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by

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Abstract

Background: The human postural control system, which controls balance, is constantly taking in sensory input to help maintain balance while allowing one to pay attention to their daily activities. Using visual search tasks, we will be able to understand information relevant to how changes in visual input affects one's postural control representative of a more real-life scenario. *Purpose*: With the help eye tracking technology, this study assesses changes in postural control during various visual conditions. Postural control will be measured during such tasks to analyze how it compares to a simple, quiet balancing task. Following Bonnet and Baudry's Functional Synergist Model, I hypothesize postural sway will be larger during free gaze and precise search tasks compared to a fixed gaze condition. *Methodology*: 15 healthy, young adults (22 ± 2yrs, 1.69 ± 0.08m, 75.8 ± 17.0kg, 3 men, 12 women) volunteered to participate in this cross-sectional study. Participants were asked to visit the lab and complete standardized assessments while standing quietly on a force plate: 1) a free gaze condition, 2) a fixed gaze condition (representative of the traditional assessments of postural steadiness), and 3) a precise search task. The precise search task was then analyzed in 2 portions: a "pre" section representative of the individual searching for the hidden object, and a "post" section representing fixation once the individual has found the object. During each condition, three 30 second trials were collected, but only 10 seconds were analyzed for each trial due to the aptitude of some participants finding the hidden object in less than 10 seconds during the precise search task. Sway area was calculated from the force plate data and eye tracking data was collected using TobiiPro eye-tracking glasses to confirm task success. *Results*: Participants displayed 19 ± 21mm of sway area during the free gaze condition, 11 ± 8mm during the fixed gaze condition, 21 ± 31mm while searching for the hidden object, and 9 ± 6mm while fixating on the hidden object. *Discussion*: These results support my hypothesis that postural sway is larger in both free gaze and the searching portion of the precise search task compared to the fixed gaze condition and the fixation portion of the precise search task. Interestingly, sway area was not larger in the free gaze condition compared to the searching portion of the precise search condition; I anticipated that with a larger area to scan, postural sway would increase due to the unlimited range of visual input, but perhaps participants naturally fixated on a specific area without instruction. Understanding the natural tendencies of participants during the free gaze condition and the precise searching task could help clarify the role of postural control in preventing falls as people tend to scan visual input in daily life.

Key words: *Postural control*, *sway area*, *visual input*, *gaze*

Introduction and Background

Although commonly overlooked by many during daily life, human postural control (also referred to as balance) is one of the body's most complex systems. In its entirety, balance relies on three main sensory input systems: visual, vestibular, and somatosensory (Prieto et al., 1996). Visual input allows us to recognize where we are relative to our surroundings and aids in adapting our postural control to respond appropriately. For example, Lee and Aronson's moving room paradigm developed in the 1970's demonstrated that human infants fall down when placed in a room with walls that could move (1974). This clearly illustrated that their visual system recognized the walls were moving causing them to adjust their balance, which made them fall down in expectation that the entire room was shifting forwards or backwards. Similarly, our vestibular system provides information regarding the position of our head, as well as the motion of our head (Gaerlan, 2010). Finally, our somatosensory system provides information regarding the locations of our limbs relative to the environment around us, as well as providing feedback about the surface we are standing on (Gaerlan, 2010). Measuring postural steadiness characterizes the dynamics of the postural control system while balancing during quiet standing (Prieto et al., 1996). These measures of postural steadiness are most often taken as participants are standing quietly, alone, and with their eyes fixated straight ahead at a blank wall or a fixed target. While quiet standing can be beneficial to understanding one's postural control, this artificial environment loosely reflects how one's postural control system operates in "real world" situations.

As the roles of the vestibular and somatosensory systems are important in understanding balance, changes to visual input are rarely explored beyond a comparison of eyes open vs. eyes closed. Although it is beneficial learning the adaptations of the postural control system during an eyes closed condition, a complete assessment of one's vision requires more than simply asking them to close their eyes. Human vision is a combination of both central, or foveal, and peripheral vision working to integrate signals and extrapolate information from the world around us (Stewart et al., 2020). Foveal vision refers to what you are looking at directly, such as the blank wall you may fixate on during the act of quiet standing, as opposed to peripheral vision, which refers to the ability to see and scan your surroundings without moving your head or re-focusing. Studying foveal visual input with regard to the postural control system is one of the most common research conditions. But, when studying postural control in response to visual stimuli in one's periphery, research shows that postural sway decreases revealing that peripheral vision plays an essential role in maintaining stable quiet standing (Berencsi et al., 2005). Understanding the role of peripheral vision in one's postural control system can bring awareness to the unpredictability of one's day-to-day environment. For example, someone living in New York City may stop and pay attention to an ad being played on a Times Square screen, but they must also try to be aware of the people moving around them as they stand still. It is nearly impossible to fully isolate and study one's postural control and visual systems separately, but the use of eye tracking technology allows for analysis of gaze data and center of pressure data simultaneously. Eye tracking technology allows for the quantification of one's visual behaviors, or in other words, allows researchers to determine when, where, and how long someone has been looking at a particular area.

One of the newest alterations to the input of sensory information studied has been changing attentional demands required by participants; after having participants watching and playing a video game, research done by DeCouto et al. revealed that greater mental effort required in playing the video game led to an increase in postural sway (2021b). These results imply that when participants were required to focus their attention on a primary task, balancing developed into a secondary task that was not as tightly regulated as simply balancing during quiet standing (DeCouto et al., 2021a). The connection between one's visual input system and postural control has been explored through what is known as The Functional Synergist model, and this model emphasizes the functional capabilities of the central nervous system to perform postural and visual behaviors in a unified way (Bonnet & Baudry, 2016). Bonnet and Baudry found that it may be impossible to fully understand visual and postural behaviors in an isolated way, so closing the gap between each field of research could better explain how indviduals succeed in search tasks when upright (2016). Understanding the relationship between visual input and postural control can reveal information relevant to preventing falls in unanticipated events, such as missing the last step of the staircase, (Dakin & Bolton, 2018) or understanding the relationship between postural control and injury prevention in populations that may require a balance training program, such as in patients improving balance performance after a stroke, (Lubetzky-Vilnai & Kartin, 2010). Balance training often includes simple and familiar exercises, like the single-leg stand and is used with special populations such as elderly patients, patients with neurological disorders, and even patients who suffer from arthritic conditions.

As patients begin to see improvements in their balance, activities of daily living seem to come easier; it's often overlooked at how simple it seems to put on your shoes in the morning or walk down to your mailbox, but for those special populations, normal activities of daily living take nearly all the energy they have. In a study performed by Lubetzky-Vilnai & Kartin, they found that "intensive balance training for 2 to 3 times per week may be sufficient" in improving the balance of patients in the acute stage of stroke (2010). Another study introduced patients with multiple sclerosis to a 12-week balance program and researchers found that balance training should include a theoretical framework and focus on “systematic manipulation of the primary constraints on the control of dynamic equilibrium” (Kasser et al., 1999). Kasser et al. also recommended that such training programs focus on varied sensory inputs (1999) in hopes of exposing patients to balance “challenges,” rather than simple, quiet balancing tasks seen in most labs.

Knowing that both foveal and peripheral vision are intricately related (Stewart et al., 2020) further supports the idea that traditional laboratory assessments of postural steadiness are lacking in daily applications; when a participant’s balance is analyzed through a simple fixed-gaze condition, only the relationship between balance and foveal vision is being examined. While this is important to understand the basic relationship of one’s balance when asked to fixate on a point on the wall, it is highly unrealistic that they might be asked to quietly fixate on a point in their daily life for any particular length of time. Life and the world surrounding us is constantly moving; as one college student is walking to class, they are navigating the cars driving on the street to their left, as well as navigating the other students walking to their right. All while taking in the information regarding to what is around them, this student must still be paying attention to what they are seeing in front of them with an occasional fixation on maybe that one odd brick on the side of a building. Fixations do occur in real-world scenarios, but rarely will humans be faced with the need to quietly fixate on a point in such an environment as a clean, effectively lit laboratory.

This study was designed with the goal of exploring postural steadiness in a more “real-world” environment; balance was measured and analyzed during a free-gaze condition, a fixed gaze condition, and a precise search task condition. The fixed gaze condition was included to represent traditional assessments of postural steadiness, but it was critical to introduce conditions that would primarily affect visual input. First, a free-gaze condition was simply introduced as a chance for participants to look at the wall ahead of them while maintaining balance. Although this task required no other attentional demands, it assesses one's natural tendency to scan a large area while maintaining balance. People scan large areas of visual input on a daily basis, such as someone standing in front of their closet deciding which shirt to wear to work that day. And then, participants were asked to take part in a dual-task scenario which involved a precise searching task displayed on a screen in front of them. Including a precise searching task represents one's capability to follow a second set of directions ("find the hidden object") while maintaining balance. Imagine the cognitive requirements asked in what seem to be simple daily tasks, such as grocery shopping. Yes, you are scanning the aisles as you were when deciding what to wear for work, but you are also following a set of second directions, i.e., that grocery list on your phone. It may not seem as straight-forward as "find the hidden object," but most people take the time to search for that specific brand of mayonnaise or coffee they prefer. As one takes the time to go through that list, making sure they get each and every item, they are also maintaining balance while paying attention to the other shoppers around them.

Determining patterns to what young, healthy participants were naturally doing in each condition provides an opportunity for further studies or exercise training programs to apply fall prevention strategies to special populations that might not feel comfortable in their ability to navigate their world on a daily basis. Thus, the purpose of this study was to assess changes in postural control during various visual tasks. Postural control was measured during such tasks to analyze how it compares to a simple, quiet balancing task. Following Bonnet and Baudry's Functional Synergist Model, I hypothesized that postural sway would be larger during free gaze and precise search tasks compared to the fixed gaze condition.

Methods

Participants: A total of 15 participants (3 male and 12 female) between the ages of 18 and 30 years old were recruited from the University of Arkansas campus for this study. Participants must have had no history of diagnosed neurological or orthopedic problems that do, or could, impair balance function and general mobility. All participants were to be able to stand unassisted for at least 20 minutes at a time without rest to ensure they could complete the assessments safely and comfortably. Participants were required to have normal or corrected-to-normal vision using contact lenses for the eye tracking technology to record the data. Participants must have been capable of providing informed consent and complying with the trial procedures. This study was approved by the University's Institutional Review Board prior to any study activities, and participants were consented to the study prior to participating in any study activities.

Protocol: Participants were invited to the MOVE lab for a single study visit where their postural control was measured and analyzed using Nexus Software (Vicon Motion Systems, Oxford, UK) and force platforms embedded in the lab floor (AMTI, Watertown, MA). Participants were asked to complete each task while wearing TobiiPro Glasses 3 (Tobii Technology, Inc., Reston, VA), an eye tracking technology to confirm task success. Participants completed three, 30 second balance conditions in a standardized order: 1) a free gaze condition with no specific instructions for where to look, 2) a fixed gaze condition (representative of traditional assessments of postural steadiness) where participants were asked to look at an "X" on the wall 5 meters in front of them, and 3) a precise search task condition (representative of a dual-task paradigm) where participants were asked to "find the hidden object" on a 46-inch television positioned 1.5 meters in front of them.

Data Analysis: The average movement of the center of pressure assessing postural stability was measured and analyzed using the data collected from the force platforms. This data was processed using custom Matlab software (Mathworks, Natick, MA) to resample the center of pressure data (50 Hz) and calculate sway area, the amount of movement covered by one's center of pressure over time (Prieto et al., 1996). Sway area was determined for all three standardized conditions with the precise search task condition being analyzed as two sections: a "pre" and a "post" section; the "pre" section of this condition is representative of the individual scanning visual input, as they would scan for something specific in their daily life, and the "post" section was analyzed as more fixed gaze data once they had found the hidden object. Although each condition was collected in 30 second trials, 10 seconds of data became the threshold for analysis. While working with young, healthy participants, there were instances where a participant found every hidden object in less than 10 seconds; I felt the most confident in inputting and analyzing at least 10 seconds of data, so some data was unable to be analyzed due to the lack of at least one trial lasting 10 seconds or longer.

Results

A total of 15 participants were recruited to participate in this study, but due to protocol changes, data from only 13 participants was able to be used for analysis. Along with protocol changes, only 10 of those 13 participants' data was analyzed due to the aptitude of 3 participants finding the hidden object in less than 10 seconds for each trial.

CONDITION	MEAN	STANDARD DEVIATION
Free Gaze Condition	19 mm	± 21mm
Fixed Gaze Condition	11 mm	± 8mm
Precise Search Task – "Pre"	21 mm	± 31mm
Precise Search Task – "Post"	9 mm	± 6 mm

Fig. 1 *Average sway area computed*

Stabilograms were created of each participant and their respective values of postural sway (Fig. 1); a stabilogram is a graphical representation of an individual's sway area measured during standing balance.

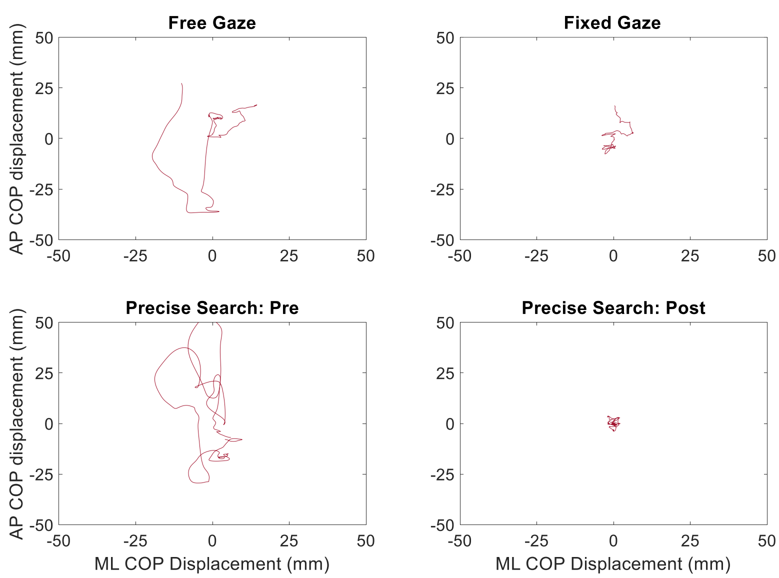

Fig. 2 *Stabilograms from a representative participant illustrate characteristic changes in sway area.*

Discussion

The purpose of this study was to compare postural control sway area during various visual tasks. I hypothesized that postural sway would be larger during the free gaze and precise search tasks compared to the fixed gaze condition. The data from this study supports the Functional Synergist Model (Bonnet & Baudry, 2016); postural sway increased during the free gaze and “pre” section of the precise searching task compared to the fixed gaze condition and the “post” section of the precise searching task.

Interestingly, as the amount of area the participants were asked to scan increased, the amount of postural control sway area decreased. The largest synergy, or connection, between the individual’s central nervous system occurred during the free gaze task; the Functional Synergist Model found that the strongest connection should occur during precise visual tasks (Bonnet & Baudry, 2016), but the data from this study revealed that the strongest connection between one’s central nervous system and visual behaviors occurred when not given any additional instructions, or cognitive engagements, beyond to maintain balance (DeCouto et al., 2021b). This might confirm that humans have a natural tendency to fixate on a certain point without explicit instructions. Because the participants of this study were young and healthy indviduals, further studies should assess the natural tendencies of special populations and their postural control system when faced with various visual tasks. This study provides evidence of patterns found in how young, healthy indviduals manage to maintain balance while completing various visual tasks. Such patterns could serve as guidelines for healthcare providers, or even caregivers, in implementing safer and more effective strategies in balance training programs designed for special populations. It may be commonly overlooked in everyday life, but having control of your own body and postural control system gives special populations, such as patients with multiple sclerosis or patients recovering from a stroke, the chance to feel as confident as the world around them.

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