A Virtual Reality Bus Ride as an Ecologically Valid Assessment of Balance: A Feasibility Study

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ABSTRACT

Balance disorders can lead to severe consequences for older adults. Computerized posturography offers an objective assessment of balance, and VR can help to increase its ecological validity. We investigate to what extent a posturographic VR bus ride is ecologically valid and suitable to assess balance. Sixteen healthy adult participants underwent the VR bus ride. Participants felt a moderate level of presence, and the simulation elicited significant postural changes responses, which correlated with validated posturography assessments of the participants. The results support the viability of our tool for balance assessment in the context of a meaningful activity.

1. INTRODUCTION

Balance disorders or problems maintaining postural balance can have substantial implications on the performance of most daily activities and lead to an increased risk of falls, which often have severe consequences for older adults (Salzman, 2010). However, for community-dwelling older adults, most of the research-based assessments are abstract single-tasks evaluations that do not feature a representative design of functional activities, and there is a need for items that better reflect postural control demands in daily-life situations (Pardasaney et al., 2013). There is a lack of ecological validity that can hinder the transferability of results to real-world situations for which virtual reality (VR) could provide a solution. To design a digital system that could overcome the limitation in the transferability of older adults posturography results to real-world situations, we developed the "VR Bus Assessment of Balance." A dynamic posturography test that introduces optical-flow perturbations in a realistic and ecological valid task. This work represents a feasibility study, done with healthy adults, where we investigate to what extent this simulation is suitable to assess balance by comparing it against a validated posturography tool. First, we measured how much participants felt present in the simulated world, thus increasing the ecological validity of the tool. Then, we investigated if this tool could produce observable and significant changes in participants' posture, measured trough centre-of-pressure (CoP) position. Lastly, we followed up on the previous question and examined if there were significant correlations between the participants' responses to our VR simulation and their ability to keep balance.

2. METHODS

The VR Bus Assessment of Balance, a virtual bus ride, was built with the game engine Unity 3D. The backdrop of the ride are the virtual streets of Reh@City, a grid plan neighbourhood of a city with over 200 buildings (Teresa

Paulino, Ana Faria and Sergi Bermudez i Badia, 2019). The bus drives a closed circuit with realistic behaviour, which lasts approximately 4.5 minutes to complete. The experience takes place inside a CAVE, mediated through the KAVE software (Gonçalves and Bermúdez, 2018). During the virtual ride, data are collected from the virtual bus itself (position and orientation) and a Wii Balance Board (WBB) (CoP position over the board).

Participants had their balance and postural control assessed with a validated WBB-based posturography system (Llorens et al., 2016). After that, they completed the VR bus ride, acting as a standing bus passenger over the WBB, facing the front wall of the CAVE. Lastly, answered the Slater-Usoh-Steed Questionnaire (SUS) (Slater et al., 1995), and the Presence Questionnaire (PQ) (Witmer et al., 2005).

3. RESULTS & DISCUSSION

Participants reported moderate levels of presence, comparable to other VR experiments with the same system. The immersive characteristics of the VR system contributed positively to presence, while the lack of interaction had a negative effect. Statistical testing revealed significant differences in posturographic measurements between different segments of the ride. Segments in which the bus turns, significantly increased maximum CoP excursion in the medial-lateral axis and CoP mean speed, relatively to straight segments. It made them adopt an anticipatory compensation behaviour when subjected to variations of the visual stimuli. This tells us that the VR bus ride can be used to trigger balance control responses successfully. Lastly, participants' CoP excursions during the static posturography assessment correlated negatively with medial-lateral excursions in the VR ride, that presented them with visual information contrary to vestibular. This finding suggests that the VR Bus Assessment of Balance is sensitive to detect people with a lower visual information weight when integrating it with somatosensory and vestibular information for balance and postural control.

4. CONCLUSIONS

Our study supports the feasibility of our paradigm to assess balance based on a more ecologically valid scenario, contextualized by a meaningful activity of daily living. Following this feasibility study, the system will be re-evaluated to assess its discriminative properties in older adults with an increased risk of falls.

7. REFERENCES

Gonçalves, A., Bermúdez, S., 2018. KAVE: Building Kinect Based CAVE Automatic Virtual Environments, Methods for Surround-Screen Projection Management, Motion Parallax and Full-Body Interaction Support. Proc ACM Hum-Comput Interact 2, 10:1–10:15. https://doi.org/10.1145/3229092

Llorens, R., Latorre, J., Noé, E., Keshner, E.A., 2016. Posturography using the Wii Balance Board™: A feasibility study with healthy adults and adults post-stroke. Gait Posture 43, 228–232. https://doi.org/10.1016/j.gaitpost.2015.10.002

Pardasaney, P.K., Slavin, M.D., Wagenaar, R.C., Latham, N.K., Ni, P., Jette, A.M., 2013. Conceptual Limitations of Balance Measures for Community-Dwelling Older Adults. Phys. Ther. 93, 1351–1368. https://doi.org/10.2522/ptj.20130028

Salzman, B., 2010. Gait and Balance Disorders in Older Adults. Am. Fam. Physician 82, 61–68.

Slater, M., Steed, A., Usoh, M., 1995. The Virtual Treadmill: A Naturalistic Metaphor for Navigation in Immersive Virtual Environments, in: Virtual Environments '95, Eurographics. Springer, Vienna, pp. 135–148. https://doi.org/10.1007/978-3-7091-9433-1_12

Teresa Paulino, Ana Faria and Sergi Bermudez i Badia, 2019. Reh@City v2.0: a comprehensive virtual reality cognitive training system based on personalized and adaptive simulations of activities of daily living. Presented at the The Experiment@ International Conference 2019 (exp.at'19), IEEE, Funchal, Portugal.

Witmer, B.G., Jerome, C.J., Singer, M.J., 2005. The Factor Structure of the Presence Questionnaire. Presence Teleoperators Virtual Environ. 14, 298–312. https://doi.org/10.1162/105474605323384654