

Development and feasibility of a mobile-based vestibular rehabilitation therapy application for healthy older adults

Dear Editor,

Vestibular hypofunction (VH) is the clinical condition where there is partial or complete loss of the vestibular organs and/or vestibular nerves. Symptoms of VH include vertigo, postural unsteadiness, and oscillopsia with head movements.^{1,2} These symptoms, if untreated, can affect an individual's daily activities, occupational performance and mobility, leading to deconditioning and withdrawal from social activities.³ VH in the elderly is a major risk factor for falls and reduction of physical activity.⁴

Vestibular rehabilitation therapy (VRT) is the recommended exercise-based treatment for patients with VH.⁵ A comprehensive customised VRT programme consists of adaptive training of the vestibular ocular reflex (VOR) through gaze stabilisation exercises, balance and gait training, and habituation exercises for symptoms reduction.^{2,5}

Current VRT programmes involve patients being taught home exercises by trained therapists, with exercise performance feedback received only during follow-up sessions (average 4–6). Without timely feedback, patients who perform home exercises suboptimally may aggravate their symptoms and prematurely stop their exercise programme.⁵ Furthermore, patients rely on their therapists to progress further into their exercise programme during follow-up sessions, resulting in multiple and costly visits to the clinic.

Virtual reality has a favourable potential to optimise the outcomes of patients with VH during VRT. The use of virtual reality and conventional VRT has demonstrated better results, sustained at 1 year compared to the sole use of conventional VRT programmes.⁶

Earlier home VRT mobile applications (apps) are purely instructional, thus providing no feedback for end users,^{7,8} and do not facilitate clinicians' monitoring and assessment of end users' participation in home VRT.

Recent innovations have incorporated virtual reality via smartphone apps, used together with low-cost devices, to include gamifications aimed at improving visual and vestibular stimulation,⁹ and gaze stability and balance training in VRT.¹⁰ The level of difficulty of the games is determined at the clinicians' discretion.¹⁰

Development of a mobile-based vestibular rehabilitation therapy app (mobile VRT): The study

team developed a mobile VRT prototype, which aims to empower patients with subacute to chronic VH to administer and progress home VOR exercises correctly and safely.

VOR exercises involve patients moving their head horizontally or vertically, while focusing their eyes on a target, and keeping the target clear at all times at a prescribed rate and intensity. Patients need to slow down their head movement when the target becomes blurred or dizziness increases.

The mobile VRT uses an Android operating system and deep learning technology to accurately track and measure head and eye movement, to consequently determine horizontal and vertical VOR performance. The mobile camera system measures (1) head rotation angles, (2) frequency of on-target visual fixation, and (3) frequency of head rotations achieving a minimum angle, to compute therapy routine performance.

Users receive immediate on-screen feedback on their performance of the VOR exercises, which empowers self-progression according to the severity of their symptoms (Fig. 1). They will be informed to modify the speed of their head movement based on self-perceived dizziness severity rating. Other feedback includes keeping their eyes focused on the target, if not maintained consistently throughout the VOR exercises.

Cloud-based service can be incorporated to enable remote supervision and monitoring of individual compliance and performance of VOR by clinicians. The number of horizontal and vertical head movement per minute will be recorded per training session to track users' performance. Dizziness intensity will be rated on a visual analogue scale of 1–10.

From 2012 to 2014, there was a 30% increase in smartphone internet usage among senior citizens aged 50–59 years, and a 19% increase among adults aged ≥ 60 years.¹⁰ Given senior citizens' increasing familiarity with the use of smartphones in Singapore, the introduction of the mobile VRT for therapy in older adults is a timely idea.

We sought to test the experience and acceptance of older adults towards the mobile VRT, particularly given that these are unknown for apps that allow users to self-progress in VOR exercises.

Sixteen healthy older adults (mean age 57 ± 7 years, 11 females) with no prior experience with vestibular rehabilitation consented to participate based on the

