INFLUENCE OF DELAYS AND COGNITIVE DISTRACTORS DURING BLIND NAVIGATION

Sarah Piekarski, B. Sc.

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Members of the Thesis Committee:

Dr. Nicole Paquet (Supervisor)
Dr. Yves Lajoie
Dr. Martin Bilodeau

School of Interdisciplinary Health Sciences
Faculty of Health Sciences,
University of Ottawa

Abstract

Navigating to a previously seen target without vision was unaffected by a 30-sec delay period at the beginning of the walking task. This study investigated whether a 60-sec delay, with or without a cognitive task, would modify the accuracy of reaching an 8-meter target. Thirty young adults participated. The delay, located at 0, 4, or 7 meters, was either to wait, or to count backwards. Kinematic data of distance travelled, distance-to-target, angular deviation, and body rotation from participants' final position were recorded with a 3-D motion analysis system. Navigation precision was not significantly different with or without a delay, and whether or not the delays contained a cognitive task. However, comparisons among delays revealed a significant effect of delay position with larger distance errors occurring at the 0-meter delay in the 16 participants who walked at least 7 meters, suggesting that a delay at the beginning was more disruptive for navigation accuracy than when it occurred closer to the target.

Abrégé

L'habileté à atteindre une cible préalablement vue n'a pas été affectée par une période d'attente de 30 secondes au début de la marche. Ce projet a testé si un délai de 60 secondes, avec ou sans tâche cognitive, modifie la précision d'atteinte d'une cible placée 8 mètres. Trente jeunes adultes ont participé. Le délai à 0, 4 ou 7 mètres, était soit d'attendre ou de compter à rebours. Les données cinématiques de la distance marchée, la distance par rapport à la cible, la déviation angulaire et la rotation du corps ont été enregistrées à l'aide d'un système d'analyse du mouvement en 3-D. La précision de la navigation n'était pas significativement différente s'il y avait un délai ou non, et si les délais étaient occupés ou non par la tâche cognitive. Toutefois, des comparaisons entre les délais ont montrées un effet significatif de la position du délai, avec des erreurs de distance

plus grandes au délai à 0 mètre chez les 16 participants qui ont marché au moins 7 mètres, ce qui suggère qu'un délai au début a davantage affecté la précision de la navigation que lorsque le délai était plus proche de la cible.

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Abbreviations

AD – Angular Deviation

BMI – Body Mass Index

BR – Body Rotation

DT – Distance Travelled

D-T – Distance to Target

SD – Standard Deviation

M - Meters

Cm – Centimeters

Mm – Millimetres

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Chapter I

Introduction

Navigation is fundamental cognitive function essential to the survival of most creatures, whether it be towards food, shelter, or away from danger. Often this is accomplished without the use of a physical map, whereby effective navigation depends upon one's ability to update their current position and orientation during travel, their use of navigational representations, and their ability to plan efficient travel routes (Loomis et al., 1993). Spatial navigation is especially complex in that it incorporates, manipulates and integrates many external environmental cues and internal cognitive processes over time and space (Wolbers & Hegarty, 2010). Navigation may involve re-orientation and mental spatial manipulation if an individual becomes lost or the destination changes. Humans estimate their displacement through the combination of signals from the body's vestibular system, visual system, kinesthetic system (proprioceptive and cutaneous inputs), and efferent copies of motor commands. Human navigation research has led to two basic streams of ability to perceive spatial attributes, first, egocentric "self to object" distances, and second, allocentric "object to object" distances (Wolbers & Hegarty, 2010). These forms of navigation are interdependent in maintaining complete and accurate spatial representations while an individual interacts with their environment. For this thesis, egocentric navigation will be the type exclusively examined. Egocentric navigation relies more on landmark-type navigation, and uses more personal signals, such as left/right, and forwards/backwards (Klatzky, 1998). Egocentric spatial cues are all relative to the individual navigating, and tend to be more dependent on fixed visual stimuli, being optimized in small, well-known areas (Loomis et al., 1993). Egocentric tasks can help us examine the underlying mental concepts in how humans perceive spatial information, create and maintain spatial representations in memory, and manipulate spatial representations to complete tasks.

Assisting egocentric navigation is the cognitive process of path integration during blind navigation. Path integration is the term given to the process whereby individuals actively perceive self-motion cues and evaluate them critically to form an interactive spatial representation of the environment (Wolbers & Hegarty, 2010; Loomis, Klatzky, Golledge & Philbeck, 1999). Path integration in blind navigation is a complex concept that requires dynamic cognitive and sensori-motor integration, and as a result, some individuals tend to perform better on tasks of spatial navigation (Paquet et al., 2007). In addition, this navigation process provides ongoing estimations of positions relative to the initial starting position, providing the navigator the ability to create a rough internal cognitive map. As path integration occurs in reference to an original starting location it can be difficult for the navigator to retrace a route previously travelled that does not include the location of the starting point. As a result, path integration processes are not exclusively relied upon for everyday navigation.

Navigation errors are created when people deviate from the ideal path trajectory in their navigation towards a set target location. In walking navigation, distance errors are created when a person navigates beyond the target's perceived location (overshoots) or they stop short of the location (undershoots). Direction errors are when a person veers to the left or right of the target's location and creates a curved trajectory to the target rather than a direct, ideal path. These errors can increase when variables that assist the person in their navigation are removed or manipulated or when the navigation path to the target becomes longer or more complicated. In particular, in tasks of "blind navigation" or when a participant's visual input is removed, distance and direction errors can be created. However, blindfolded participants tend to be rather accurate in reproducing a previously walked path or in walking to a target within 12 meters (Loomis, Da Silva, Fujita & Fukisima, 1992; Elliot, 1986; Rieser, Ashmead, Talor, & Youngquist, 1990; Steenhuis & Goodale, 1988). Although, when variables such as step length, walking velocity, and step rate are altered (Mittelstaedt & Mittelstaedt, 2001) distance errors can occur. Additionally, navigation errors can be created when the target distance is over 12 m (Loomis et al. 1993; Philbeck & Loomis, 1997) or when a concurrent cognitive task is added (Richer, Paquet & Lajoie, 2014).

Periods of delays before participants navigate towards a target in tasks of blind navigation have also been implemented to add difficulty to the task or to examine the role of spatial memory in blind navigation (Thomson, 1983; Elliot, 1986; Steenhuis & Goodale, 1988; Rieser, Ashmead, Talor & Youngquist, 1990; Tyrrell, Rudolph, Eggers & Leibowitz, 1993). This is the purpose of the present research work. This thesis addresses the influence of 60-sec delays in navigation precision in a task of navigation without vision towards a previously seen target in young adults. This thesis will also serve to increase the understanding of the influence of a distraction during the delay in navigation precision.

Chapter II

Review of Literature

1.0 Blind navigation towards a previously seen target

Walking without vision towards a previously seen target is an experimental research paradigm that assesses an individual's performance based on the measurement of their distance and direction errors. In general, these errors are small for targets up to 12 meters when participants walk in the forward direction (Loomis, Da Silva, Fujita, & Fukusima, 1992; Mittelstaedt & Mittelstaedt, 2001; Steenhuis & Goodale, 1988; Thomson, 1983) and in some cases up to 24 meters in the forward direction (Rieser, Ashmead, Talor, & Youngquist, 1990). Navigation without vision to a previously seen target requires participants to visually evaluate their distance from the target and to then estimate their own body displacement from proprioceptive, vestibular and cutaneous inputs, as well as efferent copies of motor commands as they progress towards the target. At every instance of the navigation, they update their actual position relative to the target destination with the use of a computational mechanism of computing distances and directions relative to the destination (Wolbers & Hegarty, 2010). All the while they must remember the target destination by using their short-term memory of spatial location. As many cognitive processes are needed to be integrated in reaching a target location without vision, errors can accumulate over the walk to the target if any one process is imperfect. The short-term memory of spatial location is the topic of this thesis.

Previous studies have found that distance travelled in a blind navigation task is variable among participants, with some individuals being quite accurate and others demonstrating large errors (Paquet, Rainville, Lajoie, & Tremblay, 2007). Furthermore, Rieser et al. (1990) found half his participants overshot the 6 and 8 meter target with the other half undershooting it.

Error in navigation precision, or constant error, increases when the target distance increases. Elliot (1987) found the mean constant error for his participants to be 0 cm when they were navigating to a 4 meter target, 20 cm for an 8 meter target, and 45 cm for a 12 meter target. Participants also show the tendency to overshoot the target location at shorter distances of 2 meters or less (Loomis et al., 1993; Philbeck et al., 1997), but to undershoot its location at longer distances of 10 meters or greater (Fukusima et al., 1997; Sun et al.; 2004). In addition, the variable error (trial-to-trial error) also increases with greater target distances to navigate. In Elliott (1987), the mean variable error in distance was 24 cm for the 4 meter target, 51 cm for the 8 meter target and 67 cm for the 12 meter target.

Regarding direction errors, angular deviation of the path was less than 10º when navigating in the forward direction towards an 8 meter target (Paquet, Rainville, Lajoie, & Tremblay, 2007). Rieser et al. (1990) also demonstrated that participants are able to maintain their forward direction with little veering, and Vuillerme at al. (2002) found their participants made an average of an 8º deviation when they blindly navigated to a target 15 meters away.

