Attention Focus and Balance Control
in Young and Older Adults

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Submitted in partial completion of the requirements for the degree of
Master of Science in Applied Health Sciences
(Kinesiology)

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ABSTRACT

This thesis investigated attention focus and balance control in eighteen healthy young adults and eighteen healthy older adults. All participants performed sixteen consecutive trials of a balance task which involved standing for 30-s on an unstable platform that could rotate only in the roll direction. There were no attention focus instructions provided on any of the sixteen trials. Following the completion of the initial and final attempt in the series, participants reported "where" their attention had been focused when performing the task. The results showed differences in balance between young and older adults and improvements in balance with practice in both young and older adults. However, there were no differences in attention focus strategies between young and older adults. Both age groups directed attention to multiple sources during the balance task. An equal focus on internal (i.e., feet, trunk, and other body parts) and external (i.e., the platform) sources with little focus on events not related to the task dominated on the first attempt of the balance task. Focus on internal sources was maintained and focus on events not related to the task increased at the expense of focus on external sources on the final attempt of the balance task. Following the series of sixteen trials to establish "natural" attention focus, participants performed three randomly presented trials, each with specific attention focus instructions (i.e., think about minimizing movements of the feet, the trunk, or the platform). The results showed that, in contrast to the literature, instructions to focus on an internal source, the trunk, actually augmented control of the task as reflected in reduced trunk sway whereas instructions to focus on an internal source, the feet, or an external source, the platform, did not benefit performance on the task. Thus, the distance from the interaction point of the body with
the external source is critical and may not depend on whether the source is internal or external. Thus, a global attention focus instruction may not be beneficial and the nature of the task should be considered when adopting attention focus instructions for young and older adults.
ACKNOWLEDGEMENTS

I would first like to thank my supervisor, Dr. Allan Adkin, for all of his support and guidance throughout my masters’ degree. I am grateful for the time he was willing to spend going over all the aspects of my thesis, for this I am in debt to him.

I thank my committee members, Dr. David Gabriel and Dr. Jae Patterson, for being part of my thesis process. Your advice and guidance were greatly appreciated. I would also like to thank my external committee member, Dr. William Gage, for taking the time to be part of my thesis defence. The thought and time put into all the recommendations and comments about my research were appreciated.

Jenn Huffman is also in line for kudos. If she was not there to help me collect all of my data I would not be where I am today. Kinga, I must thank, for always being there to listen and offer advice when I was in need.

Lastly, but not least, I would like to thank Gavin for keeping me calm, and always helping me look at situations in a different light. Thank you to my family, for all their support in everything that I do.
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CHAPTER 1: LITERATURE REVIEW

1.1. Balance Control System

The ability to maintain balance is critical for the successful performance of many of our activities of daily living. Balance control has been defined as the process by which the central nervous system (CNS) generates the patterns of muscle activity required to regulate the relationship between the centre of mass (COM) and the base of support (BOS) (Maki & McIlroy, 1996). Thus, the control of balance is important for maintaining independent mobility (Horak, Shupert & Mirka, 1989).

Multiple sensory and motor processes contribute to the maintenance of balance. Sensory information from the somatosensory, vestibular, and visual systems has been shown to be important for balance control (Horak, et al., 1989). These three sensory systems contribute unique types of information. The balance control system functions most effectively with access to all three types of information. However, if information from one system is not available, the remaining systems can compensate for the loss of this information in order to control balance (Winter, 1995). If more than one system is impaired, the challenge to maintain balance becomes more difficult and a fall may occur. This sensory information must be integrated together to allow for appropriate selection and execution of the balance adjustments necessary to maintain upright stance (Jacobs & Horak, 2007). The structures of the CNS that have been implicated in this sensori-motor integration are the spinal cord, brainstem, basal ganglia, cerebellum and cerebral cortex (Jacobs & Horak, 2007). For short, reflexive, balance control responses the spinal cord is responsible, however these responses are not enough to stabilize balance, but are enough
to maintain muscle tone against gravity, so in order to maintain balance the brainstem is needed to activate the functional stabilizer muscles (Jacobs & Horak, 2007). Postural responses that include using a stepping or reaching strategy to maintain balance require the use of the cerebral cortex, and it is thought to be recruited after the spinal cord and brainstem (Jacobs & Horak, 2007). The cerebellum and the cortex share information in order to adapt postural responses to previous postural perturbation experiences, and the basal ganglia and the cortex share information to make the selection and implementation of the postural response automatic in context-specific situations (Jacobs & Horak, 2007). It is unknown whether the reflexive postural responses are automatic responses or if the CNS prioritizes the allocation of cognitive resources, such as attention, during the postural response (Maki & McIlroy, 2007).

Balance (postural equilibrium) and posture (postural orientation) are integral parts of postural control. Balance is defined as maintaining the COM over the BOS, during static and dynamic tasks (Massion, 1994). Posture is defined as the alignment of body parts, and the orientation of the body with respect to the environment (Winter, 1995). An individuals’ stability limits are defined by how far they can lean in all directions, moving the COM, without having to change the BOS (Woollacott & Shumway-Cook, 1990). During everyday life, humans endure many perturbations to their balance control system. Some perturbations are voluntary, such as moving the arms, and some perturbations are unexpected, for example being pushed from behind. When the voluntary or unexpected perturbation is too great for the balance control system to maintain an upright position a fall occurs. To help overcome perturbations from voluntary movement, the balance control system uses anticipatory control, or feedforward information before the
perturbation takes place (Massion, 1994). Anticipatory control forces activate muscles in a sequential fashion. The prime movers are activated first, the muscles activated are dependent on the direction of the perturbation, and their job is to oppose the force of gravity and the reaction forces in order to keep the COM over the BOS (Massion, 1992). To help overcome unexpected perturbations the balance control system uses reactive control or feedback information. The structures of the CNS communicate using new and stored information to allow perturbations to be overcome, unless the perturbation is too large. The anticipatory and/or reactive forces, and sequential activation of muscles are the result of balance control strategies.

These strategies include the ankle strategy, the hip strategy, a combination of the hip and ankles strategies, and the stepping strategy, all with the goal of keeping the COM within the BOS. The ankle strategy involves movement at the ankle only. To initiate the ankle strategy, muscles are activated distally to proximally, and it is considered to be an inverted pendulum movement with the main torques about the ankle and knee (Horak, Henry, & Shumway-Cook, 1997). The hip strategy involves movement at the hip only. When the hip strategy is initiated, proximal hip and trunk muscles are activated, with a large angular trunk acceleration, and ideally with torques about the hip (Horak, et al., 1997). The combined hip and ankle strategy is a more accurate representation of how humans maintain balance, because the hip strategy actually involves torques about the hip, and knee, as well as the ankle (Horak, et al., 1997). All of the above strategies to maintain balance, have a fixed BOS, the stepping strategy, however, requires that the BOS be changed. The stepping strategy is regarded as switching body weight from one leg to the other in order to move the BOS under the falling COM to avoid loss of balance.
(Horak et al., 1997). Which strategy is used at any given time is determined by the size of the perturbation that the individual sustains, as well as the individual’s perceived stability limit. These strategies are learned through life experiences and are not something that people are born with.

1.2. The effects of cognitive factors on balance control: Attention focus

Multiple individual, task and environmental factors have been shown to influence standing, voluntary and reactive balance control (Horak, 2006). Recent research has been directed toward understanding the effects of attention on the control of balance. Results from dual and multiple task studies, where secondary cognitive or motor tasks are performed simultaneously with the balance task, suggest that balance requires attention resources (Maki and Mellroy, 2007).

Another line of research has investigated the effects of instructions related to “where” individuals should direct attention during the performance of the balance task on balance control. The location to which an individual focuses attention while executing a motor skill has been shown to influence the performance and learning of the motor skill (Wulf & Prinz, 2001). For example, an individual may adopt an internal or external focus of attention when executing a motor skill. An internal focus of attention occurs when an individual directs attention towards the actual body movements involved in executing the motor skill (Wulf & Prinz, 2001). In contrast, an external focus of attention occurs when an individual directs attention towards the effects of the body movements on an apparatus or the environment (Wulf & Prinz, 2001). The effects of adopting a specific attention focus on motor skill performance and learning has been studied in a variety of motor
skills, including, for example, a discrete golf shot task, a discrete dart throwing task, and a continuous balance task (Wulf & Prinz, 2001; Wulf, 2007).

Research has consistently shown benefits for motor performance and especially motor learning when an individual adopts an external focus of attention (Wulf & Prinz, 2001; Wulf, 2007). Research has also shown that motor performance and learning is not improved or in fact is interfered with when an individual adopts an internal focus of attention (Wulf & Prinz, 2001). An example to illustrate this phenomenon is when individuals performed a discrete golf shot task with specific attention focus instructions. Wulf, Lauterbach, & Toole (1999) investigated the effects of attention focus on motor skill learning of a discrete golf shot task in participants with no experience in golf. One group was instructed to adopt an internal focus of attention, the swinging motion of the arms during the golf shot and the other group was instructed to adopt an external focus of attention, the pendulum-like motion of the golf club when practicing the golf shot. During the practice attempts, the internal and external focus groups both increased the accuracy of the golf shots, with the external group producing the most accurate shots. The retention test showed that an external attention focus resulted in enhanced learning of the golf shot task as the external focus group had superior accuracy on the task.

Attention focus has also been studied during continuous balance tasks. Wulf, Prinz & Hob (1998, Experiment 2) looked at a continuous dynamic balance task on a stabilometer. The task was to keep either the feet at the same height, an internal focus of attention, or keep the markers placed on the stabilometer in front of the feet at the same height, an external focus of attention. Participants were randomly assigned to either the internal or external focus group. The first and second days of practice consisted of seven
90-s trials on each day, with reminders of the instructed focus every other trial. The retention test on the third day also consisted of seven 90-s trials, but no attention focus instructions were given. During the first day of practice the internal focus group performed better, smaller root mean square error, than the external focus group, and the second day of practice both groups had similar performance. The results of the retention test showed that the external focus group had better balance performance, smaller root mean square error, which indicates enhanced learning with external attention focus.

Wulf, McNevin, and Shea (2001) completed a similar study but used probe reaction time as a way to measure attentional demand when balancing on a stabilometer. The external focus group had shorter probe reaction times than the internal focus group, which indicates that the external focus group required less attention to perform the task and that the task was more automatic.

Another study was done investigating attention focus on the performance of a continuous slalom movement on a ski-simulator (Wulf et al., 1998, Experiment 1). The internal focus group was instructed to apply force on the outer foot, the external focus group was instructed to apply force on the outer wheel, and the control group was not given any attention focus instructions. General instructions to move with as large an amplitude as possible were given to all three groups. Results showed that the external focus group performed with the largest amplitude, and the internal focus group performed with the smallest amplitude.

Similar results supporting the benefits of adopting an external attention focus, whether from initial instructions or feedback given, were also found for skills such as dart throwing, American football, jumping tasks, volleyball, and soccer (Wulf, 2007). A
reason for the benefit of an external focus has been proposed as the constrained action hypothesis.

