東華三院
Tung Wah Group of Hospitals

LSCM
Logistics and Supply Chain MultiTech R&D Centre
物流及供應鏈多元技術研發中心

香港大學
THE UNIVERSITY OF HONG KONG

Evaluation Report of
VRehab Generation Programme
「共融 V 勢代」計劃
評估報告

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共融V勢代
VREHAB GENERATION

INNOVATION AND TECHNOLOGY
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TWGHs Jockey Club Yee Tai Care and Attention Home
TWGHs Jockey Club Yee Yeung Care and Attention Home
TWGHs Life X (Endless Care Services)
TWGHs Lok Kwan District Support Centre
TWGHs Prestige Care Services for Elderly
TWGHs Wu York Yu Care & Attention Home

Preface

Government and social sectors had recently promoted innovative technology to enhance its service quality, and to improve the living quality of elders and people with disabilities (PWDs).

Launched by Innovation and Technology Bureau in 2017, Innovation and Technology Fund for Better Living (FBL) sponsored $3,352,770 of a three-year joint project, 'VRehab Generation' by Tung Wah Group of Hospitals (TWGHs) and Logistics and Supply Chain MultiTech R&D Centre Limited (LSCM) since 2018. This project, applying virtual reality technology, aimed to develop a series of close-to-reality rehabilitation training programmes, including physical training, cognitive training, community-living skills training and relaxation for elders and PWDs. The virtual reality programmes allow the service users to break through their physical and environmental constraints, and to participate in rehabilitation training regarding to their progress purposefully and continuously in an enjoyable way.

Virtual reality interactive platform has been developed for some years. Its technology is well-developed and its application is widespread. Its effectiveness to improve the cognitive functioning, balance and training motivation of the people with rehabilitation needs is evident-based, few local applications are tailor-made to cater the needs, mobility and response of elders and PWDs that aim to meet their needs and compatible with their mobility functioning. Therefore, we have entrusted the School of Nursing, the University of Hong Kong to conduct a research about 'VRehab Generation' project to evaluate the acceptance of the application of virtual reality technology by service users, and to examine the efficacy of virtual reality platform for rehabilitation training.

Through the project and the research of 'VRehab Generation' we hope to arouse different sectors' concern about the needs of elders and PWDs, and to promote the application of virtual reality in rehabilitation services, to encourage sustainable development on the VR application in rehabilitation. We hope that the elders and PWDs can have more choices in their rehabilitative journey.

Last but not the least, thank you FBL sponsoring us for the implementation of the project; thanks to LSCM and The University of Hong Kong collaborating with us to develop VR rehabilitation training content, to conduct the research. And of course, thanks to the participation of service units and service users, whom allows our project to improve continuously.

LEUNG Bick-king Alice
Head of Community Service Division
Tung Wah Group of Hospitals

序言

近年政府及社會服務業界均積極推動及引入創新科技應用，以提升服務質量、改善長者及殘疾人士的生活質素。

於 2018 年，東華三院與物流及供應鏈多元技術研發中心有限公司合作，得到政府轄下創新及科技局於 2017 年推出的「創科生活基金」撥款三百三十五萬二千七百七十元資助，推行為期三年的「共融 V 勢代」計劃。本計劃以虛擬實境 (Virtual Reality) 技術，研發復康訓練內容，包括體力訓練、認知訓練、社區生活技能訓練和情緒舒緩，為長者及殘疾人士提供一個逼真的環境，讓他們能突破身體及環境上的限制，持續並按部就班地進行各類復康訓練、寓訓練於娛樂，希望加強他們日常的復康訓練治療效果，豐富生活體驗。

虛擬實境互動平台經過多年的發展，技術已見成熟，應用性高，應用層面亦非常廣泛，外國已有實證研究證明有關訓練能夠改善復康人士的認知能力、平衡力及訓練動機等。但市場上卻欠缺因應長者及殘疾人士需要、活動能力、反應及速度感的本地化虛擬訓練系統。因此，我們亦委託了香港大學護理學院為是次研發的活動內容進行研究，評估以虛擬實境技術應用的接受程度、並檢視以虛擬實境互動平台進行復康訓練的效能。

藉著「共融 V 勢代」計劃及成效研究，我們希望能夠拋磚引玉，讓不同界別人士關注長者及殘疾人士的需要，推動虛擬實境於復康服務上的應用、鼓勵復康科技的持續發展，期盼長者及殘疾人士的復康路上有更多的選擇。

最後謹此多謝創科生活基金的資助，讓計劃得以順利進行；感謝物流及供應鏈多元技術研發中心有限公司、香港大學與我們攜手合作以虛擬實境研發復康訓練內容、並為是項計劃進行成效研究。當然亦感謝一眾參與計劃研究的服務單位及服務使用者，讓計劃能持續改善，精益求精。

梁碧琼
東華三院社會服務科主管

Preface

In recent years the advancement of various technologies both in performance and (lower) cost have drastically increased the opportunities of better serving the elderly, not only in providing a safer living environment but also improving the quality of lives for these oftentimes under-attended or under-privileged population.

Technologies such as internet, internet-of-things, Wi-Fi and 5G have greatly improved the capability of remote monitoring and safeguarding the elderly with wearable electronics or sensing systems that can instantly call for help in case of accidents, and monitoring continuously of the vital signs, all of which build together the foundation of today's rapidly growing tele-health industry. Robotics, smart electric wheelchair and lifters and other ingenious exoskeleton inventions help disabled elderly in getting better accessibility to place outside of their homes with more ease and less barrier. Artificial Intelligence (AI) revolutionize the capabilities of various software and Apps which in turn provide more variety of services, functions and entertainment to the elderly with much better features and capability.

Virtual Reality, a truly unique technology which gains tremendous popularity in recent years, have been greatly enhanced by the improvement of hardware, software capability such as AI and lowering of cost to make it an ideal tool for training, rehabilitation and pure entertainment. VR has been widely deployed in professional training programs, high-end sales promotion (such as real estates) and entertainment industry. I am extremely pleased that Tung Wah Hospital Groups now introduces it to serve the elderly. Not only the VR offers very "real" sensation to the users without the hazards of actually visiting the spots (which are sometimes inconvenient, or difficult to access, or even dangerous), the programs can be changed and tuned to the need of different categories of elderly hence offering a safe, flexible and full-of-variety services. Whether for rehabilitation or pure enjoyment, VR is only second to the real deal but with much less restrictions and cost. In particular, during the current pandemic times, VR programs are ideal both in observing social distancing and keeping the elderly safe.

I sincerely wish that the program will achieve great success and bring awareness to the public of such technology being used for the betterment of our elderly and a lot more VR services would be made available in the years to come.

Simon K.Y. WONG
Chief Executive Officer
Logistics and Supply Chain MultiTech R&D Centre Limited

序言

近年來各種創新科技之進展，包括功能及較低廉之成本費用，使得各種利用科技服務樂齡人士之機會大為增加，不但能提供更安全之生活環境，並可以提升日常生活的質素，這對一般欠缺充份照顧或弱勢樂齡人士更形重要。

嶄新科技如互聯網、物聯網、Wi-Fi 及 5G 等大大改善遙距監察及保護老人家之能力，諸如可佩戴電子裝置及感應系統，能夠於危急意外時即時報警求助或長時間監察人體之重要生命訊息等，而構成今天迅速成長之遙距保健工業之基礎。

機械人、智能輪椅、升降器、及其他「外骨骼」創新設備之發明，幫助了行動不便之老人家更容易，更無障礙地離家外出，人工智能 (AI) 革命性地增強了軟件及 APPS 之能力，使其能提供更廣泛的功能，更美好的愉樂給予樂齡人士。

虛擬實境 (VR) 亦是一個真正特殊的科技，近年大行其道，經過硬件及軟件（如 AI）之大幅進步及成本價格之降低，VR 已變成訓練、復健及純粹愉樂之利器。 VR 普遍被用於各種專業及職業訓練、電子運動 (eSPORTS)、高端銷售 (如物業、地產) 及愉樂事業等，我甚為高興東華三院如今引進 VR 去服務樂齡人士，VR 不但提供極其「逼真」的感官刺激，亦能夠同時保障用者的安全，免受冒親抵現場之風險 (如不易達到、難以攀登、甚至有危險之場地場所)，軟件程式可以彈性轉換以適合不同情況之樂齡人士之需要，提供安全，多元及有彈性的服務。無論作復健或愉樂之用，VR 是僅次於實際場所之最佳選擇，兼有不受外在環境限制及低廉費用之效益！特別是目前疫症肆虐下，VR 可以達到安全社交距離及保障老人家安全健康之效！

我衷心祝願該項目完滿成功，並吸引更多公眾認知，利用 VR，以更多的 VR 設施造福樂齡人士。

黃廣揚
行政總裁
物流及供應鏈多元技術研發中心有限公司

EXECUTIVE SUMMARY

With the support of the Innovation and Technology Fund for Better Living, the Tung Wah Group Hospitals (TWGHs) developed the VRehab Generation Programme (VGP) for their service users who are elders and people with disabilities (PWDs). The VGP covers four virtual reality (VR) game domains, including physical training, cognitive training, community-living skills training, and relaxation. Special considerations for local elders and PWDs were made in terms of hardware choice and software design.

To evaluate the feasibility, acceptance, and efficacy of the VGP in improving health outcomes among users who are elders and PWDs, a team of researchers from the School of Nursing of The University of Hong Kong conducted a single-armed pretest–posttest study from 2019 to 2020. This report showed the design, implementation, and findings of the evaluation study.