Generally, at short distances, participants are accurate at blindly navigating towards a target with small direction or veering errors and small distance errors. When the distance of the target increases, errors accumulate and lead to greater distance and direction errors with more variability.

2.0 Short-term memory of spatial location

2.1 Blind navigation and delays

In experimental tasks of blind navigation, the participant views a target located some distance away and using their short term memory of its location, will navigate as best they can towards it while simultaneously using their working memory to update their position relative to the target (Rieser, Ashmead, Talor, & Youngquist, 1990; Wolbers & Hegarty, 2010). Therefore, blind navigation tasks with a delay period after the participant views the target but before they begin their walk toward it should lead to gradual degradation of their short term memory of the target location.

Chieffi and Allport (1997) examined whether short-term memory of a spatial location of a visual target shows similar independence in the encoding of distance and direction. They had seated participants point to a remembered target, and found that memory for the distance and the direction of the target declined over time. They presented the visual stimulus over delay periods of 4-30 seconds and found that the 30 second delay produced significant constant and variable distance errors, as well as variable direction errors. This seated pointing task suggests that the short-term memory of a spatial target was affected by a period of delay before commencing the spatial task. However, other studies involving blind navigation tasks have found conflicting results that distance and direction errors are created with a delay period before commencing the walk to the target.

Thomson (1983) found participants to be accurate in navigating blindly at distances of 3, 6 and 9 meters. His participants were accurate so long as no more than 8 seconds had elapsed between them closing their eyes and reaching the target. If more than 8 seconds had elapsed, accuracy in navigating distances between 6 and 12 meters was impaired. Thomson (1983) also found that errors in blind navigation were evident in navigating distances greater than 9 meters and up to 21 meters, and that these error had a large standard deviation. He demonstrated a gradual decrease in accuracy with increasing distances: more distance errors were made at 9 meters than at 3 meters. When increasing delays were imposed at the beginning of the task, greater errors were shown at shorter distances. A delay of 2 seconds showed a larger error at 9 meters and 12 meters, and a delay of 4 seconds showed a larger error at 6, 9, and 12 meters. Time to completion of the blind navigation task showed increased error when it was greater than 7-8 seconds. When participants were told to run in the blind navigation task to decrease their time to the target, they showed smaller mean distance error deviations in distances of 9-21 meters when the runs were less than 7-8 seconds. Overall, at shorter distances, between 1-5 meters, the time delays had no effect, but at 6 meters, the difference was significant. For longer delays up to 21 meters, the role of time becomes imperative, and accuracy was only high so long as no more than 8 seconds elapses between excluding vision and reaching the target.

In 1986, Elliot attempted to replicate the 8 second accuracy limitation found by Thomson, but could not. Analysis of blind walking of 3, 6, 9, 12, and 15 meter paths with a 0, 2 and 4 second delay revealed that variable error (trial-to-trial error) in distance and direction increased when distance increased and were unaffected by the delay periods. In addition, the constant direction error was unaffected by the delay period. These results demonstrated no evidence for the existence of Thomson's critical 8 seconds in navigating to the target, as the participants' variable error in the direction of the target was no greater in conditions in which walking to the visual target was delayed than when they were allowed to begin walking to the target immediately. In other words, participant's direction errors only increased when the distance to be navigated was increased and not when the delays increased.

Steenhuis and Goodale (1988) also dispute the results Thomson (1983) obtained and postulate that it is the distance to the target and not the time to reach the target that determines performance accuracy. They found no evidence of a critical 8 second time period in reaching the target when blind navigating. Experimenting with delays of 0, 2, and 4 seconds at distances of 3, 6, 9, and 12 meters revealed that those delays had no effect on navigation errors or performance variability, demonstrating that there was no evidence of a time/distance where performance broke down in an abrupt manner, as postulated by Thomson (1983)

Steenhuis and Goodale (1988) have investigated a longer delay of 30 seconds. They found no effect of this delay on the constant distance error, but a significantly greater within-subject variability in distance error. So, overall, a delay of 30 seconds does not seem sufficient to affect navigation precision up to 12 meters, but it does seem to have an effect on the trial-to-trial variability in distance error. However, this experiment only had 12 participants and it occurred in an outdoor environment which may have been influenced by external noise and feedback.

Tyrell, Rudolph, Eggers and Leibowitz (1993), hypothesized that information facilitating visual guidance persists and remains useful well beyond the time when the retinal image has faded. In their task of localization with a laser, they found that the absolute and variable localization deviation errors were significantly larger after longer periods of delay before commencing the task, consistent with the hypothesis that visual guidance information persists and then gradually decays. They then conducted a 10 meter blind walking task, with delay periods of 2, 4, 8, 16, 32, 64, and 128 seconds. They measured accuracy of navigation as the distance participants were able to walk within the narrow pathway. When they deviated and their foot strayed from the path, their travelled distance up to this point was recorded as their walking performance. Participants were less able to walk in the direction of the path after longer delays, further supporting the hypothesis that the visual guidance information that was available during their exposure to the target persisted a certain time, but then gradually decayed. They found that participant’s walking performance largely decreased after 32 seconds of delay.

Thus, with a 30 second delay period, there was change in the variable distance error in Steenhuis and Goodale (1988) and little effect on the direction error in Tyrell et al. (1993). From these results, we chose to investigate a delay of 60 seconds as it could potentially change both distance and direction errors.

2.2 Blind navigation and cognitive distraction

No previous study has reported on the impact of a cognitive distraction during the delay in a task of blind navigation. However, the influence of a concurrent cognitive task or reaction time task has been investigated during the blind navigation tasks.

Paquet, Lajoie, Rainville and Sabagh-Yazdi (2008) had participants navigate without vision towards a previously seen target located 8 meters away in four directions (forwards, backwards, leftward, and rightward). On half of the trials, participants were required to count backwards as they navigated to the target. They found that the dual task did not affect navigation performance precision. The gait velocity of the participants during the trials with the backwards counting did decrease, indicating that perhaps the concurrent mental task exceeded the participant's cognitive and attentional capacity.

Lajoie, Paquet, and Lafleur (2013) also employed a reaction time task in their blind navigation task with young and elderly participants. Participants were required to walk blindly to a target located 8 meters away. On half of the trials, participants were required to respond to an auditory stimulus as rapidly as they could, without altering their gait speed. They found that this dual task resulted in both groups walking significantly farther than in the trials without the concurrent task. Similarly, Richer, Paquet and Lajoie (2014) found that an auditory-verbal reaction time task emitted at six positions along an 8 meter blind navigation path increased participant's distance travelled when the auditory stimulus was presented early in the pathway rather than in a later location. This early stimulus presentation may interfere with participant's ability to encode the target's position and update their own position in relation, overall affecting their short-term memory of the spatial location.

Thus, cognitive distractors do appear to perturb blind navigation, but we do not know if it this result would still occur if the distraction occurred during a period of delay.

3.0 The research question

At this point, it is not clear if a delay of 60 seconds will change both distance and direction errors in a task of blind navigation over 8 meters. We also wonder if navigation precision is affected whether the 60-sec delay is occupied with a cognitive task or not. In addition, we are raising the question as to whether the position of the delay during the navigation task (early, mid-way, or late) has an impact on navigation precision.

Chapter III

Influence of Delays and Cognitive Distraction During Blind Navigation

1.0 Objectives

The purpose of this study is to determine whether 60 second delays filled with a cognitive task modify navigation precision in an 8 meter task of blind navigation. The specific aims are:

(1) To determine whether a 60-sec delay modifies direction errors (angular deviation and body rotation) and distance errors (distance travelled and distance-to-target)

(2) To determine whether direction and distance errors are further increased if the delay is filled with a cognitive distractor task

(3) To establish the effect of delay location in the navigation path (0, 4 and 7 meter) on direction and distance errors.

2.0 Hypotheses

The hypotheses are as follows:

(1) The 60-sec delay will lead to larger error in navigation precision (direction and distance) in the 8-meter blind navigation task than without delay.

(2) The administration of a cognitive distractor task during the 60-sec delay (filled delay) will lead to an even greater increase in navigation errors over the no cognitive task conditions.

(3) Among delay locations, errors will be greater when the delays are administered at the beginning of the navigation task (0 meter); errors will be smaller when administered at 4 and 7 meters in the blind navigation task.

3.0 Methods

3.1 Participants

Thirty participants recruited mainly from the University of Ottawa student community were enrolled and signed the informed consent form approved by the University of Ottawa Ethics Research Board. They completed a basic health questionnaire (participant sheet) (Appendix III). Table 1 lists the participants' information.

Table 1: Participant Demographics

Participant Demographics		
	Mean	**Standard Deviation**
Age (years)	23.4	2.03
Height (centimeters)	170.3	8.4
Weight (kilograms)	69.3	12.3
Hours of Physical Activity per week	7.2	4.45
Gender	**Males**	**Females**
	9	21

The sample size of thirty participants was calculated using the model proposed by Rigby & Vail (1998), using the value for standard deviation obtained from Paquet et al. (2008), from the Forward Distance Travelled (111 cm) in their navigation task. To detect an 80 cm difference (meaningful difference) in distance travelled between participants and conditions with an 80% power and a 0.05 alpha error, at least thirty participants were required.