1.3. **Constrained Action Hypothesis**

The constrained action hypothesis has been proposed to explain this phenomenon of enhanced performance with the adoption of an external focus of attention (Wulf et al, 2001; Wulf & Prinz, 2001; McNevin, Shea, & Wulf, 2003). This hypothesis states that an internal focus of attention constrains the motor system because it interferes with automatic motor control processes. On the other hand, an external focus of attention should allow the motor system to naturally self-organize because it focuses on the effect of the movement which is the ultimate goal of the motor system. External focus produces better learning and performance. This hypothesis also suggests that focusing on external effects that are located close to the body may also lead to interference with automatic motor control processes (Wulf, McNevin, & Shea, 2001; Wulf & Prinz, 2001; McNevin et al., 2003). The theory behind the constrained action hypothesis is called the common coding theory. This theory suggests that actions should be planned based on the desired outcome, so it should be more beneficial to pay more attention to the desired outcome (Prinz, 1997).
1.4. **Distance of Attention Focus**

An external attention focus can be directed to a source located in close proximity to the body or located further away from the body. Thus, the location of the source of the external attention focus may be an important factor that may influence motor skill performance and learning. For example, an external attention focus directed to a source located further away from the body may provide a greater benefit to motor performance and learning as it would reduce the potential interference with automatic motor control processes. McNevin et al. (2003) examined the effects of the distance of the source of the external attention focus from the body during the performance and learning of a continuous balance task in young healthy adults. The balance task involved standing on a stabilometer for 90-s and maintaining the stabilometer as horizontal as possible. Participants were randomly assigned to four attention focus groups. The internal attention focus group was instructed to focus on minimizing movement of the feet. The external attention focus groups were instructed to focus on markers placed at different locations on the stabilometer: external-near, external-far-inside, and external-far-outside. Each group was instructed to focus on their assigned markers, while keeping the stabilometer as horizontal as possible, and looking straight ahead for the 90-s trial. Two days of practice, which consisted of seven trials each day, were completed, and a retention test was done on the third day. The results of the retention test showed that the external-far-inside and external-far-outside groups performed better than the external-near and internal-feet groups. Also, the external-near group showed better performance than the internal-feet group. It was suggested that these results showed that the external-near focus is more beneficial than an internal focus, but because it is so close to the body
it may still interfere with automatic control processes. It is suggested that the far external focus is better than the near external focus, because it is more easily distinguished as an external attention focus. Thus, the strength of the external attention focus effect on augmenting the learning of a balance task has been shown to depend on the distance of the external source of attention focus from the body. The effects of the distance away from the location where the internal and external attention focus source interacts (e.g., feet and the platform) may influence movement. Thus, a question that remains unanswered is whether or not it is the distance away from this interaction point between internal and external sources that produced the effect. For example could the distance be an internal source such as the trunk or the head or must it simply be an external source.

1.5. **Attention Focus Preference**

Where an individual prefers to focus while completing a motor skill may also influence the performance and learning of the skill. However, few studies have investigated attention focus preference during motor skill performance and learning. In particular, the natural tendency as to where individuals direct their focus has not been investigated. Ehrlenstiel, Lieske, & Rubner (2004) examined the interaction between preference and attention focus in a discrete billiards shot task in young healthy participants with experience with billiards. Participants were instructed to shoot a billiard ball into a 5x5 cm area. Ten practice shots were completed with knowledge of results, and 15 test shots were completed without knowledge of results, after which participants were asked where they focused their attention. The deviation of the shot from the target was measured in order to determine performance. Participants were also asked to answer
if they were focused on the movement required to produce the shot, or if they were focused on the target. Participants were randomly split into two groups, an internal-instruction group, which was told to focus on the movement of the arm and concentrate on the feeling, and an external-instruction group, which was told to focus on the target. Fifteen more test shots were completed with instructed focus. Results showed that only when directing attention internally when the individual had an external preference was performance less consistent. This study suggests that a preferred attention focus may be established after years of experience for a given skill, and if the preferred focus is changed it may actually be detrimental to performance.

Wulf, Shea, and Park (2001, Experiment 1) looked at balancing on a stabilometer when given the choice to choose either an internal (the feet) or an external (two orange markers) focus of attention preference. Seventeen young healthy adults participated in the study. On the first day of testing participants were instructed to alternate their focus of attention between internal and external for eight 90-s trials. Four trials for each attention focus condition were performed. Depending on the attention focus condition the participants were instructed either to keep their feet as horizontal as possible or keep the markers as horizontal as possible. At the end of day 1, 10 of the participants chose an internal preference and seven chose an external preference. On the second day of testing participants were instructed to focus on their preferred attention focus from day 1 for eight 90-s trials. The results of day 2 showed no balance performance differences between the internal and external focus preference groups. The results of the retention test showed that there was an attention preference switch, only five chose an internal attention focus preference, and 12 chose an external attention focus preference. Since
there were no performance differences on day 2 between the internal and external attention focus preference groups, there may not be an advantage to adopting an external focus if an individual’s attention focus preference is actually internal.

Limitations of these studies are that it is assumed that the participants were always focused completely internally or externally based on what they reported. It may very well be that they were not always focused completely internally or externally, but were switching between an internal and external attention focus throughout a given trial.

1.6. Attention Focus and Suprapostural Tasks

When a second task is added to a stance task it has been found that postural control is modified. For example a study by McNevin and Wulf (2002) investigated how balance control on a stabilometer changes when required to touch a hanging sheet with the fingers at the same time. The participants were instructed to adopt an external focus of attention, minimizing the movement of the sheet, for two trials, and they were instructed to adopt an internal focus of attention, minimizing the movement of the index finger, for two trials. A baseline trial was also conducted. For all 30-s trials participants were instructed to stand as still as possible with their eyes closed. The results showed that postural sway during the baseline condition, no sheet, was less than the external focus and internal focus conditions. This might indicate that the added task of touching the sheet took attention away from the balance task. During the external focus conditions the frequency of the postural responses was higher than internal focus and baseline conditions. This indicates that an external focus of attention enhances postural stability.
because the balance control system is able to respond to environmental demands or disturbances (McNevin & Wulf, 2002).

Another example of performing a balance task with a secondary task was investigated by Wulf, Weigelt, Poulter, and McNevin (2003). They looked at balancing on a stabilometer while holding a wooden tube with a table tennis ball in it horizontally in front of the abdomen. General instructions were given to keep the stabilometer and tube as horizontal as possible and to keep the table tennis ball in the middle of the tube. The participants were randomly assigned to either an internal attention focus group, or an external attention focus group. The internal attention focus group was instructed to focus on their hands, and the external attention focus group was instructed to focus on the tube. The study consisted of two practice days, and a retention test the third day, seven 90-s trials were completed on each day. On both practice days the sway area was smaller for the external focus group, and the external focus group also had fewer errors, ball contacts with the end of the tube, than the internal focus group. The retention test showed similar results, the external group had smaller sway area and fewer errors than the internal group. A suprapostural task may allow the balance task to become more automatic as the attention focus becomes more external.

Each of these studies provides additional support for the benefits of an external attention focus for the performance of motor skills (McNevin & Wulf, 2002; Wulf et al., 2003).
1.7. Skill Level

How well an individual performs any given skill, whether it is a sports skill, or a skill required for everyday life depends on the level of expertise they have acquired. Coaches have known for some time that a different strategy of teaching must be used for novices versus experts when learning skills or perfecting skills needed to play a sport. One strategy may be the location that they direct a player’s focus of attention based on their skill level. Beilock, Carr, MacMahon, & Starkes (2002) investigated how skill-focused attention versus dual-tasking effects performance of a continuous soccer dribbling task in right footed experienced (≥8 years organized soccer) and novice (<2 years organized soccer) soccer players. The dribbling task consisted of dribbling a soccer ball through six pylons spaced 1.5m apart for a total distance of 10.5m, as quickly and as accurately as possible, using their right foot, as well as their left foot for different trials. Results showed that the experts performed better during the dual task condition when using their right foot (well-practiced), but performed better during the skill-focused condition when using their left foot (novel). When dribbling with either the right, or the left foot the novices performed better during the skill-focused condition.

A study done by Perkins-Ceccato, Passmore, & Lee (2003) looked at how different foci of attention influences golfers of different skill levels. The participants who were considered to be highly skilled had a mean handicap of four, and participants who were considered to be lowly skilled had a mean handicap of 26. The task was to hit a ball as close to the designated target as possible, from various distances. Occlusion goggles were used so that they could not see the outcome of each pitch shot, so they did not change the adopted attention focus based on the results. The internal focus condition was
to focus on the form of the golf swing, and the external focus condition was to focus on hitting the ball as close to the target as possible. The results of the study showed that the highly skilled participants had lower variability when they focused externally on the target. However, the lowly skilled participants had lower variability when they focused internally on the form of the pitch shot swing. Similar results were found by Beilock et al. (2002), when they investigated attention focus on more skilled versus less skilled golfers when performing a pitch shot. From these studies, direction of attention focus may depend on the skill level of the individual; however there is evidence that an external attention focus may be better even for novel tasks.

1.8 Individuals with Balance Problems

This attention focus research suggests that attention focus instructions have a significant impact on motor skill performance and learning in healthy young adults. This section will look at the effects of attention focus instructions on motor skill performance and learning in adults with balance problems.

Relearning optimal balance after an ankle sprain can prove to be difficult. A study by Laufer, Rotem-Lehrer, Ronen, Khayutin, and Rozenberg (2007) looked at the effect of attention focus on the acquisition and retention of postural control following an ankle sprain. The participants consisted of forty individuals, ages 19-33 years, who had suffered an ankle sprain within the last four months who were able to bear full weight on the injured leg. The participants were randomly assigned to either the internal attention focus instruction group or the external attention focus instruction group and were tested before and after the postural control training program, and a retention test was also
conducted. The postural control training program took place over three consecutive days, and consisted of ten 20-second trials performed on the Biodex Stability System at 2 stability levels. Overall stability, anterior-posterior stability, and medial-lateral stability were measured. The results showed that anterior-posterior stability improved significantly more in the instructed external attention focus group when compared to the instructed internal attention focus group. These results indicate that an external focus of attention is beneficial for learning a postural control task after suffering an ankle sprain.

Only one study by Landers, Wulf, Wallmann, and Guadagnoli (2005) has been conducted to determine if external attention focus is more beneficial than internal attention focus for balance control in individuals with balance problems, specifically Parkinson’s disease patients. The participants in the study stood on two pieces of rectangular contact paper, one under each foot, while standing as still as possible. There were three attention focus conditions: no attention focus instructions, internal focus instructions to put equal force on each foot, and external focus instructions to put equal force on each rectangle. Three tasks were completed under each attention focus condition: eyes open with fixed support, eyes closed with fixed support, and eyes open with sway-referenced support (which interferes with proprioception). The results of this study showed that external attention focus produced better balance, and no falls for the sway-referenced task unlike the no focus and internal focus conditions. It may be possible to reduce the occurrence of falls with an optimal attention focus, in this case an external focus.

Wulf (2007) discusses in a target article another study yet to be published (Wulf, Landers, and Tollner, 2006) about balance control in Parkinson’s disease patients when
asked to stand on an inflated rubber disc. The external focus was to keep the disc as still as possible, and the internal focus was to minimize the movement of the feet. The control group was asked to stand still. The external attention focus condition resulted in significantly less postural sway when compared to the internal attention focus group and the control group. This supports the evidence for the benefits of an external attention focus in individuals with balance problems.

