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The objective measurement of balance and vestibular function

Studied through the measurement
of cognitive function on postural
balance control through VR

Matthew Campbell
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Article Information:

Title of article.

Linking cognitive functioning and postural balance control through virtual reality environmental manipulations.

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Name and affiliation of authors

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Review of the paper:

What is the context for the study? What challenges are the authors trying to solve?

The purpose of this study was to find out if a Head Mounted Display (HMD) VR headset along with a stabilometer, can be used objectively measure vestibular function, and to check for vestibular dysfunction. This is due to its ability to activate the vestibular system and postural sway through visual stimulation. The authors of this study hoped that this form of testing could be used to test for dementia – primarily that of vascular dementia which for vertigo is one of the first symptoms you'll experience before any of the other signs begin to show (Anon., 2020). One of the challenges faced with a growing older population is the increased need to be able to diagnose age-related degenerative diseases such as dementia, so the ability to screen for these diseases early has become more important (Robinson L, 2015). The study aims to diversify the approach to dementia screening through a biomechanical approach by testing gait and posture, which are governed by vestibular function.

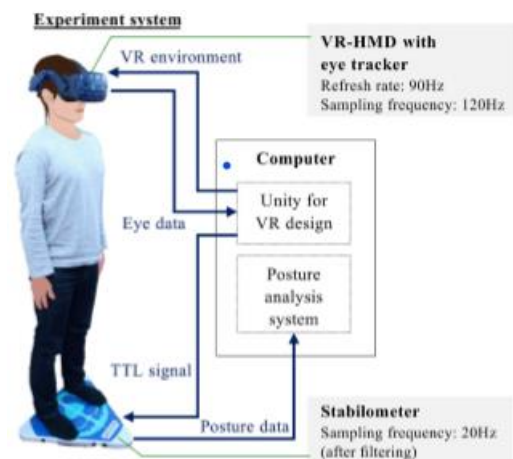


Figure 1: The setup of the experiment (Imaoka Yu, 2022)

The authors study focuses on the analysis that vestibular dysfunction could be an independent predictor for dementia due to the vestibular systems link to the hippocampus which controls spatial memory. The intention of the study is to develop a novel and comprehensive assessment system using HMD VR technology as a stimulant to induce vestibular activities through visual information to allow dementia screening that is low cost, simple and time efficient for use in a clinical setting. It is a

new study focused on the effects of visual stimuli produced by HMD-VR technology on postural sway and the link between cognition and body balance (Imaoka Yu, 2022).

What is the main question addressed by the research? Why is the problem clinically relevant?

The main question addressed by the research is whether the use of a VR headset accompanied with a stabilometer is sufficient to objectively test balance and vestibular function. The problem is clinically relevant as vestibular function is known to be affected by dementia (Lee, 2020), but recently studies have been completed into the loss of balance or vestibular dysfunction as an early indicator of dementia (Mc Ardle Ríona, 2021). Currently there are several ways to test for dementia which include an examination of personal history, physical examination, cognitive testing, neuropsychological testing, radiological tests and brain imaging techniques. An objective and functional vestibular test would help save time in declaring the presence absence of dementia and could remove the need for further testing such as MRI's, SPECT, and CT scans. One major benefit of this objective method of testing is the safe saved in a controlled environment, making it more practical in a clinical environment (Imaoka Yu, 2022). Apart from the financial benefit to patients not having to undergo these tests it would also serve to save time in an already highly pressurized environment.

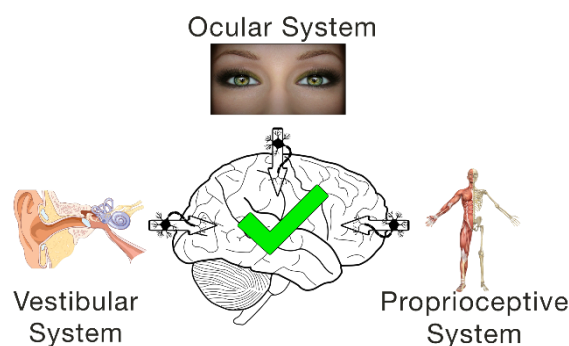


Figure 2: The parts of the brain involved in vestibular function and balance. (Anon., n.d.)

Why are the authors qualified to propose their solution? What is their prior experience?

The most experienced of the Authors is Eling D de Bruin. He is a professor at ETH Zurich whose expertise is centred around stroke rehabilitation, motor learning, neuroscience, Geriatrics and Rehabilitation medicine. He has 243 publications to date as well as 4939 citations – the most productive professors have between 20 and 78 publications and 184 to 586 citations. (Guy Madison, 2022). He has previously studied and written papers on balance and gait and vestibular measurement devices.

Yu Imaoka is a PHD student whose studies are focused on creating an assessment system for the early diagnosis of dementia, analysing gait, posture, and eye movements he has a background in electrical engineering and experience working on MRI systems. His specialties lie in Diagnostic Pathology and MedTech Data analysis. As well as this research paper he has completed three other studies on the use of VR technology to objectively measure balance and posture.

Andri Flury is holds a master's in medical technology where he specifically focused on assessing saccadic eye movements with HMD VR technology. He has also completed research in the field of

Gait and Posture, and much of his interest once again revolves around the use of VR technology as an objective form of measurement.

Finally, Laura Hauri took part in this research papers as her thesis for a master's project. She has now completed her Master of Science in Medical Technology. Other than this Laura has two other publications, both focused in the medical field.

This was a further study from Yu Imaoka and Eling D. de Bruin's previous work in 2020 where they had previously evaluated postural movements in Young Adults and older people for early dementia screening. The authors also declared that this research was carried out in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest (Imaoka Yu, 2022).