Participants were chosen on a first-come, first serve basis and were excluded if they had a history of balance impairments, dizziness, alcohol consumption in the last 24 hours, significant obesity (a BMI greater than 30), and those who were taking medications that affect concentration and balance (specifically benzodiazepines and tranquilizers).

3.2 Materials

A Vicon512^{TM} 3-D motion analysis system with 8 infra-red cameras, was used to collect kinematic data on the participants' final position, in order to calculate their travelled distance, distance from the target, body rotation, and angular deviation (corresponding to path deviation).

Each participant had one reflective marker on the acromion of each of their shoulders, one marker on the approximate position of the middle of the lateral collateral ligament of each knee, four markers on their waist (with two being on the anterior hip bones, and two placed posteriorly), and three markers on their feet (at the positioning of the first metatarsal, the ankle and the heel). A total of fourteen markers were used, and they were attached using double sided tape, except for the reflective markers on the waist, which were attached using a belt with the markers already in position.

A portable Sony sound mp3 recorder was used to record the participants' verbal responses to the cognitive task during the delay periods of testing. The device was positioned on the participant's left upper arm using a Velcro band. During each trial, the administrator spoke into the recorder stating the trial number, however only the trials where there was to be a cognitive task were recorded. This was to avoid the participant's becoming aware of trials that would contain a cognitive task by the use of the recorder by the administrator.

A stop watch was also used by the administrator during the backwards counting task baseline trials and during the walking trials that contained a delay. All baseline trials and delays were 60 seconds in duration.

Masking tape was used to mark the starting position as well as the target located 8 meters away. To assist in locating the target, the masking tape at the target location was coloured bright pink with the use of a highlighter. Measuring tape was used to identify the position of the target location 8 meters away, the delay at 4 meters, and the delay at 8 meters. Clear tape with the trial number written were used to mark the positions of the participants that were out of range of the Vicon Camera system.

Participants wore modified ski goggles that were covered in black felt to completely block vision.

3.3 Procedure

3.3.1 Baseline Counting and Practice Walking Trials

Participants were tested at the Psychomotricity Laboratory located at Lees E053. It is a large, silent, fourteen meters by ten meters space. Participants completed five baseline counting trials while seated, with the goggles blocking their vision. Each baseline counting trial was 60 seconds in duration. Participants were given a large number between 200 and 500 (which was chosen with the use of a random number generator) and they were told to count backwards as best they could by steps of seven. If participants lost track of their number, they were told to continue counting from the last number they remembered.

After the five baseline counting trials, participants were shown the starting line and the target, which was a pink line (20 cm long and 6 cm large) located on the floor 8 meters in front of the starting line. The positioning of their toes at the starting line was demonstrated and how they were to try and position their toes on the target was also demonstrated using the starting line as an example. The administrator told them when to look at the target, when to put the googles on, and when to begin walking towards the target. They were also instructed to say “here” on each trial when they believed they had reached the target, and to not remove their goggles. The administrator would then wheel a rolling office chair behind them, tell the participant to sit, and they would be pushed back to the starting position (See Figure 1 for the aerial view of the experimental set-up with an example final position labeled as “foot mark”). Once they were back at the starting position, they were allowed to remove their goggles, position their toes on the starting line facing the target and wait for the administrator to give the rest of the directions (i.e. “look at target”, “goggles on”, and “go”). The administrator aimed to have the participant look at the target for about 5 seconds before putting the goggles on, and aimed for the participants to have the goggles on for about 5 seconds before being told to “go”. This was to ensure that all participants had approximately equivalent time spent looking at the target, and equivalent time with the goggles over their eyes before walking to the target. The administrator also asked participants to avoid counting their steps when they walked towards the target and to let the administrator know if they were unable to do so. Participants practiced blind navigation 5 times before starting recorded trials.

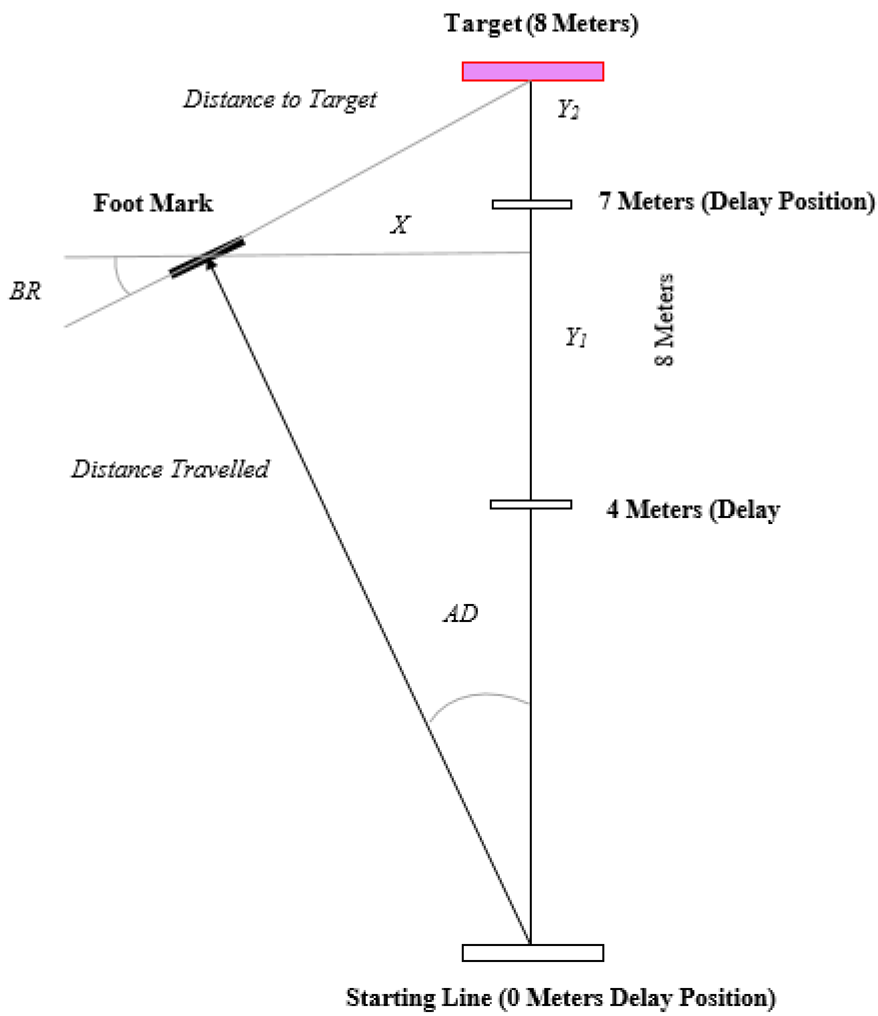

Figure 1: Experimental Set-up

Starting line, target and positions of delays are illustrated. Values collected are labelled in the picture as the "X", "Y_1", and "Y_2" values, "Body Rotation" (BR), "Angular Deviation" (AD), "Distance Travelled" and "Distance-to-Target". The "Foot Mark" illustrates a possible final position of a participant during a trial. The X value is the participant's lateral displacement from the centre of the starting line, Y_1 is the participant's forward displacement from the starting line, and Y_2 is the participant's distance from the target location.

Participants were also told that if the administrator said "stop" at any time they were required to stop immediately as that meant they were close to a wall or an obstacle. In addition, once they were told to stop, they were not allowed to remove their goggles and the administrator would come pick them up in the rolling office chair.

Participants never received any feedback to how close or far they were from the target location.

3.3.2 Walking Trials and Control Trials

After completing the five baseline counting trials and the five practice walking trials, participants were told that their walks would now be recorded. They were also instructed that on some trials they may be required to pause while walking, meaning, they will begin their blind walk towards the target but if the administrator says “pause” they will be required to stop wherever they are on the path and wait until further instruction. The administrator told them that during these pauses the administrator may say nothing, in which case they are required to wait silently until the administrator instructs them to “go” and to continue walking towards where they believe the target location was. However, if the administrator gives the participant a number after saying “pause”, the participant is required to begin counting backwards out loud until being told to “go” by the administer and to continue walking towards were they believe the target location was. Participants were given a large number between 200 and 500 (which was chosen with the use of a random number generator) and they were told to count backwards as best they can by steps of seven similar to the baseline counting trials. The participants were told that each pause would be a minute in duration, and that when blindfolded and not counting backwards that pause would seem to be very long.

They were instructed to say “here” when they believed they had reached the target location, and to not remove their googles. If one of their feet was in front of the other one, they were asked to bring their feet together for the time of data gathering by cameras. The administrator would come with a rolling office chair and wheel them back to the starting location. However, when the administrator came with the office chair, the participants were now instructed to remain standing while the administrator marked the floor with clear tape that had the participant's trial number written on it in blue ink. While the administrator did this on every trial with all the participants, only the trials that might have been out of the range of the Vicon Camera system were actually marked, on the other trials the administer only pretended to mark the floor with tape. From the starting position, the clear tape markers were invisible to the participant. The participants were also reminded that if the administrator said "stop" to discontinue walking, wait for the administrator to come with the rolling office chair and not remove their goggles - this would indicate the end of the trial. Two participants were told to "stop" during the walking trials, both on only one trial.