Individuals who have suffered a cerebrovascular accident may benefit from external attention focus instructions, in other words instructions directed toward the movement goal. A study by Fasoli, Trombly, Tickle-Degnen & Verfaellie (2002) looked at the effects of internal versus external attention focused verbal instructions given to individuals with and without a cerebrovascular accident (CVA). Sixteen participants had suffered a CVA, and 17 participants had not suffered a CVA. The participants with CVA had to be able to move their arm forward and grab the objects for the movement tasks with their affected arm. There were three movement tasks that were measured in this study: removing a can from a shelf, putting an apple into a basket, and moving a coffee mug onto a saucer. The movement tasks were presented randomly. The participants either received external instructions on all three of the movement tasks first before being instructed to focus internally on the three movement tasks, or the participants received internal focus instructions on all three of the movement tasks first before being instructed to focus externally on the three movement tasks. The external instructions directed participants to focus on the goal of the movement, and the internal instructions directed participants to focus on the movements of the arm while completing the task. Participants completed 8 trials of each task under each attention focus instruction, in total completing
a total of 48 trials. After each trial the participants were asked to determine whether they thought they focused more on the movement itself, or if they focused more on the goal of the movement, to see if they followed the instructions they were given. The quality of the movement was measured by recording total displacement of the arm, movement time, peak velocity, movement units, and time to peak velocity. The results showed that the CVA participants focused more externally during the instructed internal focus condition, when compared to the healthy control group. Significantly shorter movement time, fewer movement units, and higher peak velocity for the CVA group during the instructed external focus condition were found. The participants in the control group exhibited similar results, such that they also had significantly shorter movement time, and greater peak velocity during the instructed external focus condition. The results of this study indicate that external attention focus instructions can help with speed, and force of arm movement in individuals that have suffered a CVA. This suggests that external attention focus instructions given by therapists in a rehabilitation setting would be beneficial for stroke rehabilitation. A narrative review by van Vilet and Wulf (2006) discussed the potential benefits of instructing stroke rehabilitation patients to adopt an external focus of attention.

1.9. Balance Control in Healthy Young Adults Compared to Older Adults

Healthy young adults have become proficient at using sensori-motor strategies to maintain balance based on the environmental circumstances (Woollacott & Shumway-Cook, 1990). As humans age there is a tendency for poor balance control to become a problem. A study done by Prieto et al. (1996) used centre of pressure measurement to
evaluate postural steadiness in older adults compared to young adults. Twenty healthy young adults, 21-35 years of age, and 20 healthy older adults, 66-70 years of age, participated in the study. Two tasks were performed: quiet standing with eyes open and with eyes closed. Results showed that significant age-related differences were found in the anterior-posterior range when standing with eyes open. Age-related differences were found in sway area and mean frequency when standing with eyes closed. Age-related differences were found for mean velocity in the anterior-posterior direction when standing with eyes open or eyes closed. Research is starting to be done to determine why poor balance control seems to be almost inevitable during aging, and how it can be modified or reversed in order to decrease the number of falls, and increase the independence of older adults. Research has suggested that there are numerous factors that contribute to poor balance control in older adults. It has been found that the effectiveness of sensory receptors, and mechanical properties of tendons and muscles deteriorate, as well as the activation of muscle responses are delayed with age (Tang & Woollacott, 2004). This deterioration and delay contribute to balance deficits in older adults which lead to difficulty when performing activities of daily living and also when put into a situation or environment which may in inflict a perturbation. These problems often arise in healthy older adults, and for older adults who have a pathology many of these problems become heightened, so overcoming them become more difficult.

1.10. Balance Control and Aging

As humans age impairments in neural, sensory, and musculoskeletal systems can arise, contributing to poor balance control (Maki & McIlroy, 1996). However, not all
older adults suffer from poor balance control, so postural instability may not be inevitable with aging (Horak, Shupert, & Mirka, 1989). A few different models have been proposed for human aging. One model is the genetic model, it proposes that the functional systems of the body decline linearly according to the program of human genetics (Tang & Woollacott, 2004). Another model is the catastrophe model. It proposes that the systems of the body continue to perform at the same functional level as young healthy adults until death, unless pathology or environmental disaster is inflicted on the individual (Tang & Woollacott, 2004).

Horak et al. (1989) have broken down the functional components of balance control into motor components, and sensory components. The motor components are coordination of postural movement patterns, latency of postural response, scaling the postural response to the stimulus, motor learning, and biomechanics. The sensory components are detection of peripheral sensory stimuli, central selection and weighting of sensory information, sense of stability limits, and sensori-motor integration. In older adults, co-activation of muscles to initiate hip and ankle strategies are observed, instead of sequential activation, also older adults tend to activate more muscles than are required (Horak et al., 1989). Deficits in stimulus encoding are thought to be a reason for reduced postural response latencies (Horak et al., 1989). Decreased muscle strength, and joint flexibility are considered to be biomechanical deficiencies in older adults, which make it more difficult to recover from forward and backward sway (Horak et al., 1989). It has also been found that older adults have reduced lateral stability, which leads to a lateral stepping recovery strategy, which could put older adults at an increased risk of falling and injury (Rogers, Hedman, Johnson, Cain, & Hanke, 2001). Normal adults are able to
recover from as much as eight degrees of forward sway and four degrees of backward sway (Horak et al., 1989). In older adults who would be considered free of neurologic pathology there is a reported decrease in the effectiveness of all three sensory systems which decreases an individual’s ability to detect peripheral sensory stimuli. With a decrease in effectiveness of the sensory systems sensitivity, important sensory information may go unnoticed, meaning that less efficient motor responses may be chosen by the CNS in order to maintain balance control. An individual’s actual stability limits are determined by their biomechanical make up (Alexander, 1994). However, what a person perceives their stability limits to be can lead to poor balance strategy choices, because for the most part people tend to perceive their stability limits as smaller than they actually are, especially the older adult population (Alexander, 1994). Often older adults will respond to small perturbations by taking multiple steps as their strategy to regain balance and avoid falling, but this strategy may actually put them a more risk (Maki & McIlroy, 2006). Strength loss in certain muscles as well as a decreased rate of muscle-force production may limit postural control in older adults (Maki & McIlroy, 2006). Loss of cutaneous sensation in the sole of the foot is also thought to lead to postural instability in older adults (Maki & McIlroy, 2006). If there is a disruption of motor response, or a disruption of a sensory response, the ability to allow for sensori-motor integration is also disrupted (Horak et al., 1989). Poor balance control is prevalent in older adults as approximately one third to one half of the population over 65 years of age will experience a fall (Horak et al., 1989).
1.11. Balance Control and Changes in Attention Demands with Aging

Research has shown that attention demands are higher in older adults as compared to younger adults for balance control, especially under dual-task conditions and cognitively demanding conditions (Woollacott & Shumway-Cook, 2002). A study by Huxhold, Li, Schmiedek, and Lindenberger (2006) investigated how aging and a cognitively demanding secondary task along with focus of attention affects balance control. When performing a simple cognitive task in which attention was focused away from the standing task both older and younger adults had a smaller centre of pressure movement area as compared to the standing task alone. However, when performing a more complex cognitive task older adults had an increase centre of pressure movement area, in contrast to the younger adults who did not. When focusing attention on the cognitive task, it is beneficial for balance control only to a certain extent in older adults, but if the cognitive task becomes too difficult than it is actually detrimental to for the balance control of older adults, so a U-shape relationship exists between balance control and cognitive demand (Huxhold et al., 2006).

1.12. Aging and Falls

"Walking is a state of controlled falling in which we always are only one step away from disaster” (Frank & Patla, 2003, p.157). In the older adult population occurrence of falls is very high. Falls in older adults is a leading cause of injury, such as hip fractures, and could lead to institutionalization, and are very costly for the economy, as more than 20 billion dollars is spent each year (Bloem, Steijns, & Smits-Engelsman,
2003). A study done by Melzer, Benjuya, & Kaplanski (2004), compared the postural stability of older adult fallers, and non-fallers. A total of one hundred and forty-three healthy adults aged 65 and older participated in the study. The participants were placed into two groups: 19 fallers, experienced at least two falls in the last six months, and 124 non-fallers. Each subject performed six stability tests on a single force plate, all of which were 20 seconds in duration, the first three were completed using a wide stance, the first with eyes open, then eyes closed, and then eyes open standing on foam. The last three tasks were completed using a narrow stance, and were the same as the first three situations, eyes open, then eyes closed, and then eyes open standing on foam. COP was used to measure postural stability. Narrow stance stability limits were measured in the anterior-posterior direction, strength was measured for the ankle plantar and dorsi flexors, and the knee flexors and extensors, and sensation in the first toe was also measured. Results showed that COP path length, velocity, and medio-lateral sway for the narrow stance task with eyes open were significantly higher for fallers. COP path length, velocity, elliptical area and medio-lateral sway were significantly higher for the narrow stance task with eyes closed for fallers. When standing on foam with a narrow stance and eyes open, elliptical area, and medio-lateral sway were significantly higher for fallers. For the toe sensation test, fallers were also significantly poorer than non-fallers. The increase in medio-lateral sway in older adults showed the likelihood of a fall was increased by three times (Melzer et al., 2004). Decreased sensation in the feet may result in slower compensatory stepping and grasping time, because of the inability to detect a change in COP (Melzer et al., 2004). The results of the eyes open, and eyes closed narrow stance tasks indicate that somatosensory information seems to be more important
than visual information for fallers (Melzer et al., 2004). The results of the eyes open
while standing on foam and the eyes open narrow stance task indicate that a decrease in
somatosensory information does not affect fallers as much as non-fallers, because fallers
already have decreased somatosensation (Melzer et al., 2004). The context in which a fall
occurs should be considered to determine which balance control strategies and
physiological systems were available to the individual at the time of the fall (Horak,
2006). The situation in which the fall occurred is important to help determine the reason
for the fall. Attention focus research using a balance task may be important to help reduce
the occurrence of falls in older adults.
CHAPTER 2: RATIONALE, OBJECTIVES, AND HYPOTHESES

2.1. Rationale

Falls and their consequences remain a critical health care issue for older adults. However, it remains extremely difficult to identify individuals at risk for falls. Multiple individual, task and environmental factors may interact to influence balance control contributing to falls. One factor that may provide important insight to understanding fall risk in older adults is "where" individuals direct attention when performing a balance task. Although a great deal of research effort has been directed toward understanding the effects of attention on balance control through the use of dual-task or multiple-task paradigms, there has been less research effort directed toward understanding the effects of attention focus on balance control. An understanding of the effects of attention focus on the strategies used to maintain balance may provide key insight for the prevention and treatment of falls in older adults. As just one example, older adults with a fear of falling may start to think more about their balance and direct more attention focus toward the internal processes involved in balance control. The question is whether or not this is an effective strategy. Thus, research examining how attention focus can modify strategies for balance control is needed and this may provide key evidence for the development of novel fall prevention programs for older adults and individuals with balance problems.

There has been some research completed examining the effects of attention focus on balance control. The results of these studies have shown that an external attention focus (for example, instructions to focus on events outside of the body) compared to an internal attention focus (for example, instructions to focus on events within the body)
benefits balance performance. However, what is not currently known is where participants choose to focus when not prompted through specific instructions during a novel balance task and if this choice is influenced by age and experience with the task. To our knowledge, no study has examined the effects of attention focus on balance control in older adults. Many components of balance control are considered to be under automatic control, such that little to no attention needs to be directed towards balance, with this control generated in sub-cortical or spinal levels of the CNS. However, this automaticity may be affected by individual, task and environmental demands, resulting in greater contributions from higher centres in the CNS such as the cerebral cortex. For example, it is well-known that balance control deteriorates with advancing age. It is possible that with the general trend of deteriorating balance control with age, older adults may adopt different attention focus strategies compared to healthy young adults.