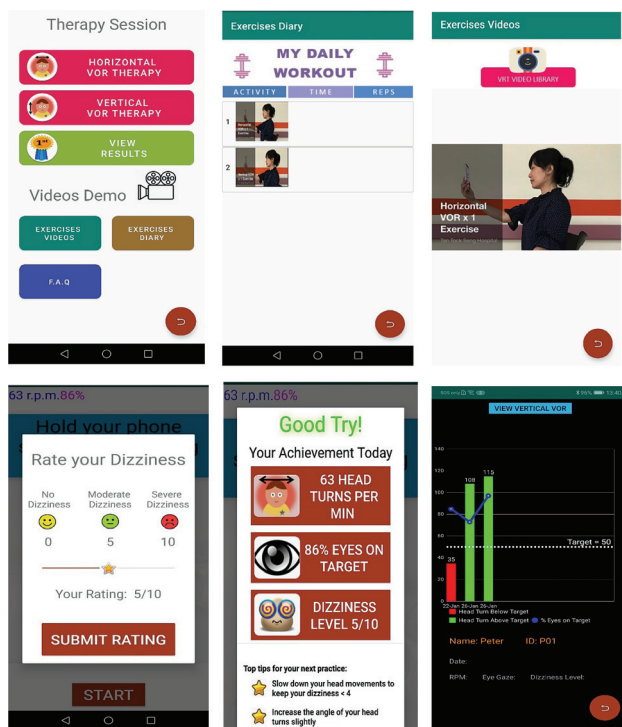


Fig. 1. Screenshots of the mobile VRT on a smartphone. Top (from left): home page, subject's customised exercise diary, and video sample of one of the home exercises. Bottom (from left): subjective rating of dizziness post-adaptive VOR exercise, on-screen feedback to users about their adaptive VOR exercises performance, and graphical representation of users' performance of adaptive VOR exercises.

National Healthcare Group Human Research Ethics Committee guidelines, to test and provide feedback on the mobile VRT. Subjects were taught to follow a series of exercise tasks over one 30-minute session, supervised by study team members before completing a questionnaire.

A 13-item questionnaire, with a combination of Likert scale and 1 open ended-question, was developed to evaluate users' experience and feedback on the ease of use, clarity of instructions, and intuitiveness of progression between exercise intensity levels.

Data were analysed using SPSS Statistics software version 27.0 (IBM Corp, Armonk, US). Descriptive statistics were used to present participants' characteristics and questionnaire responses. Categorical variables were presented as frequencies and percentages.

All recruited users found the mobile VRT easy to learn and navigate, and instructions and exercise videos simple to understand. All users also agreed that its use for rehabilitation is an innovative idea. A total of 93% reported confidence in using the app and would be keen to use it (Table 1).

Further enhancements were proposed following thematic feedback analysis. These include: fine-tuning of vertical VOR, development of instruction videos and development of a troubleshooting guide during calibration process.

Table 1. Questionnaire responses from the participants

Questions	Frequency (%)			
	Strongly agree	Agree	Disagree	Strongly disagree
1 The process of learning the mobile VRT is easy	14 (87.5)	2 (12.5)	0	0
2 The navigation of the mobile VRT is easy	15 (93.8)	1 (6.3)	0	0
3 Instructions of the mobile VRT are easy to understand	11 (68.8)	5 (31.3)	0	0
4 Exercise videos are clear and easy to understand	13 (81.3)	3 (18.8)	0	0
5 The font and size of the text are readable	12 (75.0)	3 (18.8)	1 (6.3)	0
6 The voice of the mobile VRT can be heard clearly	14 (87.5)	2 (12.5)	0	0
7 The weight and distance of the mobile VRT prototype are comfortable to me	4 (25.0)	8 (50.0)	4 (25.0)	0
8 The speed between each interface is fast	6 (37.5)	6 (37.5)	4 (25.0)	0
9 The visual appeal of the mobile VRT looks interesting	11 (68.8)	5 (31.6)	0	0
10 The use of mobile VRT programme for rehabilitation is an innovative idea	13 (81.3)	3 (18.8)	0	0
11 If I were a patient, I will be keen to use the mobile VRT as part of my rehabilitation	13 (81.3)	2 (12.5)	1 (6.3)	0
12 If I were a patient, I will be confident to use the mobile VRT to perform home rehabilitation exercises independently	11 (68.8)	4 (25.0)	1 (6.3)	0
13 I will recommend the use of the mobile VRT to patients with inner ear imbalance for their rehabilitation	12 (75.0)	3 (18.8)	1 (6.3)	0

Mobile VRT: mobile-based vestibular rehabilitation therapy application

This study has preliminarily demonstrated the feasibility and usability of the mobile VRT in healthy older adults. Following further enhancements to the mobile VRT, the team plans to evaluate its potential for virtual reality gamifications to optimise VOR, visual and vestibular stimulation, and balance training in patients with VH.

The mobile RT facilitates cost-efficiency and remote supervision of users' home exercise programmes. Thus, it can potentially complement conventional VRT with such benefits and more enjoyable experiences.

Our study has some limitations. Only English-speaking older adults were recruited and currently, only the Android version of the app is available. Development of an iPhone-compatible version and in other languages would expand the usability of the mobile VRT.

Education and cognitive levels may be potential confounding variables in determining feasibility of the mobile VRT. Future feasibility studies may recruit users from different socioeconomic backgrounds, and age and ethnic groups to better represent the population in Singapore.

The mobile VRT was found to be easy to use, innovative and favourable by healthy older adults. Findings from this study will be considered for further development of the app.

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