In the evaluation study, the usage frequency, duration, and content of VR trainings were standardised. On completion of each session, usage statistics were documented via the built-in VR software, whereas feedback on the experience of VR training and adverse events were collected via self-reports and staff observations. Feasibility was reflected by usage statistics and acceptance was reflected by positive feedback. In addition, health outcomes including upper-limb dexterity, functional mobility, cognitive function, and happiness were assessed by the research team at baseline, six weeks, and three months after baseline. The primary outcomes were upper-limb dexterity and acceptance of playing VR games.

A total of 135 participants were recruited from May 2019 to January 2020, and 124 (91.9%) completed at least one follow-up. Over three quarters (76.3%) of the participants could attend at least 70% of the proposed 18 sessions, and the majority of sessions (72.5%) had training time lasted for at least 20 minutes. The total training time of the participants had a median of 316.8 minutes. Statistically significant effects were observed in terms of upper-limb dexterity (small effect) and cognitive function (moderate effect). Among the 135 participants, 88 (65.2%) provided positive comments. About 10.4% reported mild discomfort such as dizziness, and none reported severe discomfort.

To conclude, our study demonstrated that a universal set of VR training was feasible and acceptable for local PWDs and elders. Benefits in upper-limb dexterity and cognitive function were observed despite partial compliance to the training protocol. Findings from this study informed the future planning and application of similar VR trainings. Recommendations for future practice were made at the end of the report.

報告摘要

在創科生活基金的支持下，東華三院為長者及殘疾人士開發了「共融 V 勢代」計劃。該計劃涵蓋了四個虛擬實境的遊戲範疇，包括體力訓練、認知訓練、社區生活技能訓練和情緒舒緩。其硬件的選擇和軟件的設計也特別考慮到本地長者及殘疾人士的需要。

為了評估「共融 V 勢代」計劃的可行性、接受度，以及對長者和殘疾人士使用者的健康改善效果，香港大學護理學院的研究團隊於 2019 年至 2020 年進行了一項單組前後對照研究。此報告詳述該研究評估的設計、實施和結果。

研究團隊統一了虛擬實境訓練的使用頻率、時間和內容以作評估。在每節訓練完成時，虛擬實境訓練的使用數據會通過內置的軟件記錄，而使用者對虛擬實境訓練體驗的回饋和不良反應則通過自我報告和員工觀察來收集。使用量反映了可行性，而正面的回饋反映了接受度。此外，研究團隊在參加者開始加入計劃時 (基線)、開始後六周及開始後三個月評估了參加者的健康狀況，其中包括上肢的靈活性、活動能力、認知能力和快樂程度。此項研究評估的主要指標定為上肢的靈活性及對虛擬實境訓練的接受程度。

在 2019 年 5 月至 2020 年 1 月期間，研究計劃共招募了 135 名參加者，其中 124 名（91.9%) 參加者完成了最少一次跟進評估。超過四分之三 (76.3%) 的參加者能夠在建議的 18 節訓練中，達到 70% 以上的出席率，而大部份的訓練中（72.5%) 參加者至少進行了 20 分鐘的虛擬實境遊戲。參加者總訓練時間的中位數為 316.8 分鐘。在健康狀況評估方面，上肢的靈活性和認知能力皆有統計學上顯著的效果，前者的改變效果屬小，而後者則屬中等。在 135 名參加者當中，有 88 名 (65.2%) 參加者有正面的回饋。約有 10.4%的參加者有輕度不適，例如頭暈，而嚴重的不適則沒有任何報告。

總括而言，這項研究顯示了一套通用的虛擬實境訓練對於本地不同類型的殘疾人士及長者是可行及可接受的。儘管參加者不是完全依從訓練方案，我們仍觀察到此訓練對上肢的靈活性和認知能力方面有正面的影響。未來類同的虛擬實境復康遊戲可參考「共融 V 勢代」計劃的經驗，因此報告於文末亦提出了具體的建議以作業界參考。

Chapter 1 Introduction

Virtual reality (VR) has become a popular technology that has been widely used in many areas including education, aviation, medicine, and entertainment. It is especially a breakthrough in computer games. VR provides a ‘close to reality’ and immersive three-dimensional (3D) virtual world that lets users explore and play with more possibilities. In general, VR games are categorised into different types such as action, simulation, and adventure. These games are mainly offered as a means of entertainment and excitement for the youth and adults. Users are required to have a high cognitive and physical level to play the games. In this regard, such kind of VR games are not suitable for elders and people with disabilities (PWDs) because they usually take longer response times and cannot handle controllers with buttons because of their weak fine-motor skills.

Nevertheless, researchers and service providers are developing and refining various VR games into VR training programmes for rehabilitation among elders and PWDs. VR training provides users the opportunity to engage in motivational training with many repetitions, salient stimuli, and challenging tasks (Levin et al., 2015). Instances of VR training, particularly those with a rehabilitation purpose, are well published in foreign countries, such as adults with stroke (Laver et al., 2017), community-dwelling elders (Corregidor-Sánchez et al., 2020), people living with dementia and mild cognitive impairment (D’Cunha et al., 2019), and children with cerebral palsy and Down syndrome (Lopes et al., 2020). To our knowledge, there are also several VR training programmes that have been developed locally in recent years (Hong Kong Hospital Authority, 2019). These programmes fit the language, content, and VR scenes specially designed for Hong Kong individuals, which enhanced usage experience among elders and PWDs.

Despite many VR training programmes being developed, they mainly targeted homogenous populations. There is a lack of an integrated VR training programme that targets users with different types of disabilities, including functional impairment, mobility limitation, cognitive impairment, intellectual disability, and visual impairment. Moreover, the accessibility of local VR training programmes is confined. Therefore, there is a need to develop a universal VR training programme in Hong Kong to serve more elders and

PWDs living in local communities or residential settings. Regarding such development, the efficacy of such VR training in improving physical, cognitive, and psychological status among users have to be scientifically evaluated.

Tung Wah Group Hospitals (TWGHs) is one of the leading non-government organisations in Hong Kong. One of its major services is caring for elders and PWDs, both in the residential care setting and the community setting. The government has set up the Innovation and Technology Fund for Better Living to support projects that use innovation and technology to make people's living more convenient, comfortable and safer, or address the needs of specific community groups and promote the use of innovation and technology in society. With the support of the Innovation and Technology Fund for Better Living, TWGHs are developing a set of VR games to supplement the rehabilitation of elders and PWDs. Such programme is named VRehab Generation, which aims to enrich the life experience of elders and PWDs and improve their training and treatment outcomes. With this opportunity, the feasibility, acceptance, and efficacy of VR applications in terms of improvement in functional, cognitive, and psychological status among elders and PWDs can be evaluated.

Chapter 2 Programme Development

The VRehab Generation Programme (VGP) is a set of immersive VR programme developed for physical, cognitive, relaxation, and community-living training. It was jointly developed by TWGHs and Logistics and Supply Chain MultiTech R&D Centre Limited (LSCM) in 2019. To involve users with different disabilities and functional levels, the VGP is tailor-made and fine-tuned its usability to ensure it is user-friendly and comfortable for elders and PWDs. As such, the games have to be visually attractive enough and physically easy enough to be performed. Various elements, including hardware, virtual setting, gaming operation and adaptive components, were specially considered during programme development.

Hardware

There are three contemporary types of VR simulations for rehabilitation: non-immersive, semi-immersive, and fully immersive. All these provide fully digital, computer-generated, 3D virtual environments in which users can interact with the 3D world and experience visual, auditory, and even tactile stimulation.

Both non-immersive and semi-immersive VR programmes rely on computer monitors, projectors, screens, powerful computers, joysticks, and various controllers as display methods and control interfaces. That means users must comprehend the visual image manifested by those displays and manipulate the control interface properly. Inevitably, good visual and fine-motor skills are required to successfully participate in these games.

For fully immersive simulation, head-mounted display (HMD) devices and limb motion trackers are used as the display method and control interface, respectively. Through the HMD, the images of VR games are manifested in front of the users' eyes. It enables elders and PWDs with low vision to see the VR scenery clearly. The control interface is another essential part of VR games, which allows users to interact with the virtual environments dynamically. It is undoubtedly a challenge for PWDs with intellectual disabilities and limited hand dexterity to handle a traditional joystick or controller with buttons. Instead, button-free limb motion trackers are adopted in the programme. The trackers can trace the movement of users' limbs. By detecting the movement within the system, generated signals are then converted and transferred to the computer. Therefore, users can participate in VR games by simple limb movements.

An additional benefit of using HMD device is that it is portable with high applicability. It can be adopted with a minimal space requirement (i.e., width: 1.5 meters × length: 2 meters × height: 2 meters). This fits well for a densely populated place such as Hong Kong.

Virtual Setting

Virtual setting is one of the essential considerations in game development. Although the HMD device provides 360 degrees of a fully immersive VR view and interaction zone, it is hard to apply them to limited-mobility or wheelchair-bound clients, as they may be unable to stand and move around safely. Hence, the VGP especially designed an approximately 180-degree interaction zone within the VR environments, where interactive objects or training tasks are set at arm's length or attached to users' virtual hands. Therefore, users can play VR games safely in a sitting posture without moving or bending forward.

Furthermore, cybersickness or reluctance to wear a considerably heavy HMD and loss of reference to the real world are common concerns in VR games. Some users are more adaptable to the VR apparatus, but some are not. To minimise the risk of cybersickness, users engage in VR games at a particular body position. Agile body and head movements are excluded or minimised from the gaming design to alleviate dizziness and nausea. Although the VR games have to be visually attractive (e.g., colourful and animated), the backdrop and characters of VR games are not too fancy or stimulating to cater to users with limited cognitive and visual perceptions.