2.2. Objectives and Hypotheses

The first objective of this thesis was to investigate the effects of participant age and balance task experience on balance measures, balance perception measures, and attention focus measures. Participants performed a novel balance task and following completion of the task reported “where” their attention was focused during the task. It was hypothesized that young and older adults would initially prefer an internal attention focus. More attention to body movement was expected because the task was novel, and participants would need to explore the appropriate balance control strategy required for the task. As young adults practiced the balance task, it was hypothesized that there would be a shift from an internal to an external focus of attention. This expectation was based
on the assumption that control of the task for young adults would become more automatic with practice and that an external focus of attention would be preferred as it would benefit performance on the task. In contrast, it was hypothesized that older adults would still adopt an internal focus of attention with practice on the balance task. This expectation was based on the assumption that the control of the balance task would not be as automatic and an internal focus of attention would be preferred as it would augment performance on the balance task. It was also hypothesized that young adults would have better trunk control, would be able to better maintain the platform in the horizontal position, would have greater confidence and perceived stability compared to older adults and that these differences would be magnified with practice.

The second objective of this thesis was to investigate the effects of participant age and specific attention focus instructions on balance measures, balance perception measures, and attention focus measures. Participants performed the balance task and were instructed to focus their attention to different external or internal sources. Based on the hypotheses related to natural attention focus during the practice of the task, it was expected that external focus of attention instructions (i.e., focus on the platform) would augment balance as reflected by less trunk sway and platform movement in young adults. This expectation was based on the assumption that young adults would have displayed a preference for external attention focus during the practice of the task and further instructions to focus on the external source would enhance performance. In contrast, internal attention focus instructions (i.e., focus on the feet or trunk) would impair balance as reflected by greater trunk sway and platform movement in young adults. This was expected as instructions to focus on a source not preferred during practice would impair
balance. Based on the hypotheses related to natural attention focus during practice, it was also expected that external focus of attention instructions would impair balance while internal focus of attention instructions would facilitate balance in older adults. These hypotheses were based on the expectation that balance would be impaired when older adults were required to focus on a source different from the natural source reported during the practice of the balance task. It was also hypothesized that self-reported attention focus would be directed only to the instructed internal and external source.
CHAPTER 3: METHODOLOGY

3.1. Participants

Eighteen healthy young adults (mean (M) ± standard deviation (SD) = 22.94 ± 3.46 years, 13 females, 5 males) and eighteen healthy older adults (M ± SD = 66.56 ± 3.84 years, 13 females, 5 males) volunteered to participate in this study. Exclusion criteria included any self-reported neurological or musculoskeletal deficit that could influence balance. All participants were independently living in the community. Each participant provided informed written consent to the experimental procedures which were approved by the Brock University Research Ethics Board (REB# 06-343).

3.2. Procedures

The balance task required participants to stand on an unstable platform. The platform was designed to rotate only in the roll direction with the maximum tilt angle of the platform limited to 14 degrees to the left or right. For all trials of the balance task, participants were instructed to stand as still as possible, and to attempt to maintain the platform in a horizontal position parallel to the ground. Participants stood on the platform with the feet placed shoulder width apart, the arms at the sides, and the eyes open and looking straight ahead. The platform was located 2.25 m from a blank white wall and there was no available visual fixation point. The balance task was a continuous task and was 30-s in duration.

The balance task challenged the balance control system through the elimination of a stable support surface. This balance task was selected in order to provide a significant
challenge to the balance control system, with the older adults still able to successfully complete the task. It was also decided to provide the challenge to balance in the roll direction as older adults are noted to be more unstable in this direction albeit during quiet standing on a stable support surface (Maki, Edmondstone, & McIlroy, 2000). A fall or failed attempt resulted when a step from the platform was needed to recover balance. If this occurred, the trial was re-done.

Each participant performed multiple trials of the balance task under different attention focus conditions (Table 1). First, participants performed sixteen trials of the balance task with no specific attention focus instructions. During these trials, participants were instructed to stand as still as possible and to keep the platform in a horizontal position parallel to the ground. These trials were performed in order to investigate “where” individuals chose to direct their attention during the balance task when given no specific attention focus instructions and if this changed with experience with the balance task. Balance measures, self-reported balance perception measures, and self-reported attention focus measures were collected for trial 1 and trial 16 of the balance task (Table 2). This first part of the protocol investigated the effects of participant age and experience with the balance task on these measures.

Following the completion of the sixteen trials of the balance task without specific attention focus instructions, participants then performed the balance task with specific internal and external attention focus instructions. There was one specific external attention focus instruction condition. Participants were asked to complete the task while thinking about minimizing movements of the platform. There were two specific internal attention focus instruction conditions. Participants were asked to complete the balance
task while thinking about minimizing the movements of the feet, or the trunk. During each of these trials, participants were still provided with instructions related to the goal of the task, that is, to stand as still as possible and to keep the platform in a horizontal position parallel to the ground. A single trial for each specific internal and external attention focus condition was completed. These three trials were presented in a random order. Again, balance measures, balance perception measures, and attention focus measures were collected for each of these three trials (Table 2). This second part of the protocol investigated the effects of specific attention focus instructions on these measures.

Table 1. Experimental protocol highlighting the order of the balance tasks and the instructions provided for each balance task. Note for clarity of the table only trial 1 and trial 16 are presented. However, the instructions were identical for all 16 trials.

<table>
<thead>
<tr>
<th>Balance Task</th>
<th>Instructions Related to Task Goal</th>
<th>Attention Focus Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocked</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 1 to</td>
<td>Stand as still as possible and</td>
<td>None</td>
</tr>
<tr>
<td>Trial 16</td>
<td>maintain the platform in a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>horizontal position</td>
<td></td>
</tr>
<tr>
<td>Random</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feet (internal)</td>
<td>Stand as still as possible and</td>
<td>Minimize movements of</td>
</tr>
<tr>
<td></td>
<td>maintain the platform in a</td>
<td>the feet</td>
</tr>
<tr>
<td></td>
<td>horizontal position</td>
<td></td>
</tr>
<tr>
<td>Trunk</td>
<td>Stand as still as possible and</td>
<td>Minimize movements of</td>
</tr>
<tr>
<td>(internal)</td>
<td>maintain the platform in a</td>
<td>the trunk</td>
</tr>
<tr>
<td></td>
<td>horizontal position</td>
<td></td>
</tr>
<tr>
<td>Platform</td>
<td>Stand as still as possible and</td>
<td>Minimize movements of</td>
</tr>
<tr>
<td>(external)</td>
<td>maintain the platform in a</td>
<td>the platform</td>
</tr>
<tr>
<td></td>
<td>horizontal position</td>
<td></td>
</tr>
</tbody>
</table>
3.3. **Dependent Measures**

Dependent measures were collected before, during and after the completion of the balance tasks (Table 2). Self-reported balance perceptions were collected prior to the start of the trial, balance measures were collected during the trial, and self-reported balance perceptions and attention focus measures were collected following the completion of the trial.

Table 2. Balance measures, self-reported balance perception measures, and self-reported attention focus measures that were collected before, during and after the balance task.

<table>
<thead>
<tr>
<th>Before Trial</th>
<th>During Trial</th>
<th>After Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance Confidence (%)</td>
<td>Platform Angle Variability (degrees)</td>
<td>Perceived Stability (%)</td>
</tr>
<tr>
<td></td>
<td>Trunk Roll Angle (degrees)</td>
<td>Attention Focus: Feet (%)</td>
</tr>
<tr>
<td></td>
<td>Trunk Roll Velocity (degrees/sec)</td>
<td>Attention Focus: Trunk (%)</td>
</tr>
<tr>
<td></td>
<td>Trunk Pitch Angle (degrees)</td>
<td>Attention Focus: Other Body Part (%)</td>
</tr>
<tr>
<td></td>
<td>Trunk Pitch Velocity (degrees/sec)</td>
<td>Attention Focus: Platform (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attention Focus: Irrelevant Events (%)</td>
</tr>
</tbody>
</table>
3.3.1. **Self-Reported Balance Perception Measures**

Prior to the start of each balance task, perceived balance confidence was collected. Participants were asked to rate their confidence in their ability to complete the balance task and avoid falling on a scale of 0% (no confidence) to 100% (complete confidence). After the completion of each balance task, participants were asked to rate how stable they felt during the task on a scale of 0% (not at all stable) to 100% (completely stable).

3.3.2. **Self-Reported Attention Focus Measures**

Attention focus was probed following the completion of the balance tasks. Participants were asked to estimate “where” their attention was focused during the task. Participants allocated percentages (which had to sum to a total of 100%) for five provided categories: internal-feet, internal-trunk, internal-other body part, external-platform, and irrelevant events not related to the balance task. Table 3 displays an example of how a participant allocated their attention focus for one trial of the balance task. The order of presentation of attention focus categories in the questionnaire was randomized for each balance task and each participant. This randomization was completed in an attempt to avoid biasing participant's responses to a particular attention focus category.
Table 3. A sample of the percentages assigned to the attention focus categories for one trial of the balance task for one participant. Note that the percentages assigned to the provided categories were required to sum to 100%. The order of the categories was randomized for each stance trial and each participant in an attempt to avoid biasing participant's responses to a particular category.

<table>
<thead>
<tr>
<th>To stand as still as possible and maintain the platform in the horizontal position:</th>
<th>Percentage Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>I thought about minimizing the movements of the platform.</td>
<td>10</td>
</tr>
<tr>
<td>I thought about minimizing the movements of my trunk.</td>
<td>10</td>
</tr>
<tr>
<td>I thought about minimizing the movements of my feet.</td>
<td>70</td>
</tr>
<tr>
<td>I thought about minimizing the movements of other body parts.</td>
<td>0</td>
</tr>
<tr>
<td>I thought about other things not related to the balance task.</td>
<td>10</td>
</tr>
</tbody>
</table>

TOTAL 100%

Two standard attention focus categories were selected. The internal feet and external platform categories correspond to the attention focus instruction categories used in previous studies (McNevin et al., 2003; Wulf et al., 2001). Two additional internal attention focus categories, the trunk and other body parts, were selected due to the fact that the balance task challenged whole-body stability. Thus, it was thought that the nature of the task may direct attention to other internal sources in order to balance during the task. Another category that was included examined whether attention was directed toward events that were not related to the balance task. This category was included as it was
thought that as participants gained experience with the balance task, attention focus would be directed to irrelevant thoughts not related to the balance task.

3.3.3. Balance Measures

Balance was monitored by recording trunk movements using angular velocity transducers (SwayStar System, Balance Int Innovations GmbH, Switzerland) (Figure 1). Participants wore the lightweight device which was attached to an elasticized motorcycle belt and placed on the lower back at the lumbar level of L2-L3. The major benefit of using this device is that the measurements are not influenced by support surface conditions (i.e., unstable support surfaces) (Allum & Carpenter, 2005). Thus, an estimate of balance performance using trunk sway measurements can be made when participants stand on the unstable platform.

Figure 1. Trunk sway measurement device used to quantify trunk roll and pitch angle and angular velocity values during the balance task.
The device recorded trunk movements in both pitch (forward-backward) and roll (side-to-side) directions during the balance tasks. The device employs two digitally-based angular-velocity transducers, oriented so that one transducer measures angular velocity deviations in the roll direction and the other angular velocity deviations in the pitch direction. Specifically, plots of angular displacement and velocity in the pitch and roll directions were scanned for peak-to-peak range amplitudes (Figure 2). The 5% and 95% limits were taken from the peak-to-peak amplitude, and the amplitude between these limits is the 90% range. Thus, measures of 90% range excursions in roll and pitch directions for both trunk angular displacement (with respect to reset angular positions of zero displacement at the start of each trial) and trunk angular velocity were calculated. Hence, four dependent measures were used to estimate balance: trunk roll angle, trunk roll velocity, trunk pitch angle, and trunk pitch velocity.