At the beginning of each trial the administrator would state the trial number into the voice recorder, but would only record the trial on the trials where a delay (the "pauses") would contain backwards counting. There were three positions of delay: 0 meters (the starting position), 4 meters, and 7 meters to the starting line. The last delay was placed at 7 meters (1 meter in front of the target) rather than at the target, as young participants, aged 19 to 42 years, in Paquet et al. (2008) tended to undershoot distance by about 100 cm. Therefore, to ensure that the majority of participants would encounter the last delay as close to the target as possible, the final delay was positioned at 7 meters to the starting line.

There were masking tape marks on the floor about two meters to the left of the pathway that marked the positions of the delay at 4 meters and at 7 meters. The administrator would use these markers to infer the positions of the delays from their vantage point near the starting line of the 8 meters. The administrator would call out "pause" when one of the participant's feet had reached the inferred positions marked by the masking tape.

Participants never received any feedback as to how close or how far they were from the target location.

The walking trials also included 6 “control” walking trials: the first 3 trials (pre) at the beginning of the recorded blind walking portion and the last 3 trials (post) at the end of the recorded blind walking portion. During these trials, the participant was told not to expect any delays so that their accuracy without the delay conditions when they knew there was no delay could be recorded. Comparison between the 3 trials pre and the 3 trials post was to determine if there are any fatigue or repeated testing effects in completing all the trials

Similarly, 4 “catch” trials, where there was no delay, were distributed randomly throughout the trials so that the participant’s accuracy without the delay conditions when they did not know there was not going to be a delay could be recorded.

Table 2 illustrates the sequence of the trials for each participant. The 12 backwards (filled) counting trials and the 12 waiting (unfilled) trials were randomly distributed by assigning each trial a number and using an online random number generator to place them in a random sequence. The catch trials were similarly placed randomly throughout the filled and unfilled trials by using an online number generator that generated a number between 1 and 28, and the four catch trials were placed at the position of the number generated.

Table 2: Sequence of Trials

Trials						
	DELAY – 60 seconds at 0 meters	**DELAY – 60 seconds at 4 meters**	**DELAY – 60 seconds at 7 meters**	**NO DELAY**	**STATIONARY – with no vision**	**Total # of Trials**
TASK						
Baseline Counting in sitting	------------	------------	------------	------------	5 Trials	5
Practice blind navigation	------------	------------	------------	5 Trials	----------------	5
Control Trials (PRE)	------------	------------	------------	3 Trials	----------------	3
Backwards Counting (Filled) Task	4 Trials	4 Trials	4 Trials	------------	----------------	12
Waiting (Unfilled) Task	4 Trials	4 Trials	4 Trials	------------	----------------	12
Catch Trials (No delay)	------------	------------	------------	4 Trials inserted in the 24 previous trials	----------------	4
Control Trials (POST)	------------	------------	------------	3 Trials	----------------	3
Total Trials						44

3.4 Measurements and data collection

All final positions that were captured by the Vicon System had their body rotation, angular deviation, distance-to-target and distance travelled calculated by an Excel file using 2 same reflective markers that were captured by the camera at the start of the walk and at the end of the walk. The reflective markers on the shoulders were used as the most optimal markers for accuracy, next the ankles, the knees, the toes, and the heels. No markers from the waist were used for calculations. The Vicon camera captured the participant's initial starting position and final ending position, and using an Excel file the initial and final positions of the left and right shoulder (or ankle, knee, toe, heel) were averaged in x and y. The difference between the final and initial position were then calculated, to obtain Δx and Δy. With these values, distance-to-target, distance travelled, body rotation and angular deviation were calculated. Distance-to-target corresponds to the linear distance between the final position of the participant and the target location. It is an absolute value representing the distance from the target regardless of direction. Distance-to-target was calculated with the following formula:

$$\text{Distance-to-target} = \sqrt{(\Delta x^2 + (8\text{ m} - \Delta y)^2)}$$

Distance travelled corresponds to the linear distance between the initial position and the final position. DT was calculated using the following formula:

$$\text{Distance travelled} = \sqrt{(\Delta x^2 + \Delta y^2)}$$

Body rotation corresponds to the participant's body angle at the final position in relation to the initial position. Body rotation was calculated with the following steps using Excel functions:

1. Calculating the initial body rotation:

   R1 = DEGREES(ATAN(initial Y position left – initial Y position right)/(initial X position left – initial X position right))

2. Calculating the final Body rotation:

   R2 = DEGREES(ATAN(final Y position left – final Y position right)/(final X position left – final X position right))

3. Body rotation = R2 – R1

Angular deviation corresponds to the angle of deviation from the straight trajectory towards the target. Angular deviation was calculated with the following formula using Excel functions:

$$\text{Angular deviation} = \text{DEGREES}(\text{ATAN}(\Delta x / \Delta y))$$

When the participant's final foot positions were outside of the view of the cameras, they were marked using clear tape with the trial number written on it. The administrator placed the tape at the midpoint between their toes. Three measurements were obtained from the tape mark: body rotation, lateral displacement and forward displacement. Body rotation was determined using the target orientation as 0° reference and was measured with a protractor. Lateral displacement (X) was obtained by measuring the distance between the target and the final position of the participant in the X-axis (see Fig. 1). Forward displacement (Y_1) was measured as the distance between the starting line and the final position of the participant in the Y-axis. Using these values the angular deviation, distance travelled, and distance to the target were calculated using trigonometry, specifically using the tangent equation of the completion of a triangle and Pythagorean Theorem.

The responses from the mp3 files containing the baseline counting trials, and the walking trials that involved backwards counting were typed into an excel spreadsheet. The ratio of incorrect answers for each participant was calculated using the number of incorrect responses divided by their total responses for each trial.

4.0 Statistical Analyses

Paired-samples t-tests compared the average of the 3 control trials Pre and the average of the 3 control trials Post on the four dependent variables for navigation precision: travelled distance, distance-to-target, angular deviation and body rotation.

Two-way ANOVA for repeated measures of delay location (0 meter, 4 meters, 7 meters relative to target) x cognitive distractor task (no task, backwards counting) were performed on dependent variables for navigation precision. If Mauchly's test of sphericity was violated, a Huynh-Feldt correction was performed. Since 14 of 30 participants systematically undershot the target by at least 1 meter and did not reach the location of the 7-meter delay, the two-way ANOVA included only the 16 participants who had data at the 0-, 4- and 7-meter delay location. Therefore, an additional two-way ANOVA for repeated measures was performed on delay location (0 meter, 4 meters) x cognitive distractor task (no task, backwards counting) that included data from all 30 participants.

A one-way ANOVA was done to compare the conditions of control, no delay (catch trials), the delay at 0 meters, the delay at 4 meters and the delay at 7 meters on the variables of distance travelled and distance-to-target. Again, this included data from the 16 participants who had reached the 7-meter delay location. An additional one-way ANOVA was performed to compare the conditions of control, no delay (catch trials), delay at 0 meters and delay at 4 meters on distance travelled and distance-to-target in the 30 participants. Bonferroni post-hoc analyses were used to locate significant differences.

One-way ANOVAs were done to describe the effect of the delay location on dependent variables for navigation precision. Bonferroni post-hoc analyses were used to locate significant differences, or Games-Howell tests when homogeneity of variance was violated.

One-way ANOVAs were used to determine whether the number of answers at the backwards counting task and the ratio of incorrect answers were different among condition (baseline, and the three delay locations: 0, 4 and 7 meters). Bonferroni post-hoc analyses were used to locate significant differences.

Statistical significance was set at $p < 0.05$.

5.0 Results

5.1. Comparison between pre and post control trials

Mean values of distance travelled were not significantly different between pre control trials (6895 mm) and post control trials (6945 mm). Similarly, mean values of distance-to-target were not significantly different between pre control trials (1589 mm) and post control trials (1624 mm). Mean values of angular deviation (1° pre and 2° post) and body rotation (-1° pre and -3° post) were significantly different between pre control trials and post control trials ($p < 0.05$) .

5.2. Effects of delay location and cognitive distractor task

The two-way ANOVA for repeated measure performed on the 16 participants who had reached the 7-meter delay (delay location at 0, 4 and 7 meters) revealed a significant main effect of delay location on distance travelled, $F(2,30) = 4.71$, $p=.017$, $eta^2=.24$, and on distance-to-target, $F(2,30) = 3.99$, $p=.029$, $eta^2=.21$. No main effect of cognitive distractor task, nor interaction were found for these variables. For angular deviation, a significant main effect of cognitive distractor task was found: $F(1,15) = 4.55$, $p= .05$, $eta^2=.23$, but no main effect of delay location and no interaction were found. Differences in mean angular deviation between the filled and unfilled delays were only 1°. For body rotation, no main effect of delay location, no main effect of cognitive distractor task and no interaction were found.