Game Operation

The principle of the game operation is simplicity. One of the critical elements in a VR game is the selection function with which users can select an object or option to trigger a pre-programmed action. Mainstream VR games require users to select by precisely positioning a controller by hand and simultaneously pressing the button with a finger. However, this is too complicated for elders and PWDs, especially if they suffer from cognitive impairment, abnormal muscle tone or hand deformities, such as Dupuytren's contracture.

In the VGP, button-free programming is adopted so that users can play VR games without pressing any buttons. Users only need to move the button-free tracker(s) with their limbs to a targeted position and hold it for about two seconds. Then, a pre-programmed action will be triggered. Moreover, some of the VR games allow users to either stand up or sit down to play whereas some permit the use of one or more limbs to play selectively (e.g., left, right, or both), whichever suits a user, such that even those who have suffered from mutilation can also enjoy VR games. Indeed, these different options are an added complication to programme development.

Motion-detection sensitivity is another consideration addressed. It is tailor-made to the capability of users so that even the smallest movement of their limbs and the slowest reaction time can be detected. Then, those with minimal mobility can also easily participate in VR games using button-free trackers.

Game Setting

Several elements in the game settings of the VGP are designed to facilitate participation among elders and PWDs. First, most of the games are designed with three levels of difficulty so that users can choose the most suitable one according to their functional levels. For example, in Level 1 of the *Handball Game*, users must move their upper limbs 10 cm towards the goal to trigger the ball-throwing action, but it is increased to 20 cm in Level 2.

Second, the games have timely, encouraging feedback and cues. As we know, people with intellectual disabilities need more time to understand how they can participate in a VR game. They might also feel challenged to associate their real limbs with the virtual limbs in the game. By providing immediate feedback, they will realise what they do in the real world (e.g., moving their limbs) can make something happen in the VR games (e.g., throwing a ball toward a goal). In addition to feedback, cues are provided in the form of images, words, and sound, which serve as guides to help users understand what they should do in the VR games. Staff can also use their own cues as additional guidance.

Lastly, reward and punishment are common elements in a computer game, but only positive reinforcement is adopted in the VGP's design, for example, applause and fireworks. It allows users to freely explore the VR games without any sanction and penalty (e.g., score deduction). It also provides a sense of achievement to users and encourages them to continuously engage in VR rehabilitation training through the VGP.

Components

The VGP features four components:

i) Physical training

The games involve upper limbs (*Handball*), lower limbs (*Football*) and full-body motions (*Gatekeeping*). By throwing, kicking, or guarding the ball in the VR games, they repeatedly mobilise their limbs and use their muscles, which aims to help slow down the deterioration of bodily functions, distortion of perception, and joint contracture development.

ii) Cognitive training

This consists of classification and reality orientation games. Nostalgic elements are employed to appeal to the elders.

There are two themes for classification games. One is a reference to *Lai Chi Kok Amusement Park (Lai Yuen)*. The thematic park was operated from the 1940s to the 1990s and is part of the collective memory of Hong Kong elders. Three signature games were included, namely, *Elephant Feeding, Feather Duster Throwing*, and *Coin Tossing*. Most Hong Kong elders are familiar with these games, which could provide not only cognitive stimulation but also a reminiscence of their past. Another theme simulates a home setting. The game is named *Home Items Locating*, which requires users to identify the appropriate items in the corresponding rooms.

Hong Kong Footprint is a reality orientation game. Users are virtually brought to Shek Kip Mei, Man Mo Temple, Wong Tai Sin Temple, and Chun Yeung Street. These places are typical to Hong Kong elders. Each scene is played with a soundtrack that provides a brief introduction to the place. Along the VR journey, a trained staff will discuss the place that the user is watching, for example, helping them recognise the items in the scene or recalling their memories associated with the place. The experience allows elders living in nursing homes to revisit familiar places in the old days and widen the horizons of PWDs even during a pandemic through VR technology. These aim to elicit pleasure and satisfaction, improve communication, and enhance self-esteem and social skills.

iii) Community-living skills training

The games include *Seven Must-Dos Before Leaving Home* and *MTR GO GO GO*. The former promotes users' awareness, especially the elders', of the seven safety measures that keep them and the living environment safe before leaving their homes. The latter aims to help PWDs develop skills in taking public transport and going to different places in Hong Kong by themselves. It simulates an MTR station scene and aims to familiarise users with travelling via the MTR under various conditions repeatedly and purposefully.

iv) Relaxing scenery experiences

Four relaxing scenes, including *Diving, River, Starry Sky*, and *Grassland*, accompanied by relaxing music, are provided. The experience aims to relieve users' physical tension, calm their agitated mood, and engage with them in an interactive virtual environment. In the virtual scenes, various interactive objects are merged with a real 3D scene. Users can interact with them and trigger a particular pre-programmed effect. Also, the scenes aim to provide a dramatic multisensory stimulation for some frail users who cannot actively engage in the other games that require limb motions.

Chapter 3 Methodology

Study Design

A single-armed pretest–posttest study was conducted in 2019-2020 with the following objectives:

(1) To explore the feasibility of offering the VGP to elders and PWDs;

(2) To investigate the participants' level of acceptance for the VGP; and

(3) To examine the efficacy of the VGP in improving health outcomes among users.

Participants

The target population included clients of the Rehabilitation Service Units and the Elderly Service Units of TWGHs, who have different types of disability. TWGHs identified and recruited potential participants to join the programme. Inclusion criteria were (1) clients served by the Rehabilitation Service Units and the Elderly Service Units of TWGHs; (2) aged 18 years or above; (3) with at least one of the following disabilities: functional impairment, mobility limitation, cognitive impairment, intellectual disability, and visual impairment; and (4) able to understand instructions in VR training. Exclusion criteria were (1) any conditions that restricted the participants from VR training or (2) severe discomfort with VR training.

The VR facility was expected to serve at least 130 clients. Depending on the functional status, cognitive status, and possible attrition among users, it was expected that at least half of the users (i.e., 65 participants) would be eligible for outcome assessments. This would result in about 80% power and 5% level of significance to detect a small to medium effect size (Cohen's $d = 0.35$) in pre–post difference.

Usage Protocol

In the evaluation study, the usage frequency, duration, and content of VR training were standardised. To date, the type of VR training, as well as training intensity and frequency to achieve desired outcomes, are not consistent. Benchmarking with other

VR programmes for rehabilitation (Bang et al., 2016; Cho et al., 2014; Kamińska et al., 2018; Lee et al., 2018), the participants of the evaluation study were encouraged to undergo a 30-minute VR training 3 times a week for 6 weeks.

The 30-minute session consisted of 10 minutes of upper-limb motion games, 10 minutes of lower-limb motion games, and 10 minutes of cognitive games/community-living skills/relaxing scenery experiences, as appropriate. The selected games/scenes included

- upper-limb motion games: *Handball* and/or *Gatekeeping*
- lower-limb motion games: *Football* and/or *Gatekeeping*
- cognitive games (classification skills): *Elephant Feeding, Feather Duster Throwing, Coin Tossing* and/or *Home Items Locating*
- cognitive games (reality orientation): *Hong Kong Footprint*
- community-living skills: *Seven Must-Dos Before Leaving Home* and/or *MTR GO GO GO*
- relaxing scenery experiences: *Diving, River, Starry Sky* and/or *Grassland*

Outcome Measures

Health outcomes, including upper-limb dexterity, functional mobility, cognitive status, and happiness, were assessed at baseline (T0), six weeks after baseline (T1), and three months after baseline (T2). Participants with conditions that prohibited them from performing certain assessments were excluded from the analysis for that outcome. Demographic information was collected at baseline only.

Upper-limb dexterity was measured by the standard Box and Block Test (BBT). The BBT has been shown to be a valid measure of dexterity of the older population (Desrosiers et al., 1994). The participants were asked to transfer blocks from one compartment to the other in one minute according to the standard procedure (Mathiowetz et al., 1985). The number of blocks transferred to the second compartment will be counted. Larger numbers indicated better dexterity.

Functional mobility was measured by the Timed Up and Go Test (TUG). The participants were asked to get up from an armchair, walk three meters, turn back, and return to a seated position according to standard protocol (Podsiadlo & Richardson, 1991). The time required to finish the task at each round was recorded. Three measurements were made. Shorter walking time indicated better balance. The best (fastest) of the three timed TUG trials was used (Kristensen et al., 2010).

Cognitive status was measured using the Montreal Cognitive Assessment 5-Minutes (Hong Kong Version) (HK-MoCA 5-Min) protocol. The validated assessment test covered four domains: attention, executive functions/ language, orientation, and memory (Yeung et al., 2014; Wong et al., 2015). The total score ranged from 0 to 30; a higher score indicated better cognitive status. The alternate version was not used in subsequent assessments, as literature suggested that the results were unlikely to be affected if the same assessment tool was used over the follow-up period (Lebedeva et al., 2016). If the participants were incapable of answering the HK-MoCA 5-Min, they were then examined using Benton's Temporal Orientation Test (BTO), which involves only questions about orientation to time (including identifying the year, month, day, day of the week, and time of the day) (O'Keeffe et al., 2011). An error score was calculated according to Benton's Temporal Orientation Scale (BTOS) (Benton et al., 1964), lower error score indicated better cognitive status.