What is the novelty of the study? What unique solution do the authors bring to the challenge?

This was the first time a research project had been complete in this field of research. It was original research that aimed to make the process of diagnosing dementia more efficient and simpler. Along with proving a new method of measurement, the study also set out to highlight the link between dementia and the loss of balance and vestibular function. The main hypothesis to test if cognitive function could be detected through postural sway behaviours was to see what occurred when optokinetic design based room devices were implemented, as optokinetic design is likely to stimulate vestibular function (Pavlou, 2010).

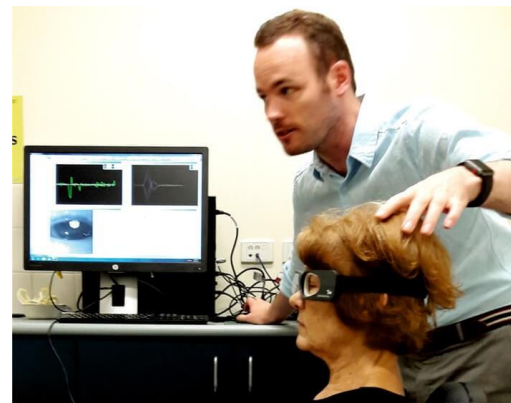


Figure 3: A standard test vestibular test for those with dementia.

The study made use of the novel concurrent comprehensive system of posture and eye movements using HMD-VR technology. It is a new and modern solution to measurement of balance and vestibular function which not only has a purpose for the early diagnosis of dementia, but it can also act as a test for those who suffer from postural and vestibular defects. It can be used to measure balance problems associated with the visual systems such as arthritis and eye muscle imbalance (Anon., 2018).

What is the clinical impact of the solution

Vestibular impairment is known to lead to dizziness and imbalance owing to gaze and postural instability (Aisha Harun, 2016). The experiment revealed the main effect of different VR environments to be most prominently in the anterior-posterior direction with little effect noted in the mediolateral direction, this is most likely due to the fact that stimulation in postural sway in this plane is controlled by the vestibular apparatus in the ear (Reimann Hendrik, 2019).

A form of objective measurement such as this would be greatly beneficial, once proven to be consistent and effective in its operation to aid diagnosis of those who often cannot reach a medical centre. The equipment could be sent to the user to allow them to carry out the test remotely where the results can then be analysed to determine if further screening is needed. In place of the stabilometer, which would not be as transportable and user friendly in a remote environment due to

the risk of falling, studies have been completed that show that wii balance boards can act as a substitute to a medical grade force plate in objective measurement of balance. individual. It has the capability to test the balance while separately eliminating sensory inputs of vision and proprioception, and also can be used to provide conflicting sensory inputs to further evaluate the postural stability in challenging environments (Anubhav Singh, 2021). This would save time for both patients and medical professionals by allowing a provisional test to be completed to see if further evaluation is needed, rather than taking up time and space in already overworked environments.

Are the conclusions consistent with the evidence and arguments presented

The results suggested that the varying of VR environments changed postural sway in the anterior-posterior direction only – but this was an expected result based of a previous study some of the authors had carried out in 2020 (Yu Imaoka, 2020). Prior research findings had shown that vestibular impairment has a strong association with cognitive ability and visual stimuli based in VR environments provoked vestibular function. This was once again shown through the results of the study where postural sway was affected by stimuli of an optokinetic design-based room with stripes

(OKR) VR environment oscillating forwards and backwards at the frequency of 23/60Hz induced (Pierre Gilfriche, 2018).

Is the solution ready for clinical use? What is the technology readiness level?

This solution is not ready for clinical use, it is the first of many studies intended to be completed into the analysis of this form of balance and vestibular measurement. It requires much larger samples of varying demographics, ages, and abilities to ensure a certainty and reliability in the diagnosis of vestibular dysfunctions. In terms of technology readiness of the equipment to be used as an objective form of measurement it would be in the stages of TRL4 Proof of concept as R&D activities have been carried out including analytical and laboratory studies to prove assumptions and predictions (Benkaddour, 2017).



Figure 4: TLR progression levels (Anderson, 2020)

What experiments tests, or trials would you do next if you were the authors?

It had been hypothesized that there would be a link between the special cognitive and vestibular function when the VR stimuli was applied so the authors had not measured these in real time. A Electrovestibulography – EvestG would allow evaluation of vestibular activity, postural sway and eye movements in real time (Daiel J. Brown, 2017), I think this would be of great benefit to further analyse this form of objective measurement. An EEG would be beneficial to clarify parietal cortex activity in real time and this relates directly to spatial cognitive function (Sack, 2009). As this is a novel study researching new forms of balance and vestibular measurement there is much that can be improved upon. The authors note the fact that they were still in the process of testing hypotheses and now that they are confirmed there is reason for further analysis.



Figure 5: EvestG testing chair.

Why did you choose this article?

When researching articles related to the topic of measurement of balance and vestibular function between the period of 2021-2023, I noticed compared to previous years that there was less research in this area. This had led me to think that some of this work had proven to be no longer relevant but one factor to be considered is that much research was not possible during these years due to the Covid-19 pandemic. I chose this article as I thought that the concept and test the authors were intending to prove was progressive, useful, and interesting. Technological advancements have steered the direction of the healthcare system in a new direction. The ability to self-test and monitor your own health has become much more prevalent and should this form of objective measurement of balance and vestibular function be refined and improved upon to make it safe for an individual to carry out by themselves it presents many opportunities. When researching this topic, I had found many articles associated with the use of VR, and gaming balance boards to measure vestibular function however this article proved to be the most informative and detailed.



Figure 7: A VR headset for ocular stimulation



Figure 67: A Wii balance board used for postural sway analysis (Fares Kayali, 2013)

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