POSTURAL RESPONSE TO VARIED VELOCITY AND DURATION VISUAL PERTURBATIONS IN VIRTUAL REALITY

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The purpose of this study was to examine the center of pressure response to visual perturbations presented in virtual reality (VR). The visual perturbations were an anterior or posterior displacement that varied in velocity (1m/s, 3m/s & 5m/s) and duration (0.6s, 1s and 2 s). The center of pressure distance travelled was measured in the anterior-posterior direction while subjects balance on one foot. Four subjects were evaluated in the pilot. A t-test was used to examine the pooled effect of the perturbations. The visual perturbation significantly increased the distance the center of pressure travelled (p = 0.041). A 2-way repeated measures ANOVA was used to assess the specific affects velocity and duration. The main effect for duration was significant (p =0.014). Duration of the visual perturbation appears to be the most important component to challenge postural control.

KEYWORDS: virtual reality, postural control, balance, perturbation.

INTRODUCTION: Maintaining balance and postural control is essential to sport performance (Edis, Vural, & Vurgun, 2016) and reducing the risk of falling (Horak, 2006). Visual, vestibular, and proprioceptive sensory information is gather to determine the status of the body and environmental conditions (Ernst & Bülthoff, 2004; Eysel-Gosepath, McCrum, Epro, Brüggemann, & Karamanidis, 2016). This sensory information is integrated and appropriate responses occur in a coordinated manner to maintain postural control. Coaches and conditioning specialists perturb balance in order to train individuals to respond to sudden changes in conditions or recovery from injury (Arundale, Cummer, Capin, Zarzycki, & Snyder-Mackler, 2017). Researchers may perturb balance in order to understand how individuals respond and what factors are important in this response (Sibley, Beauchamp, Van Ooteghem, Paterson, & Wittmeier, 2017). This allows the development of new coaching techniques and the development of protocols that can reduce the risk of injury. Particularly injuries related to falling.

Postural control can be perturbed using physical mechanisms, like pulleys or slip platforms (Yang, Saucedo, & Qiao, 2018), or by disrupting sensory inputs like fatiguing involved musculature, stimulation of the vestibular system (Scinicariello, Eaton, Inglis, & Collins, 2001) or manipulating the visual field (Lee & Aronson, 1974). Manipulating the visual field is particularly difficult. It requires the construction of large swinging structures, or projection of large images across walls. However, with the development of new immersive virtual reality (VR) technology, the same perturbations can be accomplished using only lines of code and a head mounted display. We previously found that postural control was reduced when exposed to anterior-posterior visual perturbation in virtual reality but the magnitude of the response appeared to be related to the velocity and duration of the perturbation.

The purpose of this study was to examine the center of pressure response to visual perturbations that varied in velocity and duration presented in virtual reality. We hypothesized that lower velocity and higher duration perturbations would increase the distance travelled by the center of pressure.

METHODS: Four healthy male adults participated (81.2 kg ± 7.5, 26.7 years ± 4.2) in the pilot experiment. For the experiment, subjects stood barefoot on a Bertec force plate (Bertec Corporation, Columbus, Ohio) sampling at 1000Hz with custom LabVIEW software (LabVIEW v2017, Austin, TX) and down sampled to 200Hz. The subjects wore an Oculus Rift VR headset (Oculus VR). The VR environment consisted of a corridor with a width of 3m, a height of 2.5m, and was 35m long (Fig 1). The VR environment was developed with Unity3D software (Unity Technologies v2017.2, San Francisco, CA). Subjects stood barefoot with one foot on the force plate facing the computer monitor in the lab and a closed wall of the corridor in VR. A target was place on the far end of the corridor for subjects to focus on.

The subjects were not aware of when a perturbation would occur. The experimenter initiated a perturbation by pushing a key. Ten seconds of data were collected before the perturbation and 10s after. When the key was pressed the room would displace either anteriorly or posteriorly, at 1m/s, 3m/s, or 5m/s for 0.6s, 1s or 2s. Two trials were collected for each condition for a total of 36 trials. Our previous study showed no large effect of perturbation direction but the two directions of the perturbations was maintained to prevent the subjects from habituating to the visual perturbation. The 'time zero' (T_0 = 0s, moment the key is pressed) was used to align all trials.

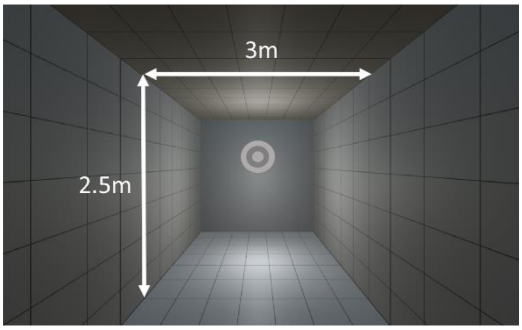

Figure 1: Corridor simulated in VR

The center of pressure (COP) in the anterior-posterior direction was calculated from ground reaction forces and moments using previous literature (Winter, 2005). Total distance travelled by the COP was used to assess changes in balance stability. Total distance travelled was determined as $\Sigma|COP_{n-} - COP\text{-}_{n\text{-}1}|$, where n is any given anterior-posterior COP data point. Data were low pass filter with a zero lag 2[nd] order Butterworth filter at a cut off frequency of 20Hz. The total distance travelled was calculated for 5s before time zero and 5s after time zero. The average of 4 trials was calculated for each condition.