The two-way ANOVA for repeated measure performed on delay location (0 meter, 4 meters) x cognitive distractor task (no task, backwards counting) on distance travelled revealed no main effect of delay location, no main effect of cognitive distractor task, but a significant interaction: F(1,29) = 19.3, p=.001, eta^2=.40. For distance-to-target a significant main effect of delay location was found: F(1,29) = 5.29, p=.029, eta^2=.15. No main effect of cognitive distractor task, nor interaction were found for this variable. For angular deviation, there was a significant main effect of cognitive distractor task: F(1,26) = 9.60, p=.005, eta^2=.27, a significant main effect of delay position: F(1,26) = 5.60, p=.026, eta^2=.18 and a significant interaction: F(1,26) = 7.62, p=.01, eta^2=.23. Differences in mean angular deviation between the filled and unfilled delays and between the 0-meter and 4-meter delays were only 1°. For body rotation, a significant main effect of delay location was found: F(1,26) = 5.01, p=.034, eta^2=.16, but no main effect of cognitive distractor task and no interaction were found. Differences in mean body rotation between the 0-meter and 4-meter delays were only 1-3°.

5.2.1 Distance travelled

Distance travelled (combined filled and unfilled delay conditions) was significantly different among delay location conditions, F(4,209) = 3,34, p=.011. Figure 2 shows that travelled distance was longer at the 7-meter delay than at the 0-meter delay (Post-hoc Bonferroni, p = .005).

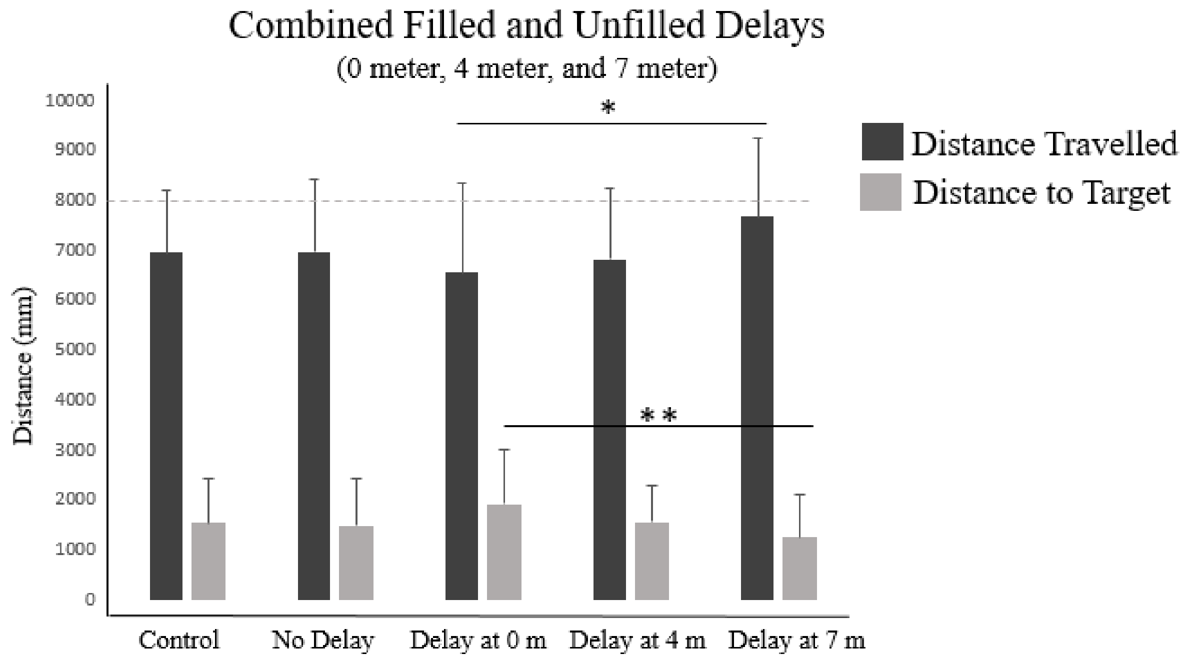

Figure 2: Combined Filled and Unfilled Delays (0 meter, 4 meter, and 7 meter)

Means + SD of distance travelled (mm) and distance-to-target (mm) of participants in the control, no delay and three delay positions (0m, 4m, 7m). Values are combined from filled and unfilled delay conditions. *p < .05, ** p < .01.

When the distance travelled (combined filled and unfilled delay conditions) was compared among control condition, no delay, 0-meter delay and 4-meter delay, the one-way ANOVA revealed no significant difference (Figure 3).

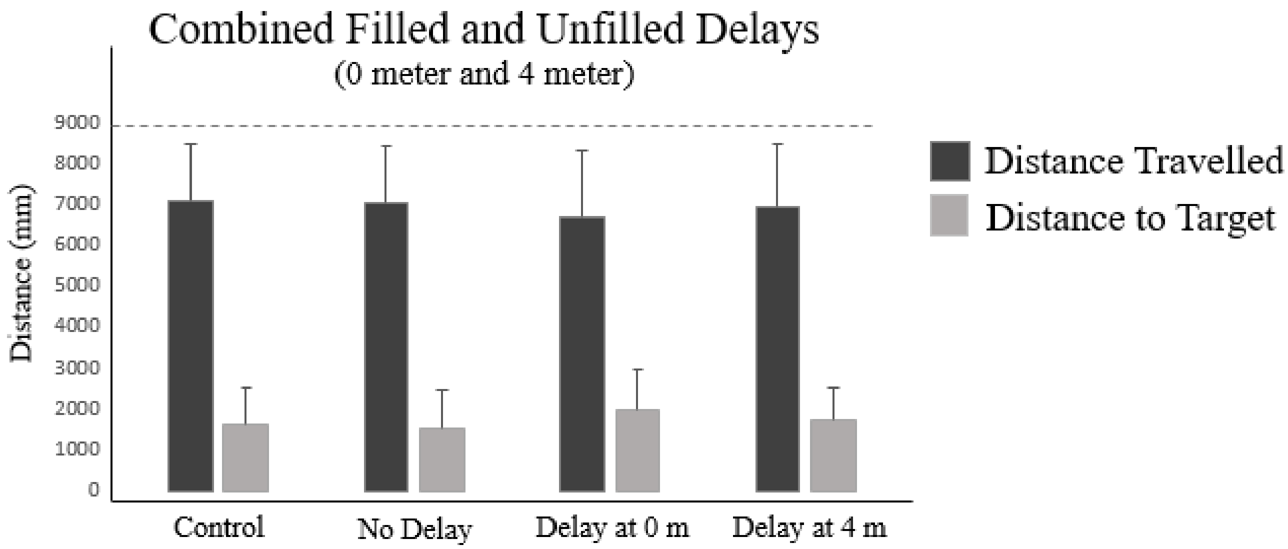

Figure 3: Combined Filled and Unfilled Delays (0 meter and 4 meter)

Means + SD of distance travelled (mm) and distance-to-target (mm) of participants in the control, no delay and two delay positions (0m and 4m). Values are combined from filled and unfilled delay conditions.

For the delay conditions filled with the cognitive distractor task, travelled distance was significantly different among the three delay locations, $F(2,77) = 3.53$, $p=.034$. Figure 4 illustrates that travelled distance was longer at the 7-meter delay than at the 0-meter delay (Post-hoc Bonferroni, $p = .034$).

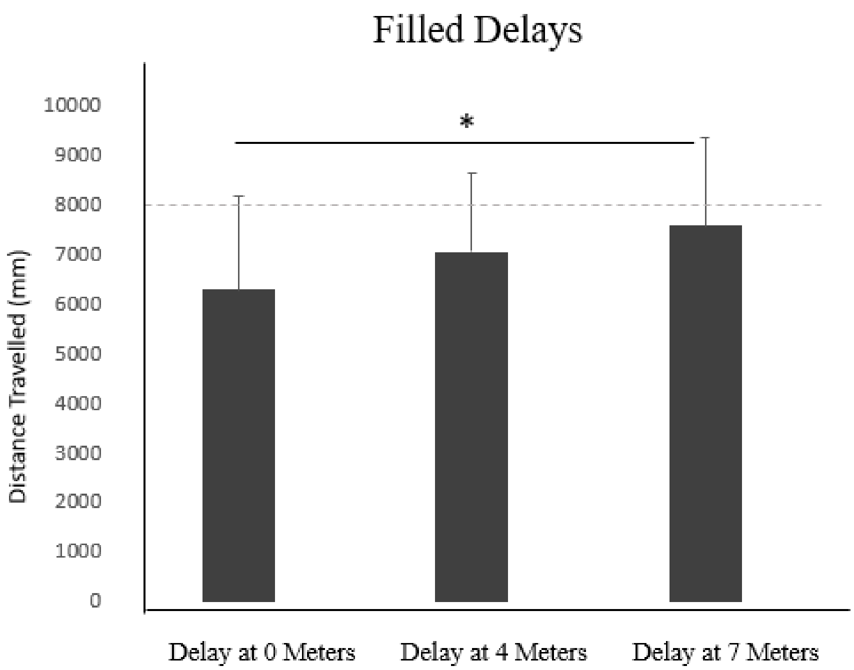

Figure 4: Filled Delays

Means + SD of distance travelled (mm) of participants during the filled delay condition at the three delay positions. *p < .05.

For the unfilled delay conditions, travelled distance was significantly different among the three delay locations, $F(2,74) = 4.42$, $p=.015$. Figure 5 shows that travelled distance was longer at the 7-meter delay than at the 4-meter delay (Post-hoc Bonferroni, $p = .015$).