Happiness was measured using a single question "for most of the time, do you feel..." (McCarron et al., 2013), accompanied with 11-point Likert-scale ruler or 5/3/2 facial expression pictures about happiness (Cummins & Lau, 2005). Following the pretest protocol suggested for the Personal Wellbeing Index – Intellectual Disability (Chinese-Cantonese), the intellectual ability of respondents was assessed to determine the response options (Cummins & Lau, 2005). The options (for respondents with descending order of ability) included an 11-point scale (0–10), a 5-point scale (0–4), a 3-point scale (0–2), and a 2-point scale (0–1). Then, the score was standardised into units of 'percentage of scale maximum', with a possible range of 0 to 100 and higher score indicating higher levels of happiness (Cummins & Lau, 2005).

Demographic and medical information, which included age, gender, education level, living arrangement (community-dwelling vs institutional setting), dependence status, mobility status, cognitive status, intellectual disability status, visual impairment status, medical history (e.g., stroke, fracture), and medical conditions (e.g., mental illness and autism), were extracted from the records of the residents/members at baseline.

Information on VR training including usage time and game scenarios were collected via the built-in VR software system to ensure data accuracy. In each session, the trained staff who accompanied the participants in the VR training collected qualitative feedback on the training experience, if any. Any adverse health effects (such as dizziness) induced after playing the VR games were also recorded via self-reports and staff observations.

Procedure

Upon recruitment, informed consent was sought from the participants or their legal guardians. Eligibility screening and baseline assessment were conducted by trained research assistants. Then, eligible participants were scheduled for 30-minute VR training 3 times a week for 6 consecutive weeks (giving a total of 18 sessions). Deviations were allowed according to the actual situation of the users. For example, if a week of training was missed due to sickness, the user was allowed to continue the programme in the seventh week.

In each session, a trained staff was always in the same room with the participant. The staff was responsible to assist the participants in putting on the HMD device and limb motion trackers (both hand and foot), to guide the users in playing the VR games, and to closely monitor conditions of users during game play for ensuring safety. In-between different training components, the participants could take off the HMD device and rest if needed. Any training components that is not applicable to the clients would be skipped, for example, those with total loss of lower-limb function would not be engaged in lower-limb motion training. The participants may terminate the session whenever they wished or if they experienced discomfort. Adverse events were monitored and recorded as appropriate. After each session, the staff asked the participants for feedback on their experience of VR games in that particular session, if any.

At baseline, six weeks, and three months after baseline, the trained research assistants assessed the health outcome measurements of the participants.

Data Analyses

The primary outcomes were upper-limb dexterity and acceptance of VR training. The secondary outcomes were usage statistics, functional mobility, cognitive status, and happiness. SPSS version 25 was used for statistical analyses. A 5% significance level was adopted.

The participant characteristics were summarised using descriptive statistics. Characteristics of dropout participants were examined using a logistic regression model. VR training usage statistics were calculated and used to reflect feasibility of the intervention. Linear mixed-effects models were used to analyse the change in health outcomes, adjusting for age, gender, education level, living arrangement, disability, and medical history/condition. In the first model, assessment time was used as the independent variable, and its fitted coefficients indicated the temporal change in health outcomes in T1 and T2 as compared with T0. In the second model, analysis was based on usage time, which was used as an independent variable, and its fitted coefficients reflected the change in health outcomes for unit increase in usage time. Standardised effect size in terms of Cohen's d index was calculated using the adjusted mean difference divided by the standard deviation (Cohen, 1988). A Cohen's d index of 0.2, 0.5, and 0.8 indicated small, moderate, and large effect sizes, respectively.

Content analysis was performed for the qualitative feedback on the experience of VR training. Feedback comments were grouped into positive and negative, which were further categorised into different themes. Acceptance level of VR training experience was reflected by the proportion of participants providing positive comments, with a larger proportion indicating a higher level of acceptance. Participants were further classified into three groups: (i) only or mostly positive comments, (ii) only or mostly negative comments, and (iii) no comments or equal positive/negative comments. The proportions of participants in each group were calculated. Multiple multinomial regression was conducted to investigate factors associated with a higher chance of giving positive or negative comments. Adverse health events were also summarised.

Ethics Statement

This service evaluation study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (reference number UW19-336). Written informed consent was obtained from participants or their legal guardians.

Chapter 4 Findings

Characteristics of Participants

From May 2019 to January 2020, a total of 158 potential participants were recruited from both institutional and community settings, including four homes for the severely disabled, eight homes for the intellectually disabled, six homes for the visually impaired, one old-age home, one community centre for the intellectually disabled, and three elderly community centres. Twenty-three potential participants (14.6%) were not eligible for the VGP, giving a total of 135 participants for the evaluation study. **Table 1** summarises the baseline characteristics of the 135 participants. The participants had a mean (±standard deviation [SD]) age of 62.7(±21.5). About 50.4% of the participants were male, 76.3% had an education level of primary school or below, or special educational needs, and 70.4% were living in residential care settings. All participants had at least one type of disability, with 52.6% having moderate to severe functional dependence, 78.5% requiring walking aids or wheelchairs, 28.1% having mild to severe cognitive impairment, 54.8% having mild to severe intellectual disability, and 45.9% having mild to severe visual impairment. About 9.6% of the participants had stroke history, 9.6% had fracture history, 13.3% had mental illness, and 9.6% had autism. About 91.9% (124 of 135 eligible participants) completed at least one follow-up. Some of them dropped out because of loss of interest (n = 8) while a few of them did so because of non-programme-induced injuries (n = 2) and hospitalisation (n = 1). Logistic regression model showed none of the participant characteristics was associated with dropout.

Table 1. Baseline characteristics of the participants (n = 135).

Characteristics	n (%)
Age (years), mean ± SD	62.7 ± 21.5
Gender	
Male	68 (50.4)
Female	67 (49.6)
Educational level	
Primary or below, or Special Educational Needs	103 (76.3)
Secondary or tertiary	32 (23.7)
Living arrangement	
Community-dwelling	40 (29.6)
Residential care setting	95 (70.4)
Dependence level	
Independence or slightly dependence	64 (47.4)
Moderate to severe dependence	71 (52.6)
Mobility status	
Without auxiliary equipment	29 (21.5)
Require walking aids	34 (25.2)
Wheelchair bound	72 (53.3)
Cognitive status	
No cognitive impairment	97 (71.9)
Mild to severe cognitive impairment	38 (28.1)
Intellectual disability status	
No intellectual disability	61 (45.2)
Mild to severe intellectual disability	74 (54.8)
Visual impairment status	
No visual impairment	73 (54.1)
Mild to severe visual impairment	62 (45.9)
History of stroke	
No	122 (90.4)
Yes	13 (9.6)
History of fracture	
No	122 (90.4)
Yes	13 (9.6)
Mental illness	
No	117 (86.7)
Yes	18 (13.3)
Autism	
No	122 (90.4)
Yes	13 (9.6)

Abbreviations: n, sample size; SD, standard deviation.

Usage Statistics of VR Training

A total of 1,906 VR training sessions were conducted during the study period. Ninety-one participants participated in the VR training for six weeks consecutively and another 15 participated at least six weeks intermittently, giving a total of 106 participants (78.5%) that met the suggested usage duration of six weeks (**Figure 1**). Over three quarters (76.3%) of participants attended at least 13 sessions of VR training (i.e., >70% of the proposed 18 sessions) (**Figure 2**), and the majority (72.5%) of the sessions had training time (excluding set-up time and rest time) lasted for at least 20 minutes (**Figure 3**). The total training time of the participants had a median of 316.8 minutes. Reasons for not complying with the usage protocol, including medical appointments or other engagements, limited resources, bad weather, technical problems, disability constraints, mood swings, sickness, and tiredness, were encountered in the scheduled play session.

Figure 1. Duration of VR training attended by participants (*n* = 135 participants).

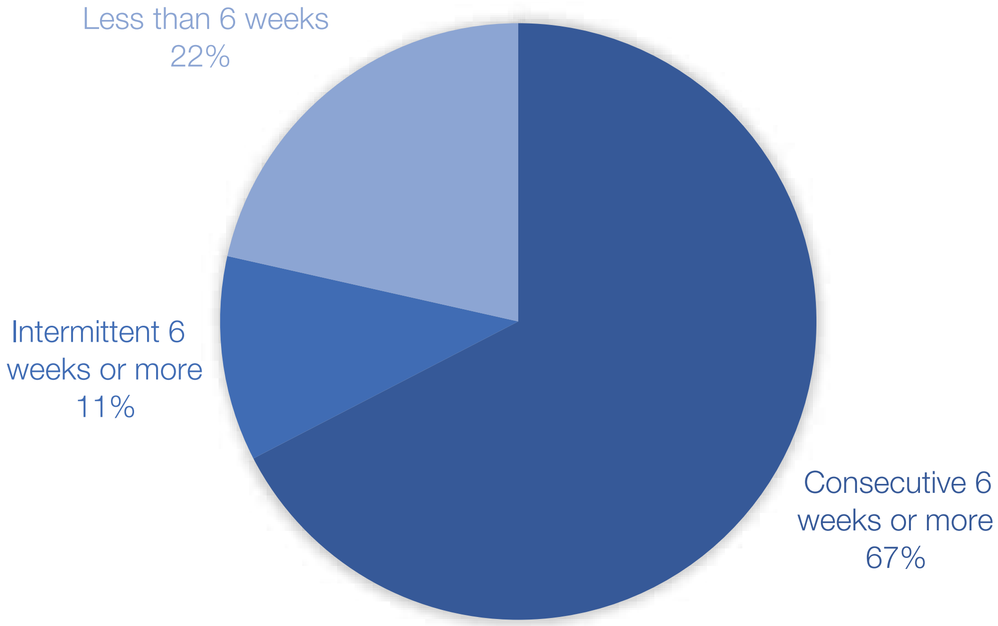


Figure 2. Number of sessions of VR training attended by participants (n = 135 participants).