To ensure the perturbations were affecting postural control as we had previously observed, a paired t-test was conducted to compare the baseline distance travelled by the COP (5s before the perturbation) to the distance travelled 5s after the perturbation. To examine the specific effects of the velocity and duration of the perturbation, we conducted a 2-way repeated measures ANOVA on the change score between baseline measurement (5s before perturbation) to after the visual perturbation. Alpha was set to 0.05 for all tests and all data are reported as mean ± standard deviations. A Bonferroni adjustment was performed for all follow up comparisons if a significant effect was found.

RESULTS: Subjects demonstrated significantly increased COP distanced travelled after the visual perturbations (p = 0.041) (Fig 2).

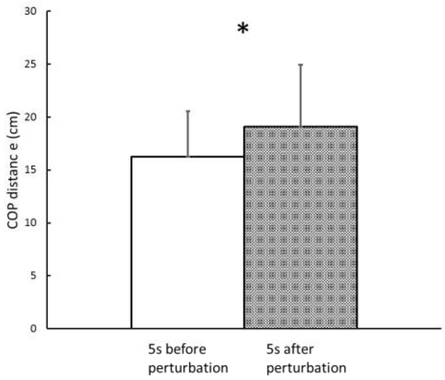

Figure 2: Distance travelled by COP before and after the visual perturbation. * $p < 0.05$

The analysis of the specific effects of velocity and duration (Fig 3) indicated that the interaction effect was not significant (p = 0.53), nor for the main effect for velocity (p = 0.2) but was significant for duration (p = 0.014). However, partial eta squared for velocity was 0.42 (Fig 3).

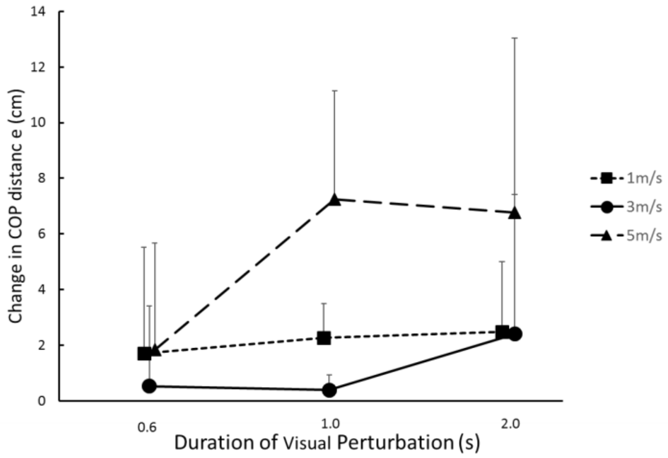

Figure 3: Effects of velocity and duration on change in COP distance travelled.

DISCUSSION: We hypothesized that lower velocity and higher duration perturbations would increase the distance travelled by the center of pressure. We found that overall, the visual perturbations did increase the total distance travelled by the COP (Fig 2). This is similar to what we observed when we had visual perturbation at a constant displacement length (3 meters) but the duration of the exposured to visual perturbation differed. However, our follow up analysis to determine the specific effect of the velocity and duration demonstrated that duration of the visual perturbation is the most influencial in challenging postural stability. However, the result is not conclusive at this point.
The interaction effect and main effect for velocity were not significant. However, the effect sizes for each were small to medium, 0.22 & 0.42 respectively. No follow up tests on the effect of duration demonstrated statistical significance. This indicates that the experiment, with only 4 subjects, is statistically under powered. The results are promising at this point. As with our previous study, we can say that anterior-posterior visual perturbations in virtual reality are effective in reducing postural stability. Anecdotal observations from this study idicate that the magnitude of the effect is dependent on both the velocity and duration of the visual perturbation.
We can see that regardless of the velocity, if a perturbation is only 0.6s long, the disruption of postural control is minimal (Fig 3). Where the largest change is seen is the 5m/s velocity for durations of 1s and 2s but we did not see similar increases for 1m/s or for 2m/s. These are important observations for VR environment design. It is important to avoid visual translations that occur at speeds greater than 3m/s for more than 0.6s as this may challenge balance control if a user is on one foot. As VR continues to become more accessible, sports coaches and physical educators may turn to this technology to train athletes or encourage participation in physical activity. Developing environments that are designed to challenge balance could be used to improve motor coordination. Likewise it is important to design environments that are safe and do not increase the risk falls.

CONCLUSION: This demonstrated that visual perturbations at different velocities and duration, challenge postural control in a VR environment when standing on one foot. These observations are an important consideration in VR environment design. It could be used to develop environments to challenge postural control or to ensure that the environments are safe and do not increase the risk of falls.

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