Balance performance was also measured by monitoring platform movement. The movement of the platform was measured in degrees using an inclinometer that was attached to the bottom of the platform. The inclinometer had a resolution of 0.0025 degrees and sent time series data to the computer using a USB cable connection (Figure 2). Data was sampled at a rate of 20 Hz. The standard deviation of the time series data was calculated for data analysis. Previous work has estimated balance performance using platform movement outcome measures (Wulf, Shea, Park, 2001, Experiment 1).
Figure 2. Time series data collected for trunk roll angle, trunk pitch angle, trunk roll velocity, trunk pitch velocity, and platform angle variability for a single 30s trial for one participant.
3.4. Statistical Analyses

Before the statistical tests were conducted the data was screened for univariate outliers. This was done by calculating the standardized scores (z-scores). A z-score of greater than $\pm 3.29$ ($p < 0.001$, two-tailed test) was considered to be an outlier (Tabachnick & Fidell, 2007), and was removed from the data spreadsheet used in the statistical tests which are described below.

This thesis was designed to investigate two specific research purposes. The first purpose of the thesis was to investigate the influence of participant age and experience with the balance task on balance, self-reported balance perception, and self-reported attention focus measures. To investigate the results for this part of the thesis, three 2 x 2 repeated measures ANOVA procedures were conducted for each dependent variable outlined in Table 2. Each analysis included the between-subject factor of participant age (2 levels: young and older adults) and the within-subject factor of time (2 levels: trial 1 and trial 16 of the balance task) with repeated measures on this factor. Thus, main effects of participant age and time and the interaction between these two factors were examined for statistical differences with the significance level set to $p<0.05$.

The second purpose of the thesis was to investigate the influence of participant age and specific attention focus instructions on balance, self-reported balance perception, and self-reported attention focus measures. To investigate the results for this part of the thesis, three 2 x 4 repeated measures ANOVA procedures were conducted for each dependent variable outlined in Table 2. Each analysis included the between-subject factor of participant age (2 levels: young and older adults) and the within-subject factor of instruction (4 levels: no instruction, feet instruction, trunk instruction, and platform
instruction) with repeated measures on this factor. Thus, main effects of participant age and instruction and the interaction between these two factors were examined for statistical differences with the significance level set to $p<0.05$. When appropriate (e.g., if a significant instruction main effect was observed), post-hoc analyses were calculated based on least square differences to determine differences between the multiple levels of the independent variable.
CHAPTER 4: RESULTS

This thesis was designed to investigate two specific research purposes. The first purpose of the thesis was to investigate the influence of participant age and experience with the balance task on balance, self-reported balance perception, and self-reported attention focus measures. The second purpose of the thesis was to investigate the influence of participant age and specific attention focus instructions on balance, self-reported balance perception, and self-reported attention focus measures. Thus, the results will be separately presented to address each specific research purpose.

4.1. Effects of participant age and balance task experience on balance, self-reported balance perception, and self-reported attention focus measures.

A summary of the results of the 2 x 2 repeated measures ANOVA procedures that were conducted for each dependent variable is presented in Appendix A. Each analysis included the between-subject factor of participant age (2 levels: young and older adults) and the within-subject factor of time (2 levels: trial 1 and trial 16 of the balance task) with repeated measures on this factor.

Figure 3 shows the performance curves for both young and older adults for all five balance measures. This graph confirms that a similar amount of improvement in performance was seen for both young and older adults, which indicates that reporting statistics for just trial 1 and trial 16 was appropriate.
Figure 3. Performance of young and older adults over 16 practice trials of the balance task over all five balance measures: roll angle, pitch angle, roll velocity, pitch velocity, and platform angle variability.
4.1.1. **Balance Measures**

**Platform Angle Variability**

Figure 4 shows the mean and standard error of the mean for the platform angle variability values for trial 1 and trial 16 of the balance task for young and older adults. No significant interaction between participant age and time was observed for platform angle variability (p=0.677). The results did show a significant main effect of participant age (F (1, 34) = 65.58, p < 0.001) for this dependent variable. The variability of the platform angle was larger for older adults (mean \( M \) ± standard error of the mean \( SE \) = 9.58 ± 0.34 degrees) compared to young adults (\( M \pm SE = 5.73 \pm 0.28 \) degrees). The results also showed a significant main effect of time (F (1, 34) = 76.74, p < 0.001) for this dependent variable. There was a significant reduction in the variability of platform angle for trial 16 (\( M \pm SE = 6.62 \pm 0.41 \) degrees) compared to trial 1 (\( M \pm SE = 8.68 \pm 0.42 \) degrees).
Figure 4. Platform angle variability values (M and SE) for trial 1 and trial 16 of the balance task for young and older adults. Note that there were significant main effects of participant age and time but no significant interaction between these two factors.

**Trunk Roll Angle and Velocity**

Figure 5 shows the mean and standard error of the mean for the trunk roll angle values for trial 1 and trial 16 of the balance task for young and older adults. No significant interaction between participant age and time was observed for trunk roll angle (p=0.998). The results did show significant main effects of participant age (F (1, 34) = 17.37, p < 0.001) and time (F (1, 34) = 23.33, p < 0.001) for this dependent variable. The examination of the participant age main effect revealed larger trunk roll angle values for older adults (M ± SE = 13.71 ± 0.75 degrees) compared to young adults (8.76 ± 0.56...
degrees) while the examination of the time main effect showed a significant reduction in trunk roll angle for trial 16 \((M \pm SE = 12.39 \pm 0.78\) degrees) compared to trial 1 \((M \pm SE = 10.08 \pm 0.73\) degrees).
Figure 5. Trunk roll angle values (M and SE) for trial 1 and trial 16 of the balance task for young and older adults. Note that there were significant main effects of participant age and time but no significant interaction between these two factors.

Figure 6 shows the mean and standard error of the mean for the trunk roll velocity values for trial 1 and trial 16 of the balance task for young and older adults. No significant interaction between participant age and time was observed for trunk roll velocity (p=0.394). Similar to the observations for trunk roll angle, the results did show significant main effects of participant age (F (1, 34) = 6.20, p = 0.018) and time (F (1, 34) = 28.40, p < 0.001) for this dependent variable. The direction of the change for the participant age main effect was the same as that observed for trunk roll angle. Larger
trunk roll velocity values were observed for older adults ($M \pm SE = 31.86 \pm 2.13$ degrees/sec) compared to young adults ($M \pm SE = 22.95 \pm 1.75$ degrees/sec). The direction of the change for the time main effect was also the same as that observed for trunk roll angle. There was a significant reduction in trunk roll velocity for trial 16 ($M \pm SE = 24.06 \pm 1.82$ degrees/sec) compared to trial 1 ($M \pm SE = 30.74 \pm 2.20$ degrees/sec).

![Figure 6. Trunk roll velocity values (M and SE) for trial 1 and trial 16 of the balance task for young and older adults. Note that there were significant main effects of participant age and time but no significant interaction between these two factors.](image-url)
Trunk Pitch Angle and Velocity

Figure 7 shows the mean and standard error of the mean for the trunk pitch angle values for trial 1 and trial 16 of the balance task for young and older adults. No significant interaction between participant age and time and no significant main effect of time were observed for trunk pitch angle (p=0.066 and p=0.802, respectively). The results did show a significant main effect of participant age (F (1, 34) = 10.15, p = 0.003) for this dependent variable. Larger trunk pitch angle values were observed for older adults (M ± SE = 5.31 ± 0.29 degrees) compared to young adults (M ± SE = 3.84 ± 0.24 degrees).
Figure 7. Trunk pitch angle values (M and SE) for trial 1 and trial 16 of the balance task for young and older adults. Note that there was a significant main effect of participant age but no significant main effect of time and no significant interaction between participant age and time.

Figure 8 shows the mean and standard error of the mean for the trunk pitch velocity values for trial 1 and trial 16 of the balance task for young and older adults. No significant interaction between participant age and time was observed for trunk pitch velocity (p=0.712). However, the results did show a significant main effect of participant age (F (1, 34) = 6.99, p = 0.012) and time (F (1, 34) = 10.14, p = 0.003) for this dependent variable. The examination of the participant age main effect revealed larger
trunk pitch velocity values for older adults ($M \pm SE = 13.72 \pm 0.88$ degrees/sec) compared to young adults ($M \pm SE = 9.86 \pm 0.73$ degrees/sec) while the examination of the time main effect showed a significant reduction in trunk pitch velocity for trial 16 ($M \pm SE = 10.74 \pm 0.77$ degrees/sec) compared to trial 1 ($M \pm SE = 12.84 \pm 0.93$ degrees/sec).

![Bar chart](chart.png)

Figure 8. Trunk pitch velocity values (M and SE) for trial 1 and trial 16 of the balance task for young and older adults. Note that there were significant main effects of participant age and time but no significant interaction between these two factors.
4.1.2. Self-reported Balance Perception Measures

*Perceived Confidence and Stability*

The results revealed no significant interaction effect between participant age and time and no significant main effect of participant age for perceived confidence ($p=0.384$ and $p=0.876$, respectively) or perceived stability ($p=0.280$ and $p=0.164$, respectively). However, there was a significant main effect of time for both perceived confidence ($F(1, 34) = 5.07$, $p = 0.031$) and perceived stability ($F(1, 34) = 20.73$, $p < 0.001$). The examination of these main effects revealed a significant increase in perceived confidence for trial 16 ($M \pm SE = 78.49 \pm 4.42 \%$) compared to trial 1 ($M \pm SE = 67.78 \pm 4.34 \%$) and a significant increase in perceived stability for trial 16 ($M \pm SE = 73.44 \pm 4.43 \%$) compared to trial 1 ($M \pm SE = 59.17 \pm 4.39 \%$).

4.1.3. Self-reported Attention Focus Measures

No significant interaction effect between participant age and time, and no significant main effects of participant age or time were observed for attention focus percentage allocated to the feet, trunk, or other body part internal attention focus categories (range: $p=0.128$ to $p=0.856$). There was no significant interaction effect between participant age and time and no significant main effect of participant age for attention focus percentage allocated to the platform external attention focus category ($p=0.825$ and $p=0.523$, respectively) or the irrelevant events attention focus category ($p=0.268$ and $p=0.585$, respectively). However, the results did show a significant main effect of time for attention focus percentage allocated to the platform external attention focus category ($F(1, 34) = 21.10$, $p < 0.001$) and the irrelevant events attention focus
category (F(1, 34) = 14.34, p = 0.001). An examination of the time main effects revealed that attention focus on an external source (i.e., the platform) was significantly decreased from trial 1 (M ± SE = 45.95 ± 4.36 %) to trial 16 (M ± SE = 25.09 ± 4.16 %) while attention focus on irrelevant events not related to the balance task was increased from trial 1 (M ± SE = 4.49 ± 1.64) to trial 16 (M ± SE = 25.28 ± 5.33).

To test for differences between attention focus categories, the attention focus percentage values were submitted to a 2 x 2 x 5 ANOVA procedure. The analyses included the factors of participant age (2 levels: young and older adults), time (2 levels: trial 1 and trial 16 of the balance task), and attention focus category (5 levels: feet, trunk, other body part, platform, and irrelevant events). The results showed a significant interaction effect between time and attention focus category (F(3, 340) = 8.48, p<0.0001) for attention focus percentage (Figure 9). An examination of the interaction effect showed consistent findings with those previously described, in that, attention focus on an external source (i.e., the platform) was significantly decreased by 20.86 % from trial 1 to trial 16 while attention focus on irrelevant events not related to the balance task was increased 20.79 % from trial 1 to trial 16. There were no significant differences for attention focus percentage for the feet, trunk, and other body part internal attention focus categories from trial 1 to trial 16.