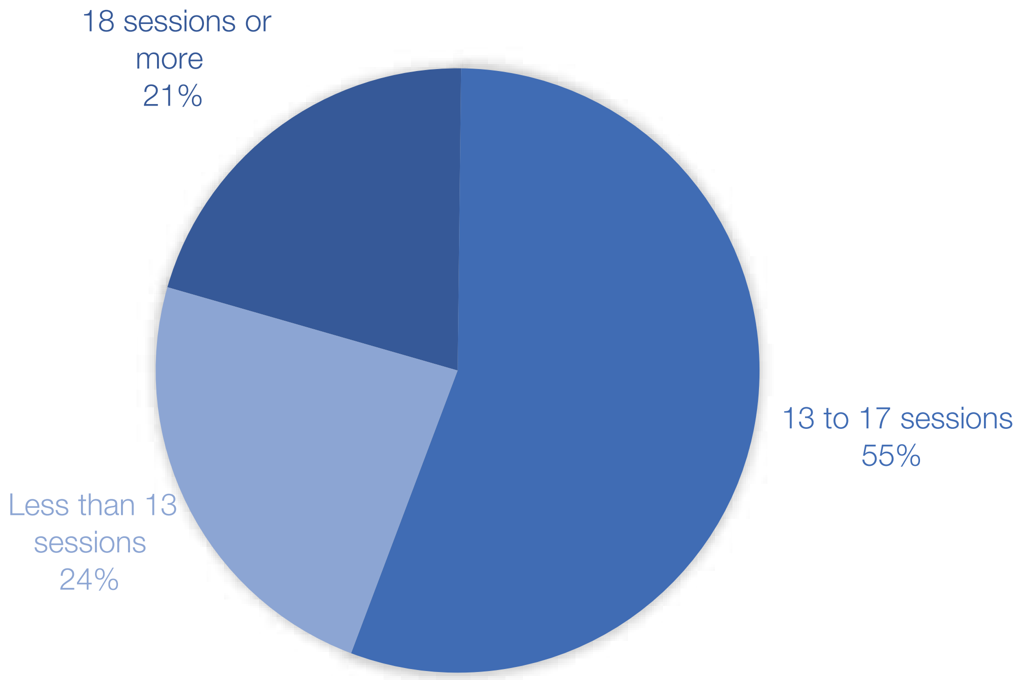
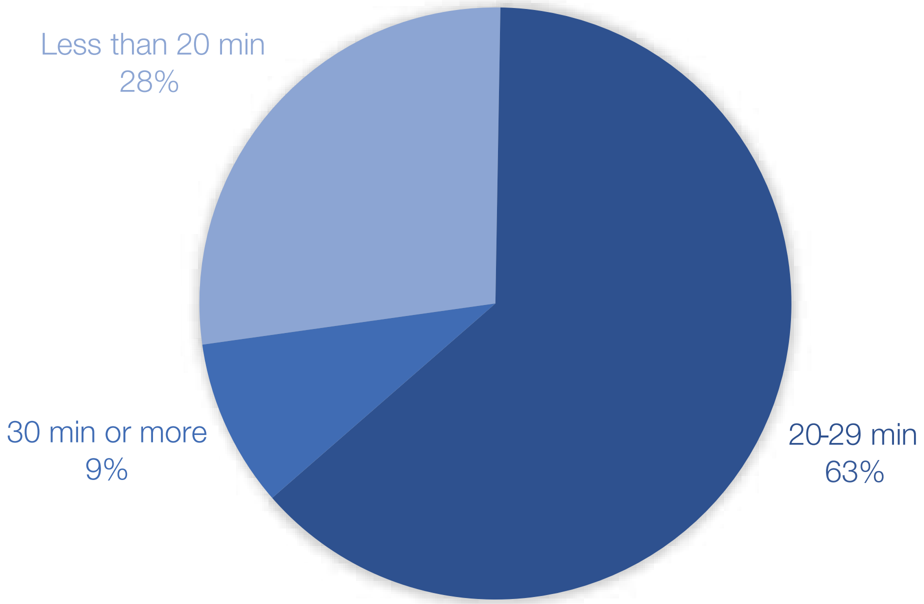


Figure 3. VR training time per session provided (n = 1,906 sessions).



Change in Health Outcomes over Time

According to their conditions, the participants received varying health outcome assessments at baseline, with BBT (n = 134 for dominant hand and n = 128 for non-dominant hand), TUG (n = 104), HK-MoCA 5-Min (n = 94), BTO (n = 30), and happiness (n = 130) (**Table 2**). **Figure 4** shows the change in health outcomes over the three assessment time points. Among the health outcomes, upper-limb dexterity (P = .008 for dominant hand and P = .043 for non-dominant hand) and cognitive function (P < .001 for overall performance) showed significant improvement over time whereas functional mobility (P = .142), orientation to time (P = .718), and happiness (P = .337) did not show any statistically significant change.

Table 2. Baseline outcome measures of the participants (n = 135).

Outcome measures	***n***	**Mean (SD)**
BBT (in blocks)		
Dominant hand	134	27.7 (14.1)
Non-dominant hand	128	28.0 (14.7)
TUG (in seconds)	104	15.4 (11.8)
HK-MoCA 5-Min score		
Overall performance	94	13.7 (7.8)
Attention domain	94	2.3 (1.4)
Executive functions/ language domain	94	3.9 (2.3)
Orientation domain	94	3.6 (2.1)
Memory domain	94	3.9 (3.2)
BTO score (in error scores)	30	37.8 (25.9)
Happiness score	130	79.1 (30.0)

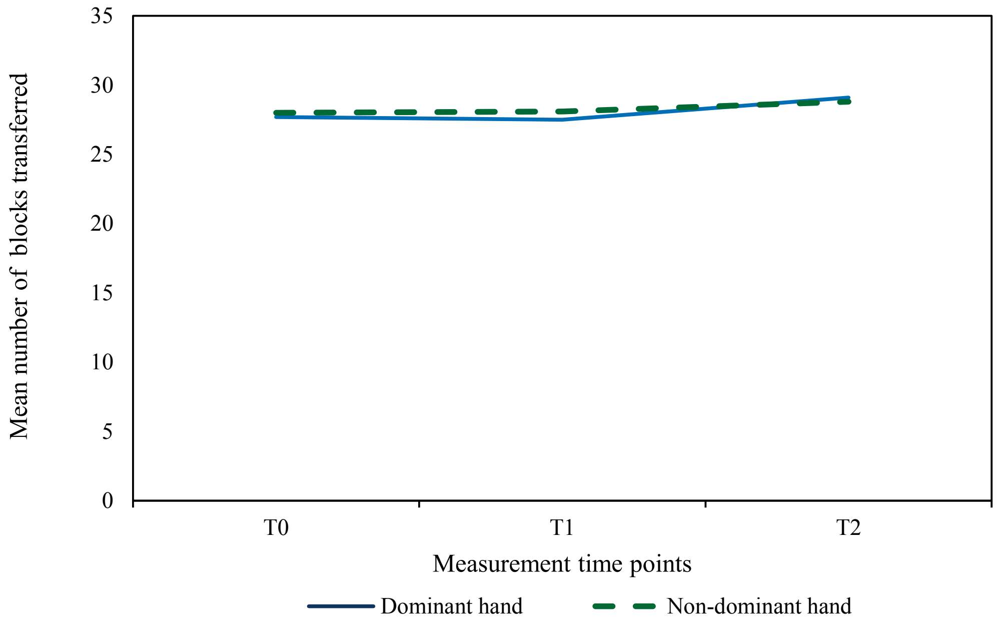
Abbreviations: n, sample size; SD, standard deviation; BBT, Box and Block Test; TUG, Timed Up and Go Test; HK-MoCA 5-Min, Montreal Cognitive Assessment 5-Minute (Hong Kong Version); BTO, Benton's Temporal Orientation Test.

Based on the linear mixed-effects models (**Table 3**), the number of blocks transferred by the dominant hand significantly increased by 2.4 blocks (P = .007, Cohen's d = 0.17), and that by the non-dominant hand increased by 1.9 blocks (P = .038, Cohen's d = 0.13) when comparing T2 with T0. However, no significant differences in number of blocks transferred were observed for both dominant and non-dominant hands when comparing T1 with T0.