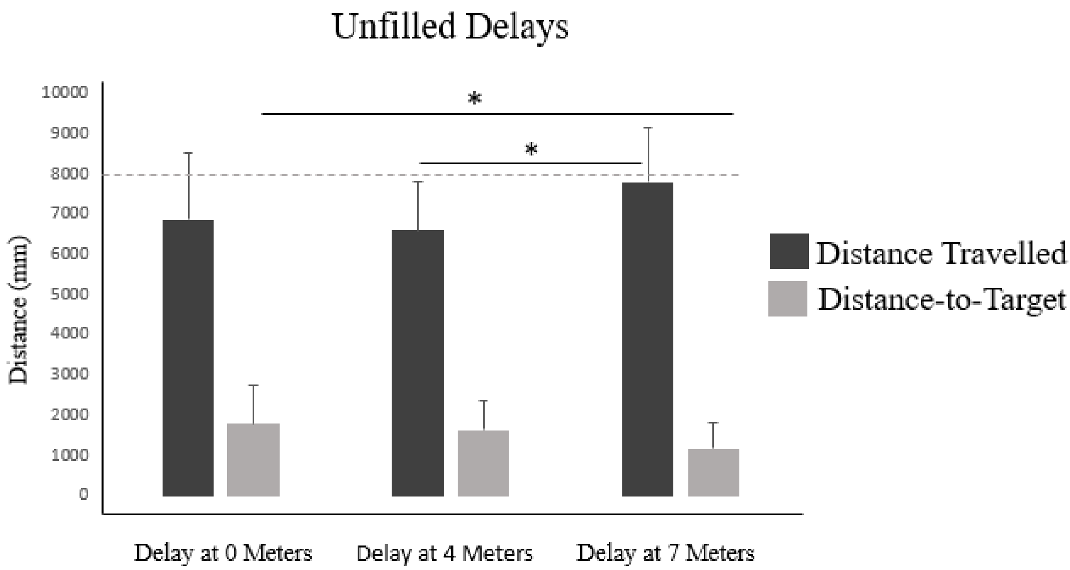

Figure 5: Unfilled Delays

Means + SD of distance travelled (mm) of participants during the unfilled delay condition at the three delay positions. *p < .05.

5.2.2 Distance-to-target

Distance-to-target (combined filled and unfilled delay conditions) was significantly different among delay location conditions, F(4,214) = 3,53, p = .008. Figure 2 illustrates that distance-to-target was shorter at the 7-meter delay than at the 0-meter delay (Post-hoc Games-Howell, p = .007). When the distance-to-target (combined filled and unfilled delay conditions) was compared among control condition, no delay, 0-meter delay and 4-meter delay, the one-way ANOVA revealed no significant difference (Figure 3).

For the unfilled delay conditions, distance-to-target was significantly different among the three delay locations, F(2,76) = 3.64, p = .031. Figure 5 shows that distance-to-target was shorter at the 7-meter delay than at the 0-meter delay (Post-hoc Bonferroni, p = .022).

5.3. Backwards counting performance

5.3.1. Number of responses

The number of responses to the 60-second backwards counting task was significantly different among conditions (baseline and the three delay locations), $F(3,441) = 12,18$, $p<.001$. Figure 6 shows that the number of responses at baseline was significantly less than at any of the three delay locations, Post-hoc Bonferroni, $p<.01$.

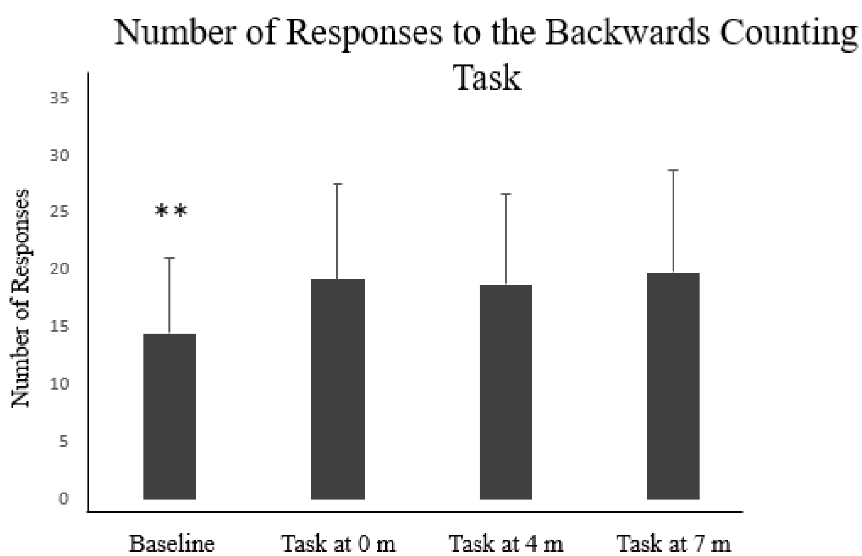

Figure 6: Number of Responses to the Backwards Counting Task

Means + SD for the number of responses to the backwards counting task. ***p < .01* relative to all delay locations.

5.3.2. Ratio of incorrect answers

The ratio of incorrect answers at the 60-second backwards counting task was significantly different among conditions (baseline and the three delay locations), $F(3,441) = 9,59$, $p<.001$. Figure 7 shows that the ratio of incorrect answers at baseline was significantly higher than at any of the three delay locations, Post-hoc Bonferroni, $p<.001$.

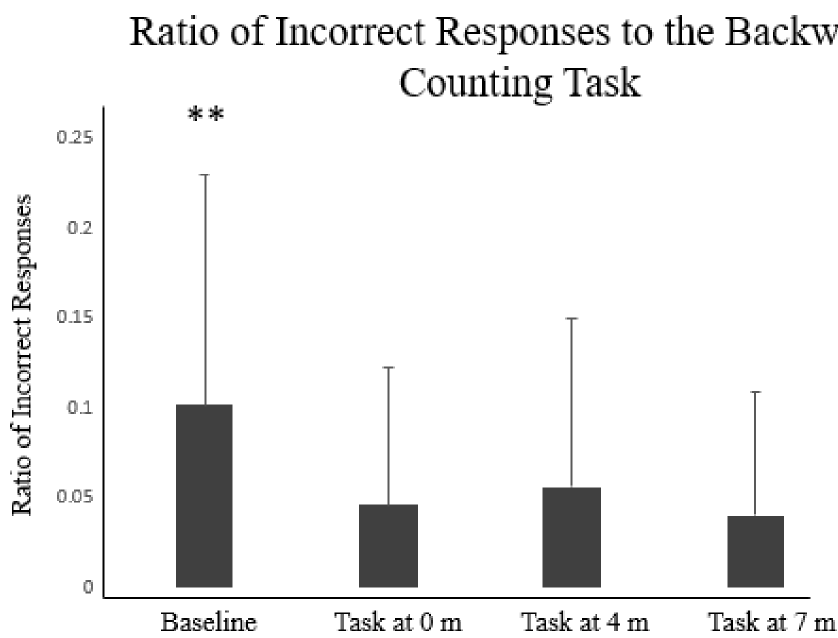

Figure 7: Ratio of Incorrect Responses to the Backwards Counting Task

Means + SD for the ratio of incorrect answers the backwards counting task. ***p < .01* relative to all delay locations.

5.3.3. Correlation between backwards counting performance and navigation precision

As an exploration, possible correlation between backwards counting performance and navigation precision was tested. There was no significant correlation (Pearson's r = 0.001, p=0.983) between the ratio of incorrect answers and distance-to-target.

6.0. Discussion

This experiment revealed three main findings: (1) there was no significant difference on participants' navigation precision when there was a 60 second delay or when there was no delay in the 8 meter pathway towards the target location; (2) there was no significant difference on navigation precision when the 60 second delays were filled with a cognitive task or when those 60 second delays were unfilled; (3) there was a significant effect of delay position on participants' navigation precision in participants who had performed the 7-meter delay (n=16). Errors were larger when the delays were at the beginning rather than later in the 8-meter navigation pathway.

6.1 Comparisons between pre and post control trials:

Before running the main analyses of this study, pre control trials were compared to post control trials to reveal possible effects of fatigue during the testing session. Our data has revealed that there were no significant differences in the mean values of distance travelled and the mean values of distance-to-target on the pre and post control trials. While, the mean values of angular deviation and body rotation were significantly different, these values are very small and are not meaningfully different. Altogether, these result can be interpreted to mean that the participants probably did not experience any fatigue effects during the testing that would impact the interpretation of the other results. This indicates that participants performed at the same capacity throughout the testing session, and there was no effect due to the repetition of the trials. In fact, we were careful to not provide the participants with feedback about their performance on the trials, and took steps to minimize any sensory input indicating their positions. Furthermore, as all our participants were young and healthy, they were probably resistant to the repetitive effects of the trials and any fatigue effects due to the testing. Therefore, significant differences in navigation precision obtained in this study can be interpreted as not due to the effects of fatigue.