As the results of this analysis revealed no significant differences between the feet, trunk, and other body part internal attention focus categories for attention focus percentage, the percentages for each of these three categories were summed to provide a single internal attention focus category and the analyses were conducted again using this new variable.
Figure 9 shows the mean attention focus percentage values for internal sum, platform external, and irrelevant events attention focus categories for trial 1 and trial 16 of the balance task collapsed across both participant age groups. For this analysis, there was no interaction between participant age and time (p=0.978) or significant main effects of participant age (0.246) or time (0.998) for attention focus percentage for the internal sum category. For the analysis examining differences between attention focus categories, there was a significant interaction effect between time and attention category ($F(2, 215) = 11.34, p < 0.001$). An examination of the trial by attention category effect revealed that attention on internal sources did not change from trial 1 ($M \pm SE = 49.65 \pm 4.37\%$) to trial 16 ($M \pm SE = 49.63 \pm 4.37\%$). However, the amount of attention focused on the platform external and events not related to the balance task did change as previously described.
Figure 9. Mean attention focus percentage values for the internal, external, and irrelevant events attention focus categories for trial 1 and trial 16 of the balance task collapsed across both participant age groups. Note that the stacked bar for the internal attention focus category is also sectioned into the individual feet, trunk, and other body part attention focus categories.
4.2. Effect of participant age and specific attention focus instructions on balance, balance perception, and attention focus measures.

A summary of the results of the 2 x 4 repeated measures ANOVA procedures that were conducted for each dependent variable is presented in Appendix B. The analyses included the between-subject factor of participant age (2 levels: young and older adults) and the within-subject factor of instruction (4 levels: no instruction, feet instruction, trunk instruction, platform instruction) with repeated measures on the last factor.

4.2.1. Balance Measures

Platform Angle Variability

Figure 10 shows the mean and standard error of the mean for the platform angle variability for each instruction condition for young and older adults. The results revealed no significant interaction effect between participant age and instruction (p=0.187) and no significant main effect of instruction (p=0.312) for platform angle variability. However, the results did show a significant main effect of participant age (F (1, 34) = 68.68, p < 0.001) for this dependent variable. Larger platform angle variability was observed for older adults (M ± SE = 8.44 ± 0.21 degrees) compared to young adults (M ± SE = 4.83 ± 0.17 degrees).
Figure 10. Platform angle variability values (M and SE) for each instruction condition for young and older adults. Note that there was a significant main effect of participant age but no significant main effect of instruction and no significant interaction between participant age and instruction.

**Trunk Roll Angle and Velocity**

Figure 11 shows the mean and standard error of the mean for the trunk roll angle for each instruction condition for young and older adults. The results revealed no significant interaction effect between participant age and instruction for trunk roll angle \( (p=0.390) \). However, the results did show a significant main effect of participant age \( (F(1, 34) = 18.71, p < 0.001) \) and instruction \( (F(3, 102) = 3.307, p = 0.023) \) for this
dependent variable. First, larger trunk roll angle values were observed for older adults (M ± SE = 12.68 ± 0.61 degrees) compared to young adults (M ± SE = 7.27 ± 0.37 degrees). Second, a post-hoc analysis revealed that there was a significant reduction in trunk roll angle when instructed to focus on the trunk (M ± SE = 8.93 ± 0.76 degrees) compared to the no instruction, feet instruction, and platform instruction conditions (M ± SE = 10.08 ± 0.73 degrees, 10.60 ± 0.87 degrees, and 10.29 ± 0.99 degrees, respectively).

Figure 11. Trunk roll angle values (M and SE) for each instruction condition for young and older adults. Note that there were significant main effects of participant age and instruction but no significant interaction between these factors. When instructed to focus on the trunk, trunk roll angle was smaller compared to the other attention focus instruction conditions.
Figure 12 shows the mean and standard error of the mean for the trunk roll velocity values for each instruction condition for young and older adults. The results revealed no significant interaction effect between participant age and instruction for trunk roll velocity (p=0.777). Similar to the results for trunk roll angle, the results showed a significant main effect of participant age (F (1, 34) = 11.57, p = 0.002) and instruction (F (3, 102) = 3.070, p = 0.031) for trunk roll velocity. First, larger trunk roll velocity values were observed for older adults (M ± SE = 29.32 ± 1.40 degrees/sec) compared to young adults (M ± SE = 18.15 ± 1.09 degrees/sec). Second, a post-hoc analysis revealed that there was a significant reduction in trunk roll velocity when instructed to focus on the trunk (M ± SE = 21.56 ± 1.98 degrees/sec) compared to the no instruction, feet instruction, and platform instruction conditions (M ± SE = 24.06 ± 1.82 degrees/sec, 24.71 ± 1.92 degrees/sec, and 24.59 ± 2.28 degrees/sec, respectively).
Figure 12. Trunk roll velocity values (M and SE) for each instruction condition for young and older adults. Note that there were significant main effects of participant age and instruction but no significant interaction between these factors. When instructed to focus on the trunk, trunk roll velocity was smaller compared to the other attention focus instruction conditions.

**Trunk Pitch Angle and Velocity**

Figure 13 shows the mean and standard error of the mean for the trunk pitch angle values for each instruction condition for young and older adults. The results revealed no significant main effect of instruction ($p = 0.495$) for trunk pitch angle. The results did show a significant main effect of participant age ($F(1, 34) = 18.69, p < 0.001$) for this
dependent variable. Older adults displayed larger trunk pitch angle values ($M \pm SE = 5.26 \pm 0.21$ degrees) compared to young adults ($M \pm SE = 3.44 \pm 0.17$ degrees). The results also revealed a significant interaction effect between participant age and instruction ($F (3, 102) = 2.79, p = 0.044$) for trunk pitch angle. Older adults had larger pitch angle values for the no instruction condition ($M \pm SE = 5.03 \pm 0.35$ degrees) compared to the feet, trunk, and platform instruction conditions ($M \pm SE = 5.26 \pm 0.38$ degrees, $5.20 \pm 0.47$ degrees, and $5.57 \pm 0.46$ degrees, respectively). In contrast, young adults had smaller pitch angle values for the no instruction condition ($M \pm SE = 4.06 \pm 0.38$ degrees) compared to the feet, trunk and platform instruction conditions ($M \pm SE = 3.50 \pm 0.34$ degrees, $3.06 \pm 0.31$ degrees, and $3.14 \pm 0.30$ degrees, respectively).
Figure 13. Trunk pitch angle values (M and SE) for each instruction condition for young and older adults.

Figure 14 shows the mean and standard error of the mean for the trunk pitch velocity values for each instruction condition for young and older adults. The results revealed no significant interaction effect between participant age and instruction for trunk pitch velocity (p=0.513). The results did show a significant main effect of participant age (F (1, 34) = 13.38, p = 0.001) and instruction (F (3, 102) = 3.37, p = 0.021) for this dependent variable. An examination of the participant age main effect revealed that older adults displayed larger trunk pitch velocity values compared to young adults (M ± SE = 13.34 ± 0.51 degrees/sec compared to 8.74 ± 0.46 degrees/sec). A post-hoc analysis of
the instruction main effect showed that there was a significant increase in trunk pitch velocity when instructed to focus on the platform (M ± SE = 11.91 ± 0.92 %) compared to the no instruction, feet instruction, and trunk instruction conditions (M ± SE = 10.74 ± 0.77 %, 11.05 ± 0.75 %, and 10.45 ± 0.70 %, respectively).

Figure 14. Trunk pitch velocity values (M and SE) for each instruction condition for young and older adults. Note that there were significant main effects of participant age and instruction but no significant interaction between participant age and instruction.
4.2.2. Attention Focus Measures

Figure 15 shows the mean attention focus percentage values allocated to each of the five attention preference categories for each instruction condition collapsed across both young and older adults. The results revealed no significant interaction effect between participant age and instruction (range: p=0.245 to p=0.827) and no significant main effect of participant age (range: p=0.442 to p=0.979) for attention focus percentage for any of the attention preference categories. As expected, the results did show a significant main effect of instruction \( F(3, 102) = 95.32, p < 0.001 \) for the feet internal attention focus category for attention preference percentage. The majority of attention was directed to the feet \( (M \pm SE = 69.0 \pm 3.83 \%) \) when instructed to focus on the feet.

As expected, the results also showed a significant main effect of instruction \( F(3, 102) = 102.78, p < 0.001 \) for the trunk internal attention focus category for attention preference percentage. The majority of attention was directed to the trunk \( (M \pm SE = 70.0 \pm 4.10 \%) \) when instructed to focus on the trunk. As expected, the results also showed a significant main effect of instruction \( F(3, 102) = 75.98, p < 0.001 \) for the platform external attention focus category for attention preference percentage. The majority of attention was directed to the platform \( (M \pm SE = 65.8 \pm 3.98 \%) \) when instructed to focus on the platform.

The results also showed a significant main effect of instruction for the other body internal attention focus category \( F(3, 102) = 4.25, p = 0.007 \) and for the irrelevant events attention focus category \( F(3, 102) = 13.72, p < 0.001 \). Attention focused on other body parts was significantly greater for the no instruction condition \( (M \pm SE = 14.86 \pm 3.11 \%) \) compared to the feet, trunk, and surface instruction conditions \( (M \pm SE \)
Attention focused on events not related to the balance task was significantly larger for the no instruction condition \((M \pm SE = 25.28 \pm 5.33\%)\) compared to the feet, trunk, and surface instruction conditions \((M \pm SE = 5.22 \pm 1.42\%, 3.75 \pm 0.98\%,\text{ and } 7.26 \pm 1.87\%,\text{ respectively})\).

Figure 15. Mean attention focus percentage values allocated to each of the five attention preference categories (i.e., feet (gray-hatch), trunk (gray), other body (gray-dots), platform (black), and irrelevant (white)) (stacked bars) for each instruction condition. Note that this manipulation check confirmed that participants allocated a greater percentage of their attention focus to the instruction attention focus source.
CHAPTER 5: DISCUSSION

5.1. Effects of participant age and balance task experience on balance, balance perceptions, and attention focus preference measures.

The first objective of this thesis was to investigate the effects of participant age and experience with the balance task on balance measures, self-reported balance perceptions, and self-reported attention focus measures. The balance task required participants to maintain upright stance on an unstable platform which could rotate only in the roll direction. In order to probe attention focus during the performance of the balance task, participants were provided with no instructions as to “where” to direct their attention. An examination of “where” attention is naturally directed during the performance of a balance task was novel.

As expected, young adults had smaller trunk angle and angular velocity values, especially in the roll direction, compared to older adults. These results corresponded to the age-related effects on trunk sway observed between young and older adults when performing a number of different stance and gait tasks, for example, standing on one leg and tandem walking (Gill et al. 2001). Instability in the medial-lateral direction has also been observed in older adults during quiet standing (Maki et al., 2000). The platform stability measure also revealed differences in balance control between young and older adults. The young adults were able to maintain the platform in a more horizontal position parallel to the ground compared to the older adults. A decline in the ability to control balance in older adults during this type of balance task could provide a possible
explanation for the observed age-related differences (Maki & McIlroy, 1996; Horak et al., 1989).

As expected, experience with the balance task resulted in smaller trunk angle and angular velocity values, especially in the roll direction, for both young and older adults. Young adults showed a 23% reduction in trunk roll angle and 29% reduction in trunk roll angular velocity while older adults showed a 16% reduction in trunk roll angle and 16% reduction in trunk roll angular velocity from the first to final attempt of the balance task. Furthermore, young and older adults were better able to maintain the platform in a horizontal position with practice. These results suggest that practice on the balance task facilitated performance of the task and that this effect was not dependent on age. The observed improvements may suggest the adoption of a more appropriate balance control strategy to accomplish the goal of maintaining upright stance on the platform with practice.