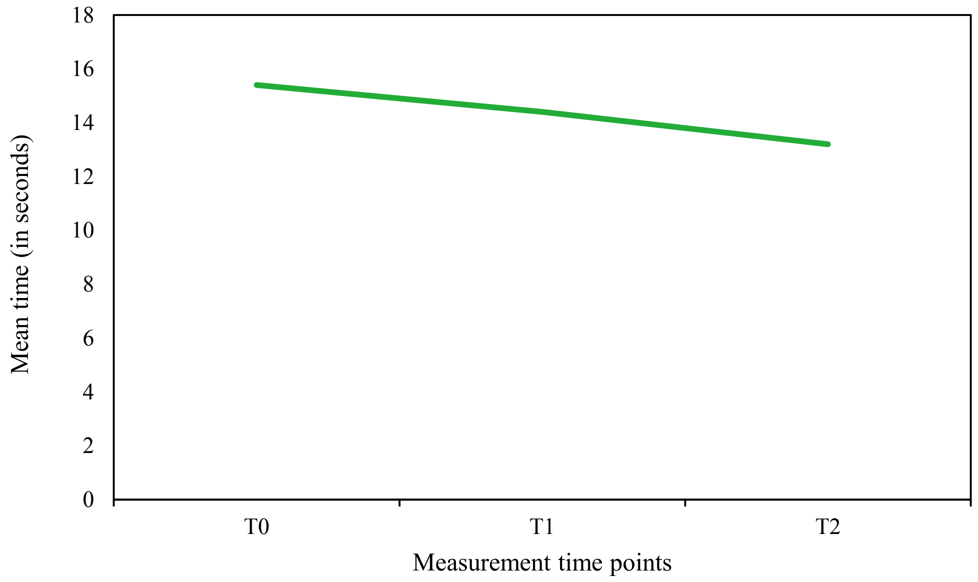
In terms of the HK-MoCA 5-Min, the overall performance score significantly increased by 2.5 (P < .001, Cohen's d = 0.31) when comparing T1 with T0, and increased by 3.5 (P < .001, Cohen's d = 0.45) when comparing T2 with T0. Significant differences were also detected in T1 and T2 compared with T0 in all domains except an insignificant difference was reported for the comparison between T1 and T0 in the orientation domain. When comparing T2 with T0, the Cohen's d of the domains ranged from 0.24 for orientation to 0.65 for attention.

Figure 4. Change in health outcomes over three measurement time points (baseline [T0], six weeks after baseline [T1] and three months after baseline [T2]).

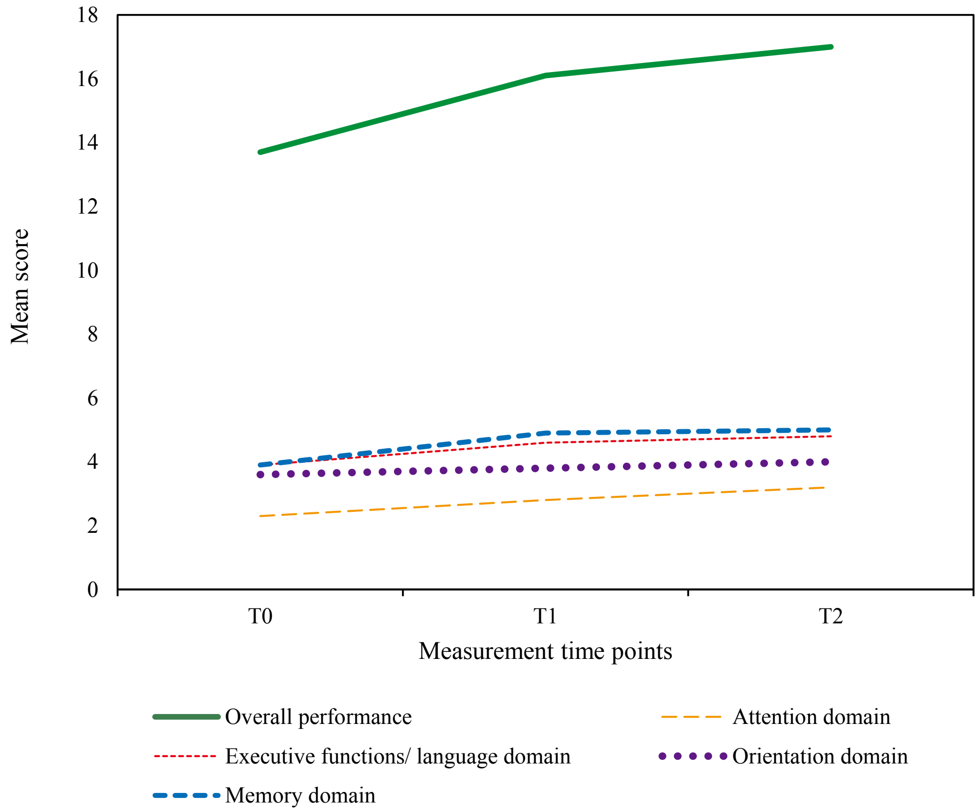
(a) Block and Block Test (BBT), larger number of blocks transferred indicated better upper-limb dexterity; P-value for time difference: .008 (dominant hand) and .043 (non-dominant hand).



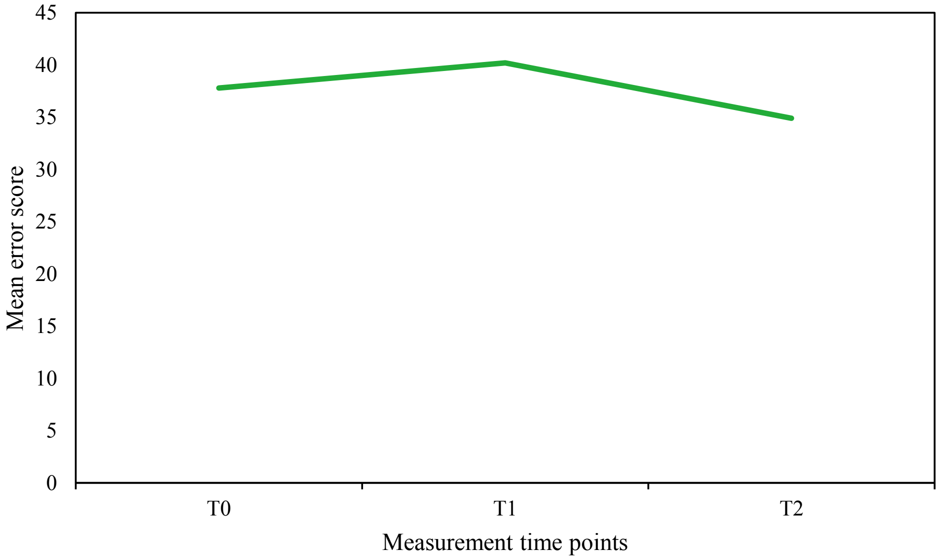
(b) Timed Up and Go Test (TUG), shorter time indicated better functional mobility; *P*-value for time difference: .142.



(c) Montreal Cognitive Assessment 5-Minutes (Hong Kong Version) (HK-MoCA 5-Min), higher score indicated better cognitive status; *P*-value for time difference: <.001 (overall performance), <.001 (attention domain), <.001 (executive functions/ language domain), .004 (orientation domain), <.001 (memory domain).



(d) Benton's Temporal Orientation Test (BTO), lower error score indicated better cognitive status; P-value for time difference: .718.



(e) Happiness, higher score indicated higher level of happiness; P-value for time difference: .337.

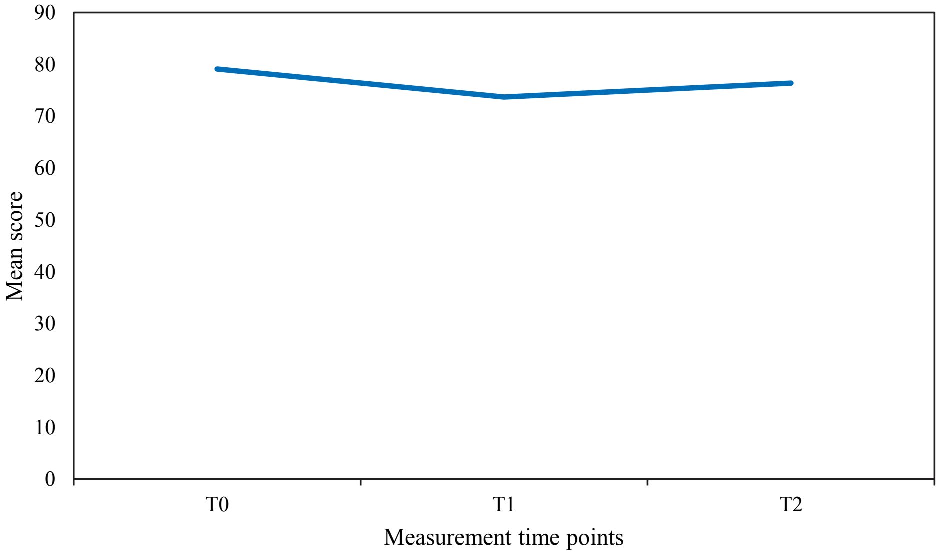


Table 3. Change in health outcomes over three assessment time points.

Outcome measures	**T1 vs T0**			**T2 vs T0**		
	Change[#] (95% CI)	**Effect size^**	***P*-value**	**Change[#] (95% CI)**	**Effect size^**	***P*-value**
BBT (in blocks)						
Dominant hand	0.7 (-0.9, 2.3)	0.05	0.391	2.4 (0.9, 4.0)	0.17	0.002*
Non-dominant hand	0.7 (-0.7, 2.2)	0.05	0.327	1.9 (0.4, 3.3)	0.13	0.013*
TUG (in seconds)	-0.5 (-1.6, 0.6)	-0.04	0.386	-1.1 (-2.2, -0.007)	-0.09	0.048*
HK-MoCA 5-Min score						
Overall performance	2.5 (1.7, 3.2)	0.31	<0.001*	3.5 (2.8, 4.3)	0.45	<0.001*
Attention domain	0.5 (0.2, 0.7)	0.33	0.001*	0.9 (0.6, 1.2)	0.65	<0.001*
Executive functions/ language domain	0.8 (0.4, 1.1)	0.33	<0.001*	1.0 (0.7, 1.3)	0.43	<0.001*
Orientation domain	0.3 (-0.005, 0.6)	0.14	0.054	0.5 (0.2, 0.8)	0.24	0.001*
Memory domain	1.0 (0.5, 1.4)	0.30	<0.001*	1.2 (0.7, 1.6)	0.37	<0.001*
BTO score (in error scores)	2.6 (-7.4, 12.6)	0.10	0.607	-1.5 (-11.4, 8.3)	-0.06	0.757
Happiness score	-4.4 (-10.6, 1.9)	-0.15	0.172	-3.5 (-9.8, 2.7)	-0.12	0.262

Abbreviations: BBT, Box and Block Test; TUG, Timed Up and Go Test; HK-MoCA 5-Min, Montreal Cognitive Assessment 5-Minute (Hong Kong Version); BTO, Benton's Temporal Orientation Test; T0, baseline; T1, six weeks after baseline; T2, three months after baseline; CI, confidence interval.

Indicators: Better condition is represented by an increase in transferred blocks from BBT, a decrease in time from TUG, an increase in HK-MoCA 5-Min score, a decrease in error scores from BTO, and an increase in happiness score.

The change in health outcomes over time were estimated using the linear mixed-effects models, controlling for age, gender, education level, living arrangement, dependence level, mobility status, cognitive status, intellectual disability status, visual impairment status, history of stroke, history of fracture, mental illness, and autism.

^ Effect size is expressed in terms of Cohen's *d* index, where 0.2 indicates small effect, 0.5 indicates medium effect, and 0.8 indicates large effect.

* Significant at 5% level of significance.

Change in Health Outcomes Based on Usage Time of VR Training

Based on the linear mixed-effects models for examining usage-response relationships, upper-limb dexterity (P = .030 for dominant hand and P = .019 for non-dominant hand) and cognitive function (P < .001 for overall performance) showed significant improvement along with increased usage of VR training whereas functional mobility (P = .336), orientation to time (P = .982), and happiness (P = .484) did not show any statistically significant change (**Table 4**).

Table 4. Change in health outcomes based on usage time of VR training.

Outcome measures	**Estimated change per minute increase in usage of VR training$^{\#}$ (95% CI)**	**P-value**
BBT (in blocks)		
Dominant hand	0.005 (0.0005, 0.009)	0.030*
Non-dominant hand	0.005 (0.001, 0.009)	0.019*
TUG (in seconds)	-0.001 (-0.004, 0.002)	0.336
HK-MoCA 5-Min score		
Overall performance	0.009 (0.007, 0.012)	<0.001*
Attention domain	0.002 (0.001, 0.003)	<0.001*
Executive functions/ language domain	0.003 (0.002, 0.004)	<0.001*
Orientation domain	0.001 (0.0004, 0.002)	0.003*
Memory domain	0.003 (0.002, 0.005)	<0.001*
BTO score (in error scores)	-0.0003 (-0.025, 0.025)	0.982
Happiness score	-0.005 (-0.022, 0.011)	0.484

Abbreviations: BBT, Box and Block Test; TUG, Timed Up and Go Test; HK-MoCA 5-Min, Montreal Cognitive Assessment 5-Minute (Hong Kong Version); BTO, Benton's Temporal Orientation Test; CI, confidence interval.

Indicators: Better condition is represented by an increase in transferred blocks from BBT, a decrease in time from TUG, an increase in HK-MoCA 5-Min score, a decrease in error scores from BTO, and an increase in happiness score.

The usage-response relationships were estimated using the linear mixed-effects models, controlling for age, gender, education level, living arrangement, dependence level, mobility status, cognitive status, intellectual disability status, visual impairment status, history of stroke, history of fracture, mental illness, and autism.

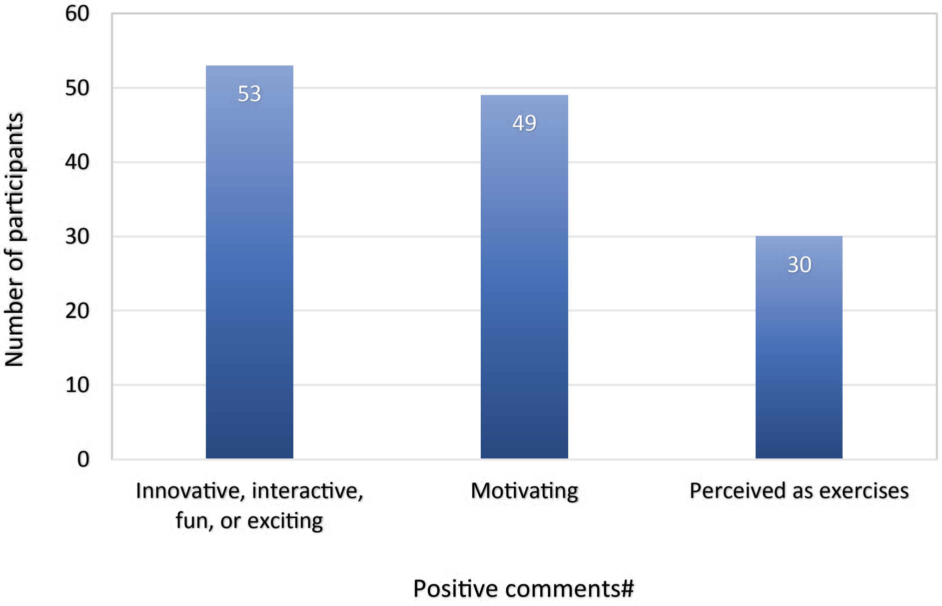
* Significant at 5% level of significance.

Feedback from Participants

Among the 135 participants, 88 (65.2%) provided positive comments#, and 63 (46.7%) provided negative ones#, and 30 (22.2%) did not provide any. Among the 88 participants who provided positive comments, 53 (60.2%) reported the VR experience as innovative, interactive, fun, or exciting, 49 (55.7%) found the experience motivating, and 30 (34.1%) perceived the VR games as exercises (**Figure 5**). Meanwhile, among the 63 who provided negative comments, 26 (41.3%) complained about the VR equipment (such as the HMD device), 25 (39.7%) felt bored, 24 (38.1%) felt physically tired, 17 (27.0%) described the experience as scary, tense, or worrying, and 16 (25.4%) reported the usage as complicated (**Figure 6**). Moreover, 38 (60.3%) of those who indicated negative comments expressed such comments during the first two game sessions.

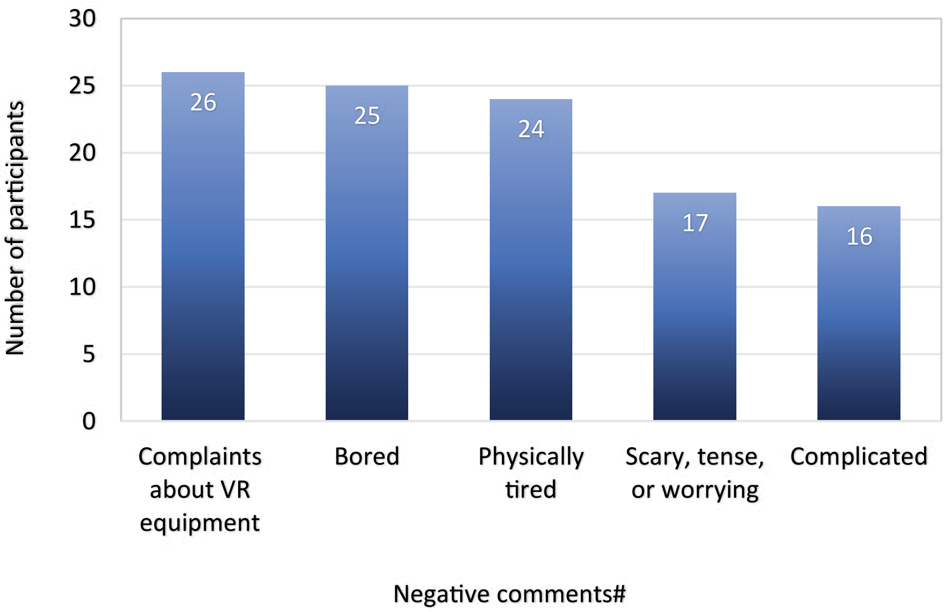
Moreover, 11 participants mentioned that they enjoyed *Elephant Feeding Game*, followed by *Handball Game* (n = 5), *Football Game* (n = 5), *Diving Scenery Experience* (n = 5), *Feather Duster Throwing Game* (n = 3), *Home Items Locating Game* (n = 3), and *Coin Tossing Game* (n = 1). At the same time, *Elephant Feeding Game* was disliked by 11 participants, followed by *Diving Scenery Experience* (n = 3) and *Seven Must-Dos Before Leaving Home Game* (n = 1).

Figure 5. Positive comments on the experience of VR training among participants (n = 88).



multiple answers allowed.

Figure 6. Negative comments on the experience of VR training among participants (n = 63).



multiple answers allowed.

The participants were further classified into three groups: those who provided only or mostly positive comments (61, 45.2%), those who provided only or mostly negative comments (34, 25.2%), and those who had no comments or provided equal positive/negative comments (40, 29.6%). Based on multiple multinomial logistic regression, home-dwelling participants ($P < .001$) and those without autism ($P = .008$) were shown to have a much higher chance of providing positive comments. On the other hand, none of the participant characteristics was associated with a higher chance of expressing negative comments.

Apart from the general feedback, reports on mild discomfort were obtained in 25 (1.3%) out of the 1,906 game sessions (14 of 135 participants, 10.4%). The most common mild discomfort was dizziness (9 sessions from 7 participants), followed by eyestrain (6 sessions from 3 participants), hand/leg pain (3 sessions from 2 participants), blurred vision (2 sessions from 1 participant), eye redness (2 sessions from 1 participant), hand tremors (2 sessions from 1 participant), and cramps (1 session from 1 participant). Over half (52.0%) of these mild discomforts occurred in the first four sessions of the VR training. None reported severe discomfort. Moreover, staff reported technical problems in 63 (3.3%) of the 1,906 game sessions.

Chapter 5 Discussions and Conclusion

Overview

The VGP demonstrated how a universal set of VR training for rehabilitation purpose can be applied to clients who are elders and PWDs, including those suffering from functional impairment, mobility limitations, cognitive impairment, intellectual disability, and visual impairment. This evaluation study explored the feasibility and acceptability of VR training for users who are elders and PWDs. Also, the efficacy of VR training in improving health outcomes over time was assessed. The findings from this study informed the future development and application of VR training to elders and PWDs in different settings.

Feasibility of Providing VR Training to Users with Different Disabilities

Few VR games have been designed for a broad coverage of different populations. The experience with the VGP was shown to be a feasible one that people with different disabilities could enjoy the same set of VR games. With different training components, clients with different disabilities could participate in suitable types of training. Nevertheless, manpower resources had to be invested in addition to the VR system, since close supervision of the users by trained staff was required.

With a rehabilitation goal, we proposed a VR game protocol of 3 days a week for 6 weeks, with a target of 18 sessions. Over 76% of the participants attended 13 sessions or more. Adherence to the proposed number of training sessions was comparable to that reported in the literature (Miller et al., 2014). Flexibility for makeup training was allowed if participants were not able to attend certain sessions. Usage statistics showed that the majority of the sessions could offer at least 20 minutes of game time. Scheduling was a critical element to the successful implementation of the programme. To facilitate a 30-minute training time, the manpower, equipment, and venue had to be made available for at least 45 minutes to allow for the necessary time for setup, instructions, and breaks. Despite the users' inability to attend all 18 sessions or spend 30 minutes of training time per session, there was a significant improvement in cognitive function and upper-limb dexterity. Hence, we propose to retain the current usage protocol until a new one with reduced usage has been tested.

In our experience, mild discomfort was reported by 14 of 135 participants (10.4%). In a local study examining the effects of VR cognitive stimulation activity (n = 236) among community-dwelling elders, 1.4% of them reported severe discomfort regarding fatigue and eye strain, blurred vision and dizziness after 20–25 minutes of VR exposure (Chan et al., 2020). However, mild discomfort was not reported. In another study conducted by U.S. researchers, it was reported that 12% of older people with Alzheimer's disease/mild cognitive impairment and 19% of older people without such conditions dropped out from the VR game because of simulation sickness (Davis et al., 2016). The proportion of participants reporting adverse outcomes among our users was comparable, if not lower, than those reported in the literature. Therefore, participants with disabilities would not put themselves at a higher risk of adverse events. At the same time, some participants reported physical tiredness after VR training. While the current study did not quantitatively investigate tiredness as an outcome, a meta-analysis suggested an insignificant difference in terms of the presence of tiredness after VR training as compared with participants engaging in traditional exercises (Ng et al., 2019).

Acceptance of VR Training among Elders and PWDs

Generally, most of the participants accepted the use of the VGP, as 88 of 135 participants (65.2%) indicated positive comments. Those living in the community and those without autism tended to provide positive remarks. This might be because these participants were more expressive of themselves. On the other hand, the HMD device and limb motion trackers might have induced discomfort, which was the major reason for negative comments. To enhance their experience and satisfaction in terms of fit and comfort, hardware designers may develop lighter devices. To accommodate the special needs of clients with limitations in head and neck movement, sensors should also be further adjusted so that clients do not need to maintain an upright position throughout the sessions.

Some participants also perceived the VR games as complicated, but they could still complete the session under the supervision of trained staff. Although some users claimed the VR training were boring, there was no evidence showing that such negative remarks were related to the proposed VR training for 18 sessions. Indeed, those who made negative comments had such perceptions in the first two sessions. This might suggest the need for more briefings or orientations prior to the usage of the VR training. In the current programme, the scoring regime had been modified to increase the users' sense of achievement. However, there was no personalised scoring regime to differentiate game difficulty levels for different disabilities over time. For future development, such feature should be incorporated for motivating clients to continue training and promoting a higher sense of achievement where progression could be felt by users.

The VR games that involved physical activity training, *Handball Game* in particular, were well received by the users. It was interesting to learn that the VR cognitive-training game featuring the elephant kept in a zoo in Hong Kong in the '70s received both favourable and unfavourable reviews from the users. Some loved it probably because it recalled memories of the old days, while some disliked it might have been scared by the elephant's roar, which was close to real life. Future design of VR scenery should take a balanced approach between excitement, calmness, and boredom.

Efficacy of VR Training in Improving the Health Outcomes of Participants

Using a single-arm pretest–posttest design, the evaluation study showed significant improvement in upper-limb dexterity assessed by the BBT and cognitive function assessed by the HK-MoCA 5-Min. Apparently, the improvement in upper-limb dexterity might be enhanced not only through the *Handball Game* but also all games that required hand movement. As understanding and following instructions to play VR games involved cognitive processing, improvement in cognitive function might be enhanced in playing all the games and not necessarily restricted to the sessions involving cognitive VR games. However, for functional mobility, although there was a favourable trend in improvement, such improvement did not reach statistical significance. It appeared that training intensity was not sufficient to achieve improvement in functional mobility. Despite the significant improvement in the oriental domain of the HK-MoCA 5-Min scale, there was insignificant change in BTO score, further research is suggested to examine the reasons. Similarly, there was insignificant change in users' level of happiness.

In our evaluation study, the HK-MoCA 5-Min overall score increased by 3.5 units. In terms of standardised effect size, such improvement was considered as moderate according to Cohen's d index, which was consistent with a recent review (Kim et al., 2019). As for BBT, the improvement among our participants was considered small in terms of Cohen's d effect size. This was consistent with a current review, which found that VR training attained small-to-moderate effects in terms of physical performance (Ng et al., 2019). Nevertheless, we would be cautious about clinical significance in terms of the improvement in BBT. Our insignificant effect in terms of mobility was also consistent with the absence of an effect in terms of gait as reported by the same review (Ng et al., 2019).

The evaluation study did not show any significant change in happiness level. This was consistent with a recent systematic review of VR exercise training that reported insignificant effects on psychological outcomes such as calmness and enjoyment (Ng et al., 2019). The review also suggested that immersive components of the VR training and longer follow-up periods tended to be associated with smaller benefits, yet statistical significance was not found. As the design of the VR games was to promote functional and cognitive ability, if happiness was to be enhanced, the content of the VR games might have to be adjusted, and a regular playing schedule might not be applied.

Strengths and Limitations of the Evaluation Study

The strengths of this evaluation study were its large sample size, adoption of validated scales as outcome measures and long follow-up period. The qualitative feedback from the participants also informed the strengths and weaknesses of the VGP. However, the study was also subject to limitations. First, the lack of a control group might have limited the interpretation of the results. Second, people with hearing impairment, bed-bound, or disability in turnaround were not included in the study, and the potential benefits or adverse effects on these users could not be reflected from the current study. In addition, progression of game difficulty level was not standardised in the usage protocol.

Implications for Practice

As a universal set of VR training was shown to be applicable to clients at advanced age or with different disabilities, the service providers can be equipped with one set for general rehabilitation purposes. The following experiences from the VGP could be considered for the future development and improvement of VR programmes:

In terms of *hardware*:

- The running of a VR system installed in a desktop computer is more stable than those in a gaming notebook. However, the latter is portable and can be used in different places.

- The quality and compatibility of the display card for a VR system is critical in the scope of system speed and stability.
- The HMD device and limb motion trackers with user-friendly design and lighter weight can promote a comfortable usage experience and user satisfaction. Besides, they should be able to precisely synchronise various users' body positions, such as standing, sitting, or even lying down.
- Modified trackers should also be developed to detect extremely low physical movement to cater to frail users.

In terms of ***software***:

- For clients with cognitive and visual perceptual limitations, the backdrop and characters of VR games cannot be too fancy or stimulating.
- Special consideration should be given to designing the range of motion and motion-detection sensitivity within the system according to the reaction time and limited range of motion of elders and PWDs.
- A personalised and easy scoring regime, along with diversified audio and visual reinforcement, could promote a higher success rate and sense of achievement.
- Scaling the difficulty of the participants' goals, as well as setting the pacing of difficulty precisely is very important for users' participation.
- For advancement, the game difficulty level has to be progressed objectively based on the personalised scoring regime via the system, but this may be limited by a large database of clients' VR game usage and confined by the complexity of different disability conditions. Whether changes in game difficulty level are determined by the practitioner or the system remains questionable and needs to be further explored.
- Aside from game difficulty level, a more interesting reward system could be incorporated, such as getting special positive reinforcement after achieving enough scores. These advancements could facilitate and maintain game excitement and fun. The users could thereby engage with a more successful and enjoyable VR training.

In terms of *usage protocol*:

- In the VGP evaluation study, usage frequency, duration, and content of VR training have been standardised, while at the same time, flexibility has to be allowed to cater to individual needs or the caring schedules of disabled participants.
- An initial decision on whether to prioritise entertainment or rehabilitation has to be set. To achieve a rehabilitation goal, a protocol with standardised frequency, duration, and content of VR games must be followed. On the contrary, if the VR games are provided simply as leisure activities, such strict protocol can be released.

In terms of *research*:

- Along with remarkable advancements in VR technology, future research should continue to investigate the optimal modalities in the domain of physical, cognitive, and psychological training for people with different vulnerable health conditions. Moreover, a controlled trial would be preferred.

Conