HUMAN VISION IS OFTEN TAKEN FOR GRANTED: CONSEQUENCES OF VISUAL GUIDANCE ON BALANCE CONTROL

Franklin N. Glozah*

Abstract:

The ability forhumans to control our balance is significantly affected by our eyes being either opened or closed. This study investigatedthe effects of human visual guidance on balance control, particularly when standing upright. Seven healthy individualsbetween the ages of 20 to30 yearsparticipated in this experimental study. An instrumented force platform was used to measure the time-varying displacements of the Center of Pressure (COP) under each participant's feet during quiet standing. The participants were tested under eyes-open and eyes-closed conditions in a repeated measures design. The average standard deviation of COP trajectories per condition wasanalysed with a paired samples t-test. The results pointed to the fact that visual guidance significantly influences the performance of balance control i.e. eyes-open balance control was significantly better than eyes-closed balance control. The key implication of this experimental finding is that when individuals are standing upright with their eyes closed, evenmomentarily, their balance and postural control is significantly altered and affected. The results indicate that visual guidance, based on eyes-open or eyes-closed conditions is a significant determinant of how well we are able to control our balance whether standing upright or walking.

Key words: Visual guidance, Balance control, Force platform, Centre of pressure, students

* PhD, Department of Psychology and Human Development, Regent University College of Science and Technology, Ghana

Introduction:

Balance is vital to normal everyday life activities such as getting out of a chair and walking, bending over to put your shoes on, driving a car or going to the market to buy foodstuff. In essence, everything we do as human beings in our daily life, whether for work or leisure requires balance control, and most of the time we do not have to think about it. Balance is construed as the ability to maintain the body's center of mass over its base of support. If balance problems develop, they may cause profound disruptions in our daily life. In addition to increased risk for falls, balance disorders can shorten our attention span, disrupt normal sleep patterns, and/or cause excessive fatigue [1, 2].Human balance control involves several different sensory modalities such as visual and vestibular systems. In order to understand better the relative contribution of some of these physiological systems in the maintenance of balance control, experimenters remove or modify one such modality and then examine the resultant performance of a subject's balance control.In the past, the visual system as a sense modality has been used in several studies to observe its effects on balance control focusing on visual guidance whiles participants stood on their feet [3, 4, 5].The present study however sought to examine balance control differences ineyes-open and eyes-close visual guidanceconditions on only one foot (non-dominant). A comparison of our balance control performance on a non-dominant foot whiles our eyes are open or when our eyes are closed couldgive more insight to our balance controlperformance since there are instances where our eyes are closedtemporarily whether standing or walking.

Human Vision and Balance Control

Balance control in humans has been studied extensively over the years. Most studies focus on balance control whiles an individual is standing upright, sitting, and walking[3, 4, 6, 7, 8, 9]. In addition, many previous research studieshave used experimental methods similar to the method used in the present study. Previous studies have also focused attention on visual guidance and its effect on balance control [10] akin to the objectives of the present study. For example, [4]have foundin their study with 25 subjects that the amplitude of postural sway increases when people's eyes areclosed. As expected, 13 of their subjects experienced two-dimensional long-term effective diffusion coefficients under eyes-closed condition that were larger than those under eyes-openedcondition. However, for the remaining 12 subjects, the reverse situation was true, wheretwo-dimensional long-term effective diffusion coefficients under eyes-closed condition were, in fact, smaller than those under eyes-open conditions.

[11]investigated the postural control in a homogeneous population of 50 unilateral vestibular deficient patients. It analyzed the postural deficits of the patients before and after surgical treatment (unilateral vestibular neurotomy) of their diseases and it focused on the visual contribution to the fine regulation of body sway. Static posturographic recordings on a stable force-plate were done with patients with eyes open (EO) and eyes closed (EC). Body sway and visual stabilization of posture were evaluated by computing sway area with and without vision and by calculating the percentage difference of sway between EC and EO conditions. Ménière's patients were examined when asymptomatic, 1 day before unilateral vestibular neurotomy, and during the time-course of recovery. Data from the patients were compared with those recorded in 26 healthy, age- and sex-matched participants. Patients before neurotomy exhibited significantly greater sway area than controls with both EO (+52%) and EC (+93%). In both populations, 54% of the subjects significantly increased their body sway upon eye closure, whereas 46% exhibited no change or significantly swayed less without vision.

[12]Examined the effect of eye closure on subjects balance control. Subjects stood on a 10-cm thick piece of foam rubber, and their balance control measure recorded. Their results demonstrated that masking the sensory inputs coming from the mechanoreceptor of the sole (by standing on the compliant surface) and/or blocking visual inputs increased the total sway when they closed their eyes much more than that of the control participants (Open eyes).

[8]Conducted a study similar to this present study where theyreported that visual information on the position and movements of the body in space (when such information is accessible) plays a significant role in the control of the vertical stance in humans. They added that a stabilizing effect of vision on the stability of the vertical stance of humans is provided by the effects of at least two components, by a nonspecific influence (related, e.g., to perception of illumination), and by the involvement of specific visual mechanisms controlling postural reactions in the course of their performance.

[13]Over intervals less than about one second, COP samples are positivelycorrelated, meaning that the COP moves continuously inone particular direction. Over longer time intervals,COP samples are negatively correlated, meaning that displacementstend to be reversed. This persistence and discontinuation in COP behaviour has been interpreted as mechanisms ofeyes-open and eyes-closed control of balance [3]. The eyes-open regime allows progressive departuresfrom an equilibrium position over short time intervals;the eyes-closed regime corrects for such departures in the long term once these departures exceed a thresholdmagnitude.

From the above review of literature, it is pertinentto hypothesize thatthere will be a significant difference between the two visual conditions such that subject's balance control with their eyes open will be significantly better than their balance control when their eyes are closed.

Method:

Design

Balance control was measured for both closed eyes and opened eyes, usingrepeated measures design. Every subject experienced both conditions (i.e. eyes open and eyes closed) alternatively in sixteendifferent trials (eight each).

Participants

Four healthy males and three healthy female participants between 20 to 30 years old participated in the study. Participantswere randomly selected from two masters programme courses at the Norwegian University of Science and Technology. Informed consent was obtained from each participant prior to his or her participation in the experiment. According to all the participants, none of them had a history of gait, postural and skeletal problems.

Materials and Procedure

A force plate (platform) was the main equipment used in the experiment to measure the time-varying displacement of the center of pressure (COP) under a subject's foot. A desktop computer connected to the force plate recorded each subject's balance. Mattresses were put around the force plate to protect the subjects in case any of them fell down. A timerwas also used to time the subjects.

Each participant was instructed to stand in an upright position on the force plates. In order to make the task difficult and to observe major differences between the two conditions, subjects were made to stand on one foot (the non-dominant foot). Thus, each participant prior to standing on the force plate was asked, “Which foot do you feel comfortable standing on”. Based on the answer given, the subject was then made to stand on the foot he/she considered non-dominant. Each trial lasted for a period of 30 seconds and the force plate data were sampled at a frequency of 100Hzyielding around 2900 data points per trial. However, the first 2500 data points were used in order to ensure uniformity between subjects and between the experimental conditions. The intention was to measure the degree of deviation from the center of pressure trajectories only. Accordingly,higherscores indicated poorer balance control of participants.

In a typical trial, participants wereasked to place their arms anyhow to maintain balance, provided theystood upright with the non-dominant footon the force plate. The dominant foot should be lifted upso that it does not touch the force plate. During testing, the participants were made to stand on the force plate without footwear.Sixteen trialswere conducted for each participant, eight while eyes are closed and the other eight while eyes are opened.In order to ensure impartialityand objectivity in the experimental conditions, the participants had to alternate or switch between trials. For example, the first trial was done eyes opened, the second trial done eyes closed,alternativelyuntil the sixteenth trial. In other words, the odd numbered trials were for eyes opened whiles the even numbered trials were for eyes closed for each participant.Participants did not really have a fixed time within which to restafter a trial because they were told to prompt the experimenter whenever they were ready for the next trial. The rest period therefore depended on the participants themselves.