Balance confidence and perceived stability were not different between age groups. However, the observed improvements in balance over time were accompanied by changes in balance perceptions. Increased balance confidence and increased perceived stability were reported on the final compared to initial attempt of the balance task in both young and older adults. As balance improved, as reflected by decreased trunk sway and decreased platform movement, there was an expectation that balance confidence would increase as individuals gained experience with the task. Research has shown that balance confidence is an indicator of balance performance (Hatch, Gill-Body, & Portney, 2003). Alternatively, the increased confidence in the ability to perform the task may have contributed to the observed improvements in balance (Maki et al. 1991). The higher
ratings for perceived stability after practice with the balance task could be attributed to the ability of the participants to accurately assess their own stability. Scheippati et al. (1999) have observed that people are actually quite successful in rating differences in their stability between trials. For example, young and older adults and individuals with neurological disorders were capable of detecting changes in their stability when standing under different stance width and vision conditions. Thus, in the present thesis, as both young and older adults showed improvements in balance over time, these improvements were detected and reflected in the increased ratings of perceived stability.

The primary objective of this part of the thesis was to examine “where” individuals directed their attention when performing the balance task and whether this changed with experience with the balance task. It was hypothesized that young and older adults would direct attention to an internal source on the initial attempt of the balance task due to the novelty associated with the task. With practice, it was hypothesized that young adults would switch to focus attention on an external source as the task became more familiar and control of the task became more automatic while older adults would continue to direct attention to an internal source as the task had not yet become automatic for them. Contrary to the hypotheses, young and older adults reported similar attention focus strategies on both the initial and final attempts of the balance task. This finding could be explained by the fact that the task was novel for both age groups and that both groups showed a similar amount of improvement on the balance task. It is possible that attention focus was similar as the strategy used to maintain upright stance on the platform (e.g., hip) was similar for both groups due to the nature of the task.
In order to assess “where” individuals were focused during the balance task, different attention focus categories were selected. It was decided to examine the internal attention focus categories together as one measure (i.e., the sum of the internal feet, trunk, and other body part categories) so as to compare internal, external and the irrelevant events categories. The differences between the internal feet, trunk and other body part categories were also separately examined. Thus, results from both approaches will be discussed and used to provide insight into attention focus strategies employed during the balance task.

First, the comparison between the internal, external and irrelevant events categories will be discussed. It is important to remember in the discussion of these results that participants were required to sum their responses for each of the provided categories to 100%. On the initial attempt of the balance task, close to one-half of attention focus was allocated to an external source, the platform, and close to one-half of attention focus was allocated to an internal source, the feet, the trunk or other body parts. The focus of attention on the platform may be explained by the larger movements of the platform on the initial attempt of the balance task. Participants may have been attempting to minimize the platform movements. When examining the allocation of attention focus to the separate internal attention focus categories, there were equal amounts of attention allocated to the feet, the trunk, and other body parts. Thus, there was no one internal attention focus source that was dominant. The focus of attention on internal sources could be explained by the fact that there was substantial whole-body movement associated with the initial attempt of the balance task. Participants may have been attempting to minimize body movements. For this first attempt of the balance task, there was also minimal
attention focus on events that were not related to the balance task. These results suggest that individuals were concentrating on developing strategies to improve performance on the balance task using both internal and external attention focus sources. Thus, the novelty or difficulty associated with the initial attempt of the balance task required participants to direct the majority of their attention to internal or external sources, and not to events unrelated to the balance task.

On the final attempt of the balance task, the amount of attention focus on internal sources did not change, as close to one-half of attention focus was directed to an internal source. An examination of the individual internal categories again revealed similar amounts of attention focus directed to the feet, trunk and other body parts. This result may suggest that an internal focus of attention is required for the performance of the balance task. If so, it is interesting to note that this internal focus did not negatively influence balance control. In fact, balance control was improved as reflected by reduced trunk and platform movement with practice. This finding is opposite to the hypotheses for young adults and to the body of research that has shown a decrement in balance performance with an internal focus of attention (Wulf, Prinz, & Hob, 1998; Wulf, McNevin, & Shea, 2001; McNevin, Shea, & Wulf, 2003). When attention focus was probed on the final attempt of the balance task, the amount of attention focus was increased by 21% for events that were not related to the balance task. The increased balance confidence and increased perceived stability which accompanied the improved balance performance with practice may have allowed individuals to think more about events not related to the balance task.
The attention focus that was directed toward these irrelevant events was drawn from the attention focus pool that was directed to an external source on the first attempt of the balance task. Attention focus on the platform was decreased by 21% for the final attempt compared to the first attempt of the balance task. Thus, attention focus on the platform, an external source, was decreased with practice. This result again is opposite to the hypotheses for attention focus for young adults and opposes results in the literature which show that external attention focus benefits motor performance and learning of balance tasks (Wulf, Prinz, & Hob, 1998; Wulf, McNevin, & Shea, 2001; McNevin, Shea, & Wulf, 2003). For a well-practiced task, an external focus should dominate over an internal attention focus and or focus on irrelevant events. Thus, it would be expected to observe a shift to a more dominant external focus with practice, especially with younger adults. However, this was not the case for either the young or older adult groups.

Second, if the internal attention focus categories are considered separately, then the attention focus to an external source, the platform, was dominant on the first attempt of the balance task. This result opposes the hypotheses and the literature which suggests that an external attention focus during the initial performance of a motor skill may not be beneficial (Beilock et al., 2002; Perkins-Ceccato, Passmore, & Lee, 2003). Interestingly, after practice on the balance task, there is no longer one dominant attention focus source as relatively equal amounts of attention are directed to all categories.

The results of this initial part of the thesis suggest that focusing on multiple sources is the strategy that participants adopt when maintaining upright stance on an unstable platform. The attention focus allocated to internal, external and irrelevant event sources changed as participants gained experience with the balance task. That is,
although the attention focus on internal sources remained the same with practice, there
was more attention directed to irrelevant events or events not related to the balance task
and less attention focus directed to external sources. Although the overall allocation
percentage for the provided categories was determined, the pattern of the attention focus
(i.e., switching between attention focus categories) was not examined. Since participants
self-report multiple attention focus sources when maintaining upright stance on the
platform, the frequency of switching attention focus between these categories during the
continuous balance task may not be the same and may provide insight into attention focus
effects on balance control. However, this is currently beyond the scope of the present
thesis.

5.2. Effect of participant age and specific attention focus instructions on balance,
balance perception, and attention focus measures.

The second objective of this thesis was to investigate the effects of participant age
and specific attention focus instructions on balance measures, self-reported balance
perceptions, and self-reported attention focus measures. Following the series of attempts
of the balance task with no specific attention focus instructions, participants then
performed the balance task with specific attention focus instructions. Research has been
directed toward understanding the effects of attention focus instructions on motor skill
performance and learning, including balance tasks (Wulf, 2007). These studies typically
provide instructions to focus attention on an internal or external source in order to study
the beneficial or negative effects of these instructions on the execution of the skill. In
this thesis, three different sources of attention focus were selected and balance was investigated when participants focused on minimizing movements of the feet (internal), the trunk (internal), or the platform (external).

Reductions in trunk sway, especially in the roll direction, were observed for both young and older adults when instructed to focus on minimizing trunk movements compared to all other attention focus instruction conditions. However, there was no significant improvement in the platform angle variability measure between attention focus conditions. Also, there were no benefits or consequences to balance when focusing attention on the feet or the platform compared to the no attention focus instruction condition. This result was unexpected as the literature would suggest that balance should improve with an external focus of attention for a well practiced task (McNevin, Shea, & Wulf, 2003; Wulf, Prinz, & Hob, 1998; Wulf, Shea, & Park, 2001; Wulf et al., 2003). Furthermore, if instructed to focus on the feet (located in close proximity to the platform or the external focus point), it may have been hypothesized that an internal focus on the feet would augment balance control. It is interesting that the instructions to focus on the trunk resulted in reduced trunk sway. The platform was oriented so that it rotated only in the roll direction, thus, generating greater instability in the roll direction when attempting to control upright standing on the platform. One option that participants may have adopted was to stiffen the trunk which would act to reduce trunk sway. This stiffening of the trunk may not have been reflected in the platform measures which showed no change with instructions to focus on minimizing movement of the trunk compared to the other attention focus instructions.
One of the primary questions addressed in this part of the thesis was related to the effects of specific attention focus instructions on balance control. One novel aspect of this part of the thesis was having participants focus on an internal source located at a distance from the interaction point between the body and the external attention focus source. Thus, the distance between the internal and external sources was increased by having participants focus on the trunk. The distance of the external focus from the body has been shown to improve motor performance and learning of a balance task (McNevin, Shea, & Wulf, 2003). The question may be asked as to whether it is simply the distance from where the body is interacting with the platform (i.e., the interaction point between the feet and platform). Thus, does directing attention to an internal source away from this interaction point (i.e., the trunk) improve balance? The results showed that this was the case as instructions to focus on the trunk resulted in reduced trunk sway especially in the roll direction. Thus, it may be that the distance away from where the internal and external sources are interacting is critical, independent of whether or not the focus is internal or external.

These results suggest that the strategy to focus on the trunk may be the best option available to the CNS to augment balance control. A focus on the larger trunk segment (an estimate of the control of the centre of mass) compared to the feet (an estimate of the control of the centre of pressure which acts to keep the centre of mass within the base of support) may be more beneficial during this whole-body task. This is opposite to the findings of both Wulf and colleagues (2001) and Vuillmere and Nafati (2007), who would suggest that increased attention to an internal source would result in a decrease in performance. This may suggest that a global attention focus for motor skills and in
particular for balance skills is not optimal. Thus, attention focus instructions should consider the nature of the task. This is of particular importance for balance tasks as current literature has only examined continuous balance tasks (Wulf, 2007) and ignored balance tasks which are discrete and serial in nature (e.g., stepping, stepping over an obstacle, climbing stairs, getting up from a chair). Many of these tasks are used to clinically evaluate balance control and are important for independent mobility (Alexander, 1994). One recommendation from the results of this thesis would be that when examining attention focus instructions, one must consider the most appropriate internal and external attention focus source that participants should focus on.

There were no differences in perceived confidence or perceived stability between any of the attention focus instruction conditions. Changes in balance confidence may not have been expected since the task was well-practiced. This could also indicate that attention focus instructions do not influence balance confidence until experienced, as confidence was always assessed prior to performing the balance task. Interestingly, participants were not able to perceive the improvement in stability, as inferred from the reduced trunk sway results when instructed to focus on the minimizing movements of the trunk. Thus, perceptions of stability may have been based on other sources, possibly the platform movement since the platform measures did not improve across any of the instructed focus conditions.

Another important aspect of this part of the thesis was the manipulation check that was done to probe attention focus when provided with specific attention focus instructions. This allowed for an estimation of the compliance of the participants to the instructions. Only one other study that investigated instruction attention focus conditions
completed a manipulation check (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002). In the present thesis, when instructed to focus on a particular source, attention focus on that source increased. However, attention focus was not exclusively directed to that source, for example, only 70% of attention focus was directed to the trunk when instructed to focus on the trunk. This suggests that individuals due to the nature of the whole-body task would not solely focus on one attention focus source (i.e., trying to minimize movements of the trunk) to the exclusion of other sources such as the feet or platform. Instead participants self-reported that there were multiple attention focus sources that they focused on when instructed to focus on just one source. For more discrete balance tasks, attention focus instructions may prove more beneficial as there is less time to shift attention focus away from the instructed source and thus less possibility that attention focus to other sources would interfere with the execution of the task.