6.2 Effect of delay vs. no delay

Our results have found that distance measures obtained in the no delay condition were not significantly different compared to those obtained in the three delay conditions (see fig. 2 and fig. 3). This is similar to the finding of Steenhuis and Goodale (1988) who reported that constant error, or mean distance error, was not different with or without a delay of 30 seconds at the start of a task of blind walking to a target. Their twelve participants were randomly presented with a target distance of either 3, 6, 9 or 12 meters and they either had to navigate towards the target with their eyes closed immediately after viewing the target, or with their eyes closed and after a 30 second delay. Our present experiment found similar results to Steenhuis and Goodale (1988), however, our delay period was twice as long. This could indicate that a delay of 30-60 seconds is insufficient to affect navigation precision, at least for a distance of up to 8 meters. Furthermore, perhaps the 30 second delay did not modify the participant's performance in Steenhuis and Goodale (1988) because their participants were provided with practice trials with feedback in order to make their performance within a good degree of precision and stable from trial to trial. One may think that performance was not easily modifiable after this training. Their participants had created a memory of the local view, a representation described by Wolbers and Hegarty (2010) that assists with navigation. In addition, they most likely were able to create a map of the area involving the target due to the feedback they received from the experimenters. However, our present experiment did not train our participants and our 60 second delay still had no impact on their navigation performance.

In another blind walking navigation task, Rieser, Ashmead, Talor and Youngquist (1990) had participants walk to one of eleven target distances (2 to 22 m) while blindfolded under three conditions: standard walking speed, delay, and fast walking speed. In the delay condition, participants waited 8 seconds after viewing the target before they were told to walk by the experimenter. The constant errors for walking without vision in the standard and the delay condition were found to be negligible. Similar to our present experiment, they did not uncover meaningfully different results in their delay condition versus their no delay or standard condition – the constant error was not modified by a delay period. In addition, Rieser et al. (1990) used an 8 meter distance like we do in our present experiment, suggesting that perhaps participants are veridical in navigating 8 meters blindly with or without a delay period. This could mean that participants are able to accurately perceive spaces, another mechanism listed by Wolbers and Hegarty (2010), which are at least 8 meters from their point of origin even when they do not receive feedback about their accuracy. However, Rieser et al. (1990) tested large distances up to 22 meters and did not uncover an effect of delay period on navigation accuracy, suggesting that there is no effect on navigation performance with the addition of a delay for larger distances up to 22 meters. However, it may be that the delay of 8 seconds was too short to have an effect on the task, and that a longer delay period such as our 60-sec delay would have created significant differences.

Another possibility to explain that our measures in the delay and no delay conditions were not different could be the large variability in our participant group. Potentially, if our number of participants was increased to more than 30, there would be significant differences found in having a delay or no delay in the walking trial. A larger number of participants might decrease the large variability we found with our participant group. It may also be that the delay period we used was, in fact, also too short to have an impact on our participant's walking performance. In addition, the target distance of 8 meters may have been too short for the 60 second delay to create a difference between the delay conditions and the no delay condition. Perhaps if the delay was increased to 120 seconds or even 5 minutes, significant differences may have been revealed.

Also, perhaps the task of walking blindly to a target located 8 meters straight ahead was too easy, and that increasing the distance to over 20 meters or having the participant navigate in directions different from going forward (backwards, sideways, curved pathways, obstacles) could have found differences in the conditions. By extension, perhaps having multiple differing lengths of the target distance may have uncovered more differences as it would have would added another degree of difficulty for the participants. The studies cited above have suggested that it is perhaps the distance of the target that has an effect on navigation and not necessarily the delay before the navigation task (Rieser et al. 1990; Steenhuis and Goodale, 1988). Therefore, having larger distances with various delay periods could potentially help determine how much of the navigation is affected by distance or delay time. Perhaps, delay time is simply a mediator as suggested by Rieser et al. (1990), and that only an extreme delay time will uncover significant differences.

Wolbers and Hegarty (2010) created a model representation of the elements involved in the complexity of spatial navigation in their review paper. They describe how there is a combination of spatial cues, computational mechanisms, and spatial representations that assist in spatial navigation. In terms of the participants in our study and those in the experiments described above, the most important computations that may have contributed to not finding a delay effect could be the establishment of a symbolic representation (cognitive map), accurate space and self-motion perception, accurate computation of direction and distances to unseen goals, and memories of local views and places. As long as these factors are accurate in the participants, it would be difficult to cause errors in their navigation precision. The addition of a delay period of 8 – 60 seconds was not significant enough to disrupt these stable elements.

6.3 Effect of cognitive distractor during the delay

In this experiment, navigation precision was not different whether a cognitive distractor task was performed or not during the 60-sec delay. In other words, participants performed similarly on trials regardless of whether they were asked to count backwards or wait patiently.

This result could be due to the participants' thinking about other things during the unfilled pauses. If this is the case, it could be that what they were thinking about during those pauses were just as "distracting" as the given backwards counting task. Therefore, this may have made the differences between the filled pause with the backwards counting task, and the unfilled pause without the task not significantly different. In addition, it is difficult to tell someone to stop thinking completely during a period of time, and their mind will naturally wander. Schooler et al. (2011) report that “we constantly generate imaginative thoughts that are unrelated to external circumstances”, but that we are often unaware that our minds are doing this and these cognitions interfere with the stimulus encoding of external information. In addition, mind wandering involves decoupling our executive functions from the external task at hand and applying them to task-unrelated, internally generated stimulus content. In an experiment examining task-related attention with a working memory task (n-back task), Kam and Handy (2014), found that mind wandering does impair working memory updating. They found lower accuracy rates when participants self-reported a mind wandering state over an on-task state. The authors suggest that this indicates that mind wandering disrupts task performance when the task required updating of information in working memory. As our present experiment requires participants to maintain a visual representation of the target location to assist in navigating accurately, their distracted mind wandering state during the unfilled pauses could have affected their representation as much as the backwards counting task did.

To overcome this problem, another subjectively easier discrete task or another subjectively harder discrete task could be performed in addition to the backwards counting task and the unfilled condition. Then, perhaps differences in navigation precision between each condition would have been discovered.

Previous studies have investigated the impact of cognitive tasks during navigation, i.e., while walking without vision. In this case, cognitive distractors occurred concurrently with the navigation task in “dual-task” paradigms. Paquet, Lajoie, Rainville and Sabagh-Yazdi (2008) had participants navigate without vision in the forwards, backwards, left and right direction to a previously seen target located 8 meters away. They had a secondary task, requiring participants to count backwards by steps of three while they navigated to the target on half of the trials. The authors found that the dual task did not have a significant impact on navigation errors in any of the four directions. The authors suggest that task prioritization may have been responsible for the results, with participants prioritizing the main task of reaching the target accurately over counting backwards. In addition, the authors postulate that perhaps a more demanding cognitive task would have yielded significant differences between the conditions, and that the short duration of their navigation task was probably a limitation. In the present study, participants were not told which task (navigation or counting backwards during the delay) to prioritize over the other, but to do their best on both. Possibly, if our participants had been told to prioritize the backwards counting, maybe then navigation precision would have been affected. As our present experiment involves a cognitive task of backwards counting during a 60-sec pause, it is difficult to compare it directly to the above studies involving mental tasks performed while navigating. However, it appears as though the difficulty of the cognitive task as well as the priority the participants place on the task particularly affect the participant's performance measures.

6.4 Effect of delay location

Our present study found that the location of the delay had a significant effect on participant's distance travelled and distance-to-target in the 16 participants whose travelled distance was longer that 7 meters and who performed the 7-meter delay. In the filled delay condition, if the delay occurred at the 0 meter position, the distance travelled was smaller (target undershooting was larger) than if the delay occurred at the 7 meter position (see fig. 4). In the unfilled delay condition, distance travelled was smaller when the delay occurred at the 4 meter position than if it occurred at the 7 meter delay position (see fig. 5). It is to be noted that the mean distance travelled was less than 8 meters in all conditions (see fig. 2), consistent with past research on blind navigation with young adults (Paquet et al., 2008; Steenhuis and Goodale, 1988; Loomis et al., 1993 and Philbeck and Loomis, 1997). Overall in our experiment, undershooting the target was worse if the delay was located at or near the beginning of the navigation task. Furthermore, when the filled and unfilled conditions are combined together, the distance travelled is smaller if the delay occurs at the 0 meter position of the navigation trial than at the 7 meter position (see fig. 2). Participant's distance-to-target values were larger when the delay was at the 0 meter position than if it was at the 7 meter position for the unfilled condition (see fig. 4) and for the combination of the filled and unfilled conditions (see fig. 2).

Richer, Paquet, and Lajoie (2014) found a significant main effect of where a reaction time task was done on linear distance travelled during blind navigation. They had participants respond "top" as quickly as they could to an auditory stimulus as they blindly navigated an 8 meter pathway to a target, either with or without obstacles. Longer distance travelled occurred when the stimulus was emitted at location 1 rather than at locations 3 or 6 or when no stimulus was emitted. Location 1 was closest to the starting line of the navigation task and location 6 was closest to the target location. The authors propose that responding to the stimulus acted as a distraction for the participants and interfered with the participant's updating of their position as they navigated towards the target. They clarify that this interruption affected the position updating leading to a longer distance travelled, and that when the stimulus is emitted in the middle or near the end of the pathway, it does not affect the path estimation as much as when it is emitted at the beginning.