Figure 1.An image of a participant on the force plates depicting how subjects stood for the trials.

The Pythagoras theorem:$h = \sqrt{(x^2 + y^2)}$was used to calculate the COP trajectories (x and y) of each of the 3000 data points yielded per trialto obtain the hypotenuses.

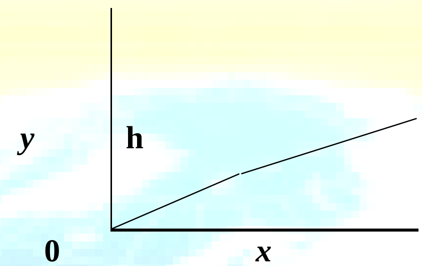

Figure 2. (*h*)represents the hypotenuse of the COP trajectory *x* and *y*

The standard deviation of each trial was then calculated from the 2500 hypotenuses obtained.As each experimental condition had eight trials each (eight standard deviations), the mean for each condition was calculated from the eight standard deviations for each condition.All the means of the standard deviations were then subjected to statistical analysis (i.e. a paired sample t-test).

3.Results

This study hypothesised that there will be a significant differences in balance control in favour of eyes open condition.

Table 1: Means and Standard deviations of Scores on Balance Control

Visual Guidance	Mean	SD
Eyes-Open Condition	.007	.002
Eyes-Close Condition	.014	.009

From table 1 above, it can be observed that subjects had a better balance control under eyes-open condition than under eyes close condition. It is worth remembering that, balance control was measured with the degree of deviation from the center of pressure trajectories. Hence, higher scores indicate poorer balance control.

Table 2: Paired sample t-test showing paired differences between eyes open and eye closed conditions

Paired Sample	*t*	*df*	*p*
Eyes open condition – Eyes close condition	-2.423	6	0.26*

* *p*< .05 (one tailed)

From table 2 above, it can be observed that there is a significant difference between eyes open and eyes closebalance controlwith subjects having a better balance control under eyes-opencondition than under eyes-closed condition.

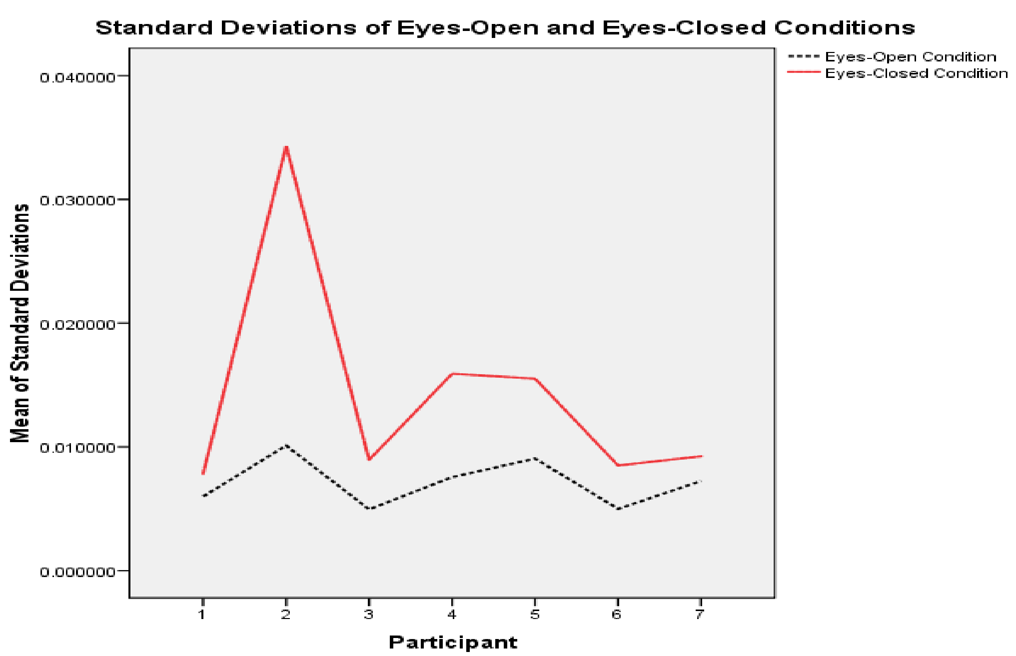

Figure 3.