5.3. Limitations

There are several limitations associated with the methodology of this thesis that should be considered when interpreting the results of the thesis. One limitation of this thesis is that the results can only be generalized to a continuous balance task and to healthy young and older adults. It is recommended that attention focus effects should be examined in a variety of different types of balance tasks, including those that are more discrete or serial in nature. Also, attention focus effects on balance should be explored in different individuals with balance problems where balance control is challenged and not as automatic. This study was also not designed to investigate motor learning of the balance task so the results are limited to a discussion of changes in balance, balance
perceptions and attention focus with practice and in response to specific attention focus instructions. Although this was the first study to report natural attention focus preference during a balance task, the measures were reliant on self report from the participants. There was no method of objectively quantifying attention focus during the balance task. Also, individual participant preference at trial 16 was not considered in the second part of the thesis when comparing this no attention focus instruction trial to the trials with feet, trunk or platform attention focus instructions. For example, if a participant had an internal feet preference compared to an external platform preference at trial 16 this was not considered when comparing this trial to the instructed attention focus conditions. With this limitation acknowledged, the group means for both young and older adults showed relatively equal distributions between attention focus categories at the last attempt of the no attention focus instruction balance task. This thesis also did not explore the issue of switching between attention focus categories. The pattern of attention focus may be of particular interest and could affect balance control. For example, percentages could be reported as equal between categories but one participant may switch constantly between these attention focus sources whereas another participant may switch very little between the categories. Future direction could examine this issue by using a question to probe the amount of switching that occurs between categories.

5.4. Conclusions

This thesis was the first to compare the effects of attention focus on balance control between young and older adults. The results of this thesis identified typical age-related differences in balance control and improvements in balance with practice but
surprisingly showed no differences in attention focus strategies between young and older adults. This study was also the first to investigate “natural” attention focus allocation during a balance task and showed that there are multiple sources of attention focus employed during a continuous balance task. This study also showed, in contrast to the literature, that an internal focus to a specific source may not be detrimental to performance, and in fact may augment control of that task. Accordingly, the distance from the interaction point of the body with the external source may be critical and may not depend on whether the source is internal or external. Thus, a global attention focus instruction may not be beneficial and the nature of the task should be considered when adopting attention focus instructions for young and older adults.
REFERENCES


APPENDIX A – Statistical results for the 2 x 2 repeated measures ANOVAs
APPENDIX A

Statistical results for the 2 x 2 repeated measures ANOVAs
(Participant Age (2 levels: young and older adults) and
Time (2 levels: trial 1 and trial 16 of the balance task)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Participant Age</th>
<th>Time</th>
<th>Participant Age x Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform Angle Variability</td>
<td>F(1,34) = 65.58</td>
<td>F(1,34) = 76.74</td>
<td>F(1,34) = 0.18</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p = 0.677</td>
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<tr>
<td>Roll Angle</td>
<td>F(1,34) = 17.37</td>
<td>F(1,34) = 23.33</td>
<td>F(1,34) &lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p = 0.998</td>
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<tr>
<td>Roll Velocity</td>
<td>F(1,34) = 6.20</td>
<td>F(1,34) = 28.40</td>
<td>F(1,34) = 0.75</td>
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<tr>
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<td>p = 0.018</td>
<td>p &lt; 0.001</td>
<td>p = 0.394</td>
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<td>Pitch Angle</td>
<td>F(1,34) = 10.15</td>
<td>F(1,34) = 0.06</td>
<td>F(1,34) = 3.61</td>
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<td>p = 0.003</td>
<td>p = 0.802</td>
<td>p = 0.066</td>
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<tr>
<td>Pitch Velocity</td>
<td>F(1,34) = 6.99</td>
<td>F(1,34) = 10.14</td>
<td>F(1,34) = 0.14</td>
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<td>p = 0.012</td>
<td>p = 0.003</td>
<td>p = 0.712</td>
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<tr>
<td>Perceived Confidence</td>
<td>F(1,34) = 0.03</td>
<td>F(1,34) = 5.07</td>
<td>F(1,34) = 0.78</td>
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<tr>
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<td>p = 0.876</td>
<td>p = 0.031</td>
<td>p = 0.384</td>
</tr>
<tr>
<td>Perceived Stability</td>
<td>F(1,34) = 2.02</td>
<td>F(1,34) = 20.73</td>
<td>F(1,34) = 1.21</td>
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<td>p = 0.164</td>
<td>p &lt; 0.001</td>
<td>p = 0.280</td>
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<td>Attention Focus: Feet</td>
<td>F(1,34) = 2.43</td>
<td>F(1,34) = 0.03</td>
<td>F(1,34) = 0.04</td>
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<td>p = 0.128</td>
<td>p = 0.856</td>
<td>p = 0.849</td>
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<tr>
<td>Attention Focus: Trunk</td>
<td>F(1,34) = 0.75</td>
<td>F(1,34) = 0.13</td>
<td>F(1,34) = 0.27</td>
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<tr>
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<td>p = 0.391</td>
<td>p = 0.720</td>
<td>p = 0.609</td>
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<tr>
<td>Attention Focus: Other Body Part</td>
<td>F(1,34) = 0.57</td>
<td>F(1,34) = 0.04</td>
<td>F(1,34) = 0.73</td>
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<tr>
<td></td>
<td>p = 0.454</td>
<td>p = 0.844</td>
<td>p = 0.399</td>
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<tr>
<td>Attention Focus: Internal Sum</td>
<td>F(1,34) = 0.96</td>
<td>F(1,34) &lt; 0.001</td>
<td>F(1,34) = 0.001</td>
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<tr>
<td></td>
<td>p = 0.334</td>
<td>p = 0.997</td>
<td>p = 0.971</td>
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<tr>
<td>Attention Focus: Platform</td>
<td>F(1,34) = 0.05</td>
<td>F(1,34) = 21.10</td>
<td>F(1,34) = 0.42</td>
</tr>
<tr>
<td></td>
<td>p = 0.031</td>
<td>p &lt; 0.001</td>
<td>p = 0.523</td>
</tr>
<tr>
<td>Attention Focus: Irrelevant Events</td>
<td>F(1,34) = 1.27</td>
<td>F(1,34) = 14.34</td>
<td>F(1,34) = 0.30</td>
</tr>
<tr>
<td></td>
<td>p = 0.268</td>
<td>p &lt; 0.001</td>
<td>p = 0.585</td>
</tr>
</tbody>
</table>
APPENDIX B – Statistical results for the 2 x 4 repeated measures ANOVAs
### APPENDIX B

**Statistical results for the 2 x 4 repeated measures ANOVAs**

(Participant Age (2 levels: young and older adults) and Instruction (4 levels: no, feet, trunk, or platform instructions)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Participant Age</th>
<th>Instruction</th>
<th>Participant Age x Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform Angle Variability</td>
<td>F(1,34) = 68.68 p &lt; 0.001</td>
<td>F(3,102) = 1.20 p = 0.312</td>
<td>F(3,102) = 1.63 p = 0.187</td>
</tr>
<tr>
<td>Roll Angle</td>
<td>F(1,34) = 18.71 p &lt; 0.001</td>
<td>F(3,102) = 3.31 p = 0.023</td>
<td>F(3,102) = 1.01 p = 0.390</td>
</tr>
<tr>
<td>Roll Velocity</td>
<td>F(1,34) = 11.57 p = 0.002</td>
<td>F(3,102) = 3.07 p = 0.031</td>
<td>F(3,102) = 0.37 p = 0.777</td>
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<tr>
<td>Pitch Angle</td>
<td>F(1,34) = 18.69 p &lt; 0.001</td>
<td>F(3,102) = 0.80 p = 0.495</td>
<td>F(3,102) = 2.79 p = 0.044</td>
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<tr>
<td>Pitch Velocity</td>
<td>F(1,34) = 13.38 p = 0.001</td>
<td>F(3,102) = 3.37 p = 0.021</td>
<td>F(3,102) = 0.77 p = 0.513</td>
</tr>
<tr>
<td>Perceived Confidence</td>
<td>F(1,34) = 0.05 p = 0.820</td>
<td>F(3,102) = 1.81 p = 0.150</td>
<td>F(3,102) = 0.70 p = 0.557</td>
</tr>
<tr>
<td>Perceived Stability</td>
<td>F(1,34) = 0.71 p = 0.404</td>
<td>F(3,102) = 1.63 p = 0.186</td>
<td>F(3,102) = 0.35 p = 0.788</td>
</tr>
<tr>
<td>Attention Focus: Feet</td>
<td>F(1,34) = 0.24 p = 0.628</td>
<td>F(3,102) = 95.32 p &lt; 0.001</td>
<td>F(3,102) = 0.34 p = 0.795</td>
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<tr>
<td>Attention Focus: Trunk</td>
<td>F(1,34) = 0.61 p = 0.442</td>
<td>F(3,102) = 102.78 p &lt; 0.001</td>
<td>F(3,102) = 0.72 p = 0.543</td>
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<tr>
<td>Attention Focus: Other Body Part</td>
<td>F(1,34) = 0.35 p = 0.559</td>
<td>F(3,102) = 4.25 p = 0.007</td>
<td>F(3,102) = 0.30 p = 0.827</td>
</tr>
<tr>
<td>Attention Focus: Internal Sum</td>
<td>F(1,34) = 0.52 p = 0.477</td>
<td>F(3,102) = 69.72 p &lt; 0.001</td>
<td>F(3,102) = 1.55 p = 0.206</td>
</tr>
<tr>
<td>Attention Focus: Platform</td>
<td>F(1,34) = 0.49 p = 0.488</td>
<td>F(3,102) = 75.98 p &lt; 0.001</td>
<td>F(3,102) = 0.74 p = 0.529</td>
</tr>
<tr>
<td>Attention Focus: Irrelevant Events</td>
<td>F(1,34) = 0.001 p = 0.979</td>
<td>F(3,102) = 13.72 p &lt; 0.001</td>
<td>F(3,102) = 1.41 p = 0.245</td>
</tr>
</tbody>
</table>
APPENDIX C – Research Ethics Clearance
APPENDIX C

DATE: June 25, 2007
FROM: Linda Rose-Krasnor, Chair
       Research Ethics Board (REB)
TO: Allan Adkin, Applied Health Science
    Erika MARTENS-PATON
    Jennifer Huffman
FILE 06-343 MARTENS-PATON
TITLE: Attention Focus Preferences and Balance Control

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: Accepted as Clarified

This project has received ethics clearance for the period of June 25, 2007 to May 25, 2008 subject to full
REB ratification at the Research Ethics Board’s next scheduled meeting. The clearance period may be
extended upon request. The study may now proceed.

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed
and cleared by the REB. During the course of research no deviations from, or changes to, the protocol,
recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must
provide clearance for any modifications before they can be implemented. If you wish to modify your
research project, please refer to http://www.brocku.ca/researchservices/forms to complete the appropriate
form Revision or Modification to an Ongoing Application.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how
these events affect, in the view of the Principal Investigator, the safety of the participants and the
continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community
organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and
clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any
research protocols.

The Tri-Council Policy Statement requires that ongoing research be monitored. A Final Report is required
for all projects upon completion of the project. Researchers with projects lasting more than one year are
required to submit a Continuing Review Report annually. The Office of Research Services will contact you
when this form Continuing Review/Final Report is required.

Please quote your REB file number on all future correspondence.

LRK/bb

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email: reb@brocku.ca
http://www.brocku.ca/researchservices/ethics/humanethics/