Therefore, error relative to the target was worse if the delay occurred at the beginning of the navigation task. This may be due to the decaying of the spatial representation of the target in the participant's working memory. Baddeley and Hitch (1974) described working memory as a limited-capacity system for the temporary storage and manipulation of information for complex tasks such as comprehension, learning and reasoning. As the participants are dynamically updating their navigation position in relation to the target's location as they progress towards it, the spatial representation of the target would be considered to be a part of the participant's working memory. Mishra, Zanto, Nilakantan and Grazzaley (2014) have found that interference in the form of a secondary task presented during a working memory maintenance period, degraded memory accuracy in the visual domain.

In our present experiment, the presentation of the delay possibly acted as an interference in the working memory representation. This is assuming that the participants were just as distracted by the unfilled delays, where their thoughts wandered, as they were by the filled delays with the backwards counting task. When the delays occurred close to the start of the trial when the representation of the target was only just starting to go through a memory maintenance period, the delays may have affected the stored spatial representation. For the delays that occurred at the 7 meter position, the participants had already been maintaining and rehearing the spatial memory for a longer period of time. Although, a potential limitation of this explanation is that the participants viewed the target at the beginning of each trial, meaning that they most likely created a consistent spatial representation of the area that got stronger and more concrete as the trials continued. However, the participants were not provided with any feedback about either the location of the target or their navigation accuracy. As they did not receive this feedback, they were unable to engrain the exact position of the target in their memory and were only able to use their perception of the location of the target.

In addition, participants knew they were closer to the target when the delay occurred at the 7 meter position than when it occurred at the 0 meter or 4 meter position. Therefore, they were able to rationalize that they were a few steps away from the target rather than if they had been stopped at the 0 or 4 meters. Perhaps after being stopped at 0 and 4 meters, they had more difficulty rationalizing how close they were to the target creating greater errors.

6.5 Direction errors in angular deviation and body rotation

Our present experiment did find effects of the different conditions on the navigational measures of angular deviation and body rotation. However, the significant differences between conditions were small, i.e. of no more than 3°. In addition, the values obtained for participant's angular deviation and body rotation were small, i.e. no more than 4° for angular deviation and no more than 6° for body rotation. This is probably due to participants completing the navigation task in the forward direction, which is a natural direction of displacement

Paquet, Rainville, Lajoie and Tremblay (2007) were examining the distance and direction errors created in a task of blind navigation when participants navigated in four directions (forward, backward, left, right) and with three gait patterns (forward stepping, backward stepping and sideways stepping) in two testing sessions separated by a 7-day interval. Twenty young, healthy adults were required to walk blindfolded to a target located 8 meters away either in the forward, backward, or left/right sideways direction. The authors found that in the forward direction, the mean angular deviation was 0° ± 4° and body rotation was 2° ± 9°. This is similar to the values we obtained for angular deviation (1° pre and 2° post control trial), and our body rotation values (-1° pre and -3° post control trial).

Overall, participants are more likely to overshoot or undershoot a target distance in a task of blind navigation, than to make veering errors. The results for body rotation and angular deviation in our present experiment are consistent with past blind navigation research.

6.6 Backwards counting performance and ratio of incorrect responses

For our experiment, a backwards counting task by steps of seven served as our distractor task during the filled pauses. We found that the number of responses during the baseline condition was significant less than the number of responses at any of the 3 delay locations (0 meters, 4 meters, and 7 meters) (see fig. 5). In addition, we found that the ratio of incorrect answers at baseline was significantly higher than at any of the three delay positions (see fig. 6). We believe this may be due to the participants initially being nervous during the baseline testing. They had not done any practice trials of the backwards counting task beforehand and were perhaps not confident in their performance yet. Furthermore, the participants were not yet accustomed to the task.

However, as the navigation trials began, participant's performance in backward counting became more stable, and probably optimal. This is a good indicator that no one delay position made it harder for participants to respond to the backwards counting trial. The participants were able to provide a similar number of responses in all delay positions.

However, if we were to re-do this study, we would propose that backward counting be practiced until performance is stable before starting the experiment. In addition, a second baseline counting session could be done after the walking trials were completed. That way we would obtain a before and after baseline of participants' counting abilities and be able to determine if their counting performance improved or stayed the same.

6.7 Correlation ratio and precision. Why no correlation?

We found no correlation between the backwards counting performance and navigation precision in the blind walking task. In particular, there was no correlation between the ratio of incorrect answers and distance-to-target values. This leads us to question if the ratio of incorrect response is a good indicator of the difficulty of the cognitive task.

We did not have a subjective measure of the task difficulty, as the cognitive task only provides indirect results (the ratio of incorrect responses). If this experiment was to be redone, perhaps asking participants how difficult they perceived the backwards counting task on a Likert scale (values of 1-5, with 5 being extremely difficult) would provide useful information.

Chapter IV

Conclusion

This experiment helped to clarify the influence periods of delay and cognitive distractor tasks have on blind navigation tasks. In contrast to hypothesis 1, there was no significant difference on participants' navigation precision when there was a 60 second delay or when there was no delay in the 8 meter pathway towards the target location. In contrast to hypothesis 2, there was no significant difference on navigation precision when the 60 second delays were filled with a cognitive task or when those 60 second delays were unfilled. In support of hypothesis 3, there was a significant effect of delay position on participants' navigation precision in the 16 participants who walked at least 7 meters. Errors were larger when the delays were at the beginning rather than later in the 8-meter navigation pathway. This result is novel in finding that the location of a delay has an influence on the precision of the blind navigation task, at least under the experimental conditions of this study. Future research should investigate the impact of delays in more complex navigation tasks, for example navigation in different directions in environments clustered with obstacles, and in a variety of populations, for example older adults and persons with cognitive impairments.

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Appendices

Appendix I

Ethics Approval

File Number: H10-14-01 **Date (mm/dd/yyyy):** 11/27/2014

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

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

First Name	Last Name	Affiliation	Role
Nicole	Paquet	Health Sciences / Human Kinetics	Supervisor
Sarah	Piekarski	Health Sciences / Others	Student Researcher

File Number: H10-14-01

Type of Project: Master's Thesis

Title: Influence of Delays and Cognitive Distractors During Blind Navigation

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
11/27/2014	11/26/2015	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 la réadaptation

University of Ottawa
Faculty of Health Sciences
School of Rehabilitation Sciences

Consent Form

Project title: Influence of Delays and Cognitive Distractors during Blind Navigation

Researchers:
Sarah Piekarski, BSc, Master's Student, School of Interdisciplinary Health Sciences.
Supervisor: Nicole Paquet, PT, PhD, Associate Professor, School of Rehabilitation Sciences

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by Sarah Piekarski and Nicole Paquet. This is a master's thesis project.

Purpose of the Study: The purpose of the study is to investigate the effect of 60 seconds waiting time on the precision of reaching an 8-meter target while walking without vision. The aims are to determine whether the location of this delay has an effect on precision, and whether performing a cognitive task during the delay affects precision.

Participation: My participation will consist of one experimental session during which I will walk towards a target located 8 meters away while wearing opaque googles. I will try to reach the target as accurately as possible. For some trials, I will be told to stop for 60 seconds, during which I will count backwards or wait.
Experimental sessions will be held at the Psychomotricity Laboratory (Lees E053). The session will last approximately 2 hours.

Risks: My participation in this study will require me to walk without vision. It is possible that I lose my balance and fall. In order to minimize this risk, the researcher will always stand close to me to catch me in case I lose my balance.

Benefits: There is no direct benefit to participate. There is no compensation for my participation.

Confidentiality and anonymity: I have received assurance from the researchers that the information I will share will remain strictly confidential. I understand that the contents will be used only for scientific publications and that my confidentiality will be protected by keeping in a locked location all the documents related to this project. **Anonymity** will be protected by using numbers to identify subjects instead of names.

Conservation of data: The data collected on paper, and electronic support will be kept in a secure manner during 5 years in a locked locker

451 Smyth
Ottawa ON K1H 8M5 Canada
www.uOttawa.ca

in Dr. Paquet's office and on a USB key with a password. Data will be kept until publication of the results for a maximum of 5 more years after which, they will be destroyed.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed.

Acceptance: I, ____________________________, agree to participate in the above research study conducted by Sarah Piekarski of the School of Interdisciplinary Health Sciences and Nicole Paquet of the School of Rehabilitation Sciences.

If I have any questions about the study, I may contact the researcher.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5

There are two copies of the consent form, one of which is mine to keep.

Participant's signature:____________________________ Date:____________________

Researcher's signature:____________________________ Date:____________________

Appendix III

Health Questionnaire (Participant Sheet)

ID: ______

Participant Sheet

Full Name:____________________ Sex: M / F Age: _____
Weight (kg / lbs): _______ Height (cm / ft): _______
Hours of physical activity/week: _______

Previous injuries (last 6 months): yes/no
If yes, please describe (sprain, tendinitis, fracture, surgery, strain):

Current status of injury (solved, persistent):

Internal ear/vestibular problems (dizziness, vertigo, balance): yes/no
If yes, please describe:

Cognitive or attention problems (ADD, ADHD, etc.): yes/no
If yes, please describe:

Vision problems or corrections (colour blindness, glasses, contacts): yes/no
If yes, please describe: