This is contrary to our hypothesis. Studies by Gallagher *et al.* (2001) and Gérin-Lajoie *et al.* (2006) both demonstrated a slower walking speed in older participants. Lafleur's study in 2009 found a tendency for young participants to walk faster than older participants, although these results failed to reach significance. The study by Sparrow *et al.* (2002) failed to find an effect of age on walking speed, however as stated previously this task was done with full vision.

Reasons for this unexpected result might be the small sample size. After looking at our control data, which was taken during comfortable walking with eyes open, without obstacles, we can see that the average AWS for young participants was faster (1.020 m/s) than the older participants (0.971 m/s). Perhaps a few older participants were fast walkers in the experimental trials (for example, average AWS of 0.854 m/s and 0.960 m/s compared to the older participant average of 0.756 m/s). Another element which could affect the data was a young subject which had an abnormally slow walking speed during trials (average AWS of 0.591 m/s compared to the young participant average of 0.714 m/s).

Chapter IV

Conclusion

In summary, the present study helped to shed some light on the attentional demands in a blind navigation task with obstacles. More specifically, results demonstrated that 1) aging has an effect on reaction time and navigation errors in a blind walking task, suggesting that the task at hand involved a larger attentional demand in older adults than in young participants; 2) obstacles have an impact on reaction time and walking speed in a blind walking task, suggesting a higher attentional demand associated to a more complex task, in this case walking with obstacles versus without; and 3) emitting an auditory stimulus at the beginning of a blind walking task increases linear distance travelled. Most of these results were expected, as they were previously demonstrated or suggested in the literature. Therefore, we can conclude by suggesting that higher attentional demands are required to navigate towards a previously seen target in a path including obstacles, and that aging has an impact on the ability to navigate in these conditions. A novel finding was that the auditory stimulus at the beginning of a task increases linear distance travelled. We propose that by acting as a distraction, this stimulus interferes with the necessary updating of the participant's position during navigation. It would be interesting to further the research in this particular area and with a larger sample size, to confirm or not the findings of this study.

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Appendices

Appendix I
Ethics Approval



Ethics Approval Notice
Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

<u>First Name</u>	<u>Last Name</u>	<u>Affiliation</u>	<u>Role</u>
Yves	Lajoie	Health Sciences / Human Kinetics	Principal Investigator
Nicole	Paquet	Health Sciences / Human Kinetics	Co-Principal Investigator

File Number: H11-08-06

Type of Project: Professor

Title: Effective Use of Vision during Navigation in a Context of Divided Attention in the Elderly

Renewal Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
03/09/2010	03/08/2011	Ia

(Ia: Approval, Ib: Approval for initial stage only)

Special Conditions / Comments:

N/A

Appendix II
Consent Form



uOttawa

Université d'Ottawa

Faculté des sciences
de la santé

École des sciences de
l'activité physique

University of Ottawa

Faculty of Health
Sciences

School of Human
Kinetics

Consent Form

Effective use of vision during navigation in a context of divided attention in the elderly

Name of Co-Investigator: Yves Lajoie, PhD.

Institution, Faculty, Department: University of Ottawa, Health Sciences, School of Human Kinetics

Name of Co-Investigator: Nicole Paquet, PhD

Institution, Faculty, Department: University of Ottawa, Health Sciences, School of Rehabilitation

Name of Co-Investigator: Heidi Sveistrup, PhD

Institution, Faculty, Department: University of Ottawa, Health Sciences, School of Rehabilitation

I am invited to participate in a research study conducted by Yves Lajoie PhD, Nicole Paquet PhD and Heidi Sveistrup PhD from the University of Ottawa, Faculty of Health Sciences.

PURPOSE OF THE STUDY:

The purpose of this study is to determine the effects of aging and cognitive tasks on navigation errors during walking with limited vision.

ELIGIBILITY:

To participate in this study I must be between 20-30 years old or between 64-75 years old. I must be free of: any neurological disorder, inner ear pathology with dizziness and vertigo, eye pathology such as macular degeneration, cataract and glaucoma and type II diabetes with peripheral neuropathy.

PARTICIPATION:

My participation will consist of one testing session that will last approximately 1 hour. During this session I will have to answer 2 questionnaires and navigate through obstacles towards a previously seen target with limited vision and answer “top” when I hear an auditory stimulus.

Questionnaires

1. Health Status Questionnaire: To determine if the study could pose any potential health risks to me, the participant.
2. Mini-Mental State Evaluation: To ensure that I am mentally compatible with the requirements of the study.

POTENTIAL RISKS:

I understand that there are some physical risks in participating in this study. Since I will have to navigate with limited vision through obstacles trying to reach a target located on the floor, there is a risk of contacting an obstacle and/or become disoriented and/or even falling.

I understand that two persons will walk beside me at all time during the experiment and act as a spotter to prevent disequilibrium and falling. Furthermore, I understand that I will hold in my hand a button that if pressed will give me vision instantaneously if needed.

POTENTIAL BENEFITS:

This research will lead to: 1) Better understanding of navigation with limited vision and the differences between young and older adults. 2) Better understanding of the role of vision during navigation in young and older adults. 3) Better understanding of the attentional demands required during navigation with limited vision and the effects of performing a dual-task on reaching a previously seen target. There is no direct benefit for the participants.

CONFIDENTIALITY AND DATA KEEPING:

I have the assurance from the researchers that the information I will share with them will remain strictly confidential and will be used for research only. The audio and video and the questionnaires will be kept in a locked filing cabinet located in the supervisor's office for a period of five years, after which they will be destroyed. The collected data will be kept on a computer accessible only to the researchers and the research assistant under the protection of an access code. They will be destroyed after 5 years

ANONYMITY:

My anonymity will be protected by the use of terms such as "the participant." No names will be mentioned on any reports or documents related to the study. The researchers will use numbers to differentiate between participants.

COMPENSATION:

There is no monetary compensation for participating in this study.

VOLUNTARY PARTICIPATION:

I realize that I may withdraw from this study at any time, even after I have agreed to participate; without providing any reason, without consequence. If I withdraw from the study, any of my collected data will be destroyed.

INFORMATION ON THE RESULTS:

Once the study has been completed and the results have been analyzed, the researcher will offer to provide me with information based on my balance assessment. Should I wish to receive my results in writing, the researcher will provide me with the results in person at my center.

MORE INFORMATION ABOUT THIS STUDY:

If I have any other questions or require more information about the study itself, I may contact the researcher or the supervisor at the numbers mentioned above.

CONSENT:

I, _____, the undersigned, agree to participate in the above research study. The study has been explained to me, I have had the opportunity to ask questions about my involvement and to receive additional details that I wanted to know about the study. I understand that by accepting to participate, I am in no way waiving my right to withdraw from the study at any time.

I have been given a copy of this form.

Participant's name: (*Please print*) _____

Participant's signature: _____ Date: _____

Appendix III
Health Status Questionnaire

Health Status Questionnaire

Participant's Number: _____

Height (cm): _____

Weight (kg): _____

Date of Birth (dd/mm/yy): _____ Age: _____

Sex (M / F) Lateral dominance: L R

Have you fallen in the past six months? YES _____ NO _____

If you answered YES, please describe the circumstances of the fall (if you have fallen more than once, use the reverse of this page)

Do you have any of the following medical conditions?

	YES	NO
A disorder of the nervous system such as Parkinson's or Huntington's.		
Heart disease or a past heart-attack or stroke.		
Diabetes		
Injury to your upper-body in the past 6 months.		
Injury to your lower-body in the past 6 months.		
Loss of sensation (peripheral neuropathy)		
Arthritis, Carpel Tunnel Syndrome.		
Severe back pain.		
Uncorrectable problems with your vision.		
Vestibular disorders, balance impairment, dizziness		

Do you currently take any medication?

If yes, for which condition?

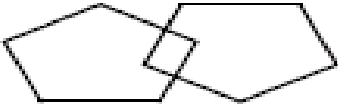
Appendix IV

Mini-Mental State Evaluation

Patient's code: _____

Date: _____

Instructions: Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

Interpretation of the MMSE:

Method	Score	Interpretation
Single Cutoff	<24	Abnormal

Range	<21 >25	Increased odds of dementia Decreased odds of dementia
Education	21 <23 <24	Abnormal for 8th grade education Abnormal for high school education Abnormal for college education
Severity	24-30 18-23 0-17	No cognitive impairment Mild cognitive impairment Severe cognitive impairment

Interpretation of MMSE Scores:

Score	Degree of Impairment	Formal Psychometric Assessment	Day-to-Day Functioning
25-30	Questionably significant	If clinical signs of cognitive impairment are present, formal assessment of cognition may be valuable.	May have clinically significant but mild deficits. Likely to affect only most demanding activities of daily living.
20-25	Mild	Formal assessment may be helpful to better determine pattern and extent of deficits.	Significant effect. May require some supervision, support and assistance.
10-20	Moderate	Formal assessment may be helpful if there are specific clinical indications.	Clear impairment. May require 24-hour supervision.
0-10	Severe	Patient not likely to be testable.	Marked impairment. Likely to require 24-hour supervision and assistance with ADL.