The line graph above shows that balance control of all the subjects was better for eyes open condition than for eyes closed condition. In other words all the subjects deviated significantly on the force plates when their eyes were closed than when their eyes were open. The highest deviation (poorest balance control),was observed by the second subject under eyes close condition whiles the least deviation (best balance control), was observed by the third subject under eyes open condition.

Discussion:

The primary aim of this study was to examine human balance control when our eyes are closed. This is in view of the fact that our eyes may close briefly when walking or standing, especially when the winds are blowing heavily. The result pointed to the fact that human balance control depended significantly on visual guidance, whether our eyes are closed or open. The results indicate that visual guidance plays an important, direction specific, role in the control of balance.This finding is consistent with previous studies on visual guidance and gait or balance control [12, 14, 15].When individualshavetheir eyes open, they are likely to maintain a better balance than when their eyes are closed, indicating thateyes-open visual guidance produces a betterbalance control than eyes-closed visual guidance in the maintenance of good balance. This is may be because when there is an obstruction in people's vision it may lead to realignment of body and headposture thereby altering their posture [16, 17, 4]. The results of the current study is also consistent with[12]who examined the effect of eye closure on subjects balance control which fundthat visual inputs increased the total sway when subjects closed their eyes much more than that of the control participants(Open eyes), and this may be influenced by the level ofillumination ofa room or space.

[13]suggests that the displacements of eyes open balance control is better than eyes closed balance control. The standard deviationsbetween vision (eyes open and eyes closed) and scaling region has characterized previous research, with deviation being less in both the short and long term for eyes open than for eyes closed[17]. The present results could also mean that whenindividuals are walking, they will most likely lose their balance during brief periods when

their eyes are closed at the same time as they have one foot hanging about to take the next step. This phenomenon is well depictedin this study as subjects had one foot up under both eyes open and eyes close conditions. This supposedly made balance control difficult and epitomises a real life situation where there may be a momentary close of eyes.

It can be generalised from the results of this study that, people with poor vision will most likely have a poorer balance control compared to those with normal vision during upward stance. This is because there are brief periods during walking when our eyes may be closed momentarily due to heavy winds, dust,and so on [17, 18].

Conclusion:

Participants performed better under eyes-open visual guidance than eyes-close visual guidance in their performance of balance control suggesting that people's visual guidance is very important if they are to maintain a correct upright posture when walking or standing[14, 19, 20, 21, 22, 23].It will be interesting if future or further studies examine the significance of the upper limbs (arms) positionon human balance control under visual guidance. Similarly, an investigation into the effect of visual guidance on balance control during walking will be remarkable, as this was not taken into consideration in the present study.

Acknowledgement

Many thanks to the students and staff of the Norwegian University of Science and Technology for their varied assistance and facilitation of the study.This study was supported by the Norwegian Education Scholarship (Quota) programme. Thanks to Magnus for manuscript review.

References

[1] Angelaki, D., and Hess, B. (2005). Self-motion-induced eye movements: effects on visual acuity and navigation. *Nature Reviews Neuroscience*, 6, 966-976.

[2] Horak, F.B., Shupert, C.L., and Mirka, A. (1989).Components of postural dys-control in the elderly: a review.*Neurobiology of Aging*, 10, 727-738.

[3] Collins, J. J., and De Luca, C. J. (1993).Open-loop and closed-loop control of posture: a random-walk analysis of center-of-pressure trajectories. *Experimental Brain Research*, 95, 308-318.

[4] Collins, J. J., and De Luca, C. J. (1995). The effects of visual input on open-loop and closed-loop postural control mechanisms. *Experimental Brain Research*, 103,151-163.

[5] Rougier, P., and Farenc, I. (2000).Adaptative effects of loss of vision on upright undisturbed stance.*Brain Research*, 871, 165-174.

[6] Rougier, P. (2003). Visual feedback induces opposite effects on elementary centre of gravity and centre of pressure minus centre of gravity motions in undisturbed upright stance. *Clinical Biomechanics*, 18, 341-349.

[7] Rougier, P. (2004).Optimizing the visual feedback technique for improving upright stance maintenance by delaying its display: behavioral effects on healthy adults.*Gait and Posture*, 19,154-163.

[8] Smetanin, B. N., Popov, K. E.,andKozhina,G. V. (2006).Dependence of Joint Stiffness on the Conditions of Visual Control in Upright Undisturbed Stance in Humans. *Neurophysiology*,38(2), 157-166.

[9] Smetanin, B. N., and Kozhina, G. V. (2007).Postural Reactions of Humans in Upright Stance: Dependence on Different Visual Conditions and the Level of Stiffness in the Ankle Joints. *Neurophysiology*,39(2),146-153.

[10] Buckley, J., MacLellan, M., Tucker, M,,Scally, A., and Bennett, S. (2007). Visual guidance of landing behaviour when stepping down to a new level. *Experimental Brain Research*, 1096-1098.

[11] Lacour, M., Barthelemy, J., Borel, L., Magnan, J., Xerri, C., Chays, A., and Ouaknine, M. (1997).Sensory strategies in human postural control before and after unilateral vestibular neurotomy. *Experimental Brain Research*, 115, 300-310.

[12] Sahlstrand, T., Ortengren, R., and Nachemson, A. (1978).Postural equilibrium in adolescent idiopathic scoliosis.*ActaOrthopScand*, 49, 354–365.

[13] Riley, M. A., Wong, S., Mitra, S., and Turvey, M. T. (1997).Common effects of touch and vision on postural parameters. *Experimental Brain Research*, 117, 165-179.

[14] Zietz, D., andHollands, M. (2009). Gaze behavior of young and older adults during stair walking. *Journal of Motion Behaviour*, 41, 357-366.

[15] Kesler, A., Leibovich, G., Herman, T., Gruendlinger, L., Giladi, N., andHausdorff, J. (2005). Shedding light on walking in the dark: the effects of reduced lighting on the gaitof older adults with a higher-level gait disorder and controls. *Journal of NeuroengineeringRehabilitation*, 2,27.

[16] Buckley, J., Heasley, K., Scally, A., and Elliott, D. (2005).The effects of blurring visiononmedio-lateral balance during stepping up or down to a new level in the elderly.*Gait and Posture*, 22, 146-153.

[17] Buckley, J. G., MacLellan, M. J., Tucker, M. W., Scally, A. J., Bennett, S. J.(2008).Visual guidance of landing behaviour when stepping down to a new level.*Experimental Brain Research*,184(2), 223-32.

[18] Chapman, G., andHollands, M. (2006). Evidence for a link between changes to gaze behaviour and risk of falling in older adults during adaptive locomotion. *Gait and Posture*,24, 288-294.

[19] Heasley, K., Buckley, J., Scally, A., Twigg, P.,and Elliott, D. (2004).Stepping up to anew level: effects of blurring vision in the elderly.*Invest Ophthalmology: Vision Science*, 45, 2122-2128.

[20] Cromwell R., Newton, R.,and Forrest, G. (2002). Influence of vision on head stabilization strategies in older adults during walking. *Journal of Gerontology: Medical Sciences*, 57A, 442-448.

[21] Osler, C. J., and Reynolds, R. F. (2012) Postural reorientation does not cause the locomotor after-effect following rotary locomotion. *Experimental Brain Research*, 220, 231-237.

[22] Reynolds, R. F.,and Day, B. L. (2005).Visual guidance of the human foot during a step.*Journal of Physiology*, 1, 677-84.

[23] Bauby, C.,andKuo, A. (2000).Active control of lateral balance in human walking. *Journal of Biomechanics*, 33, 1433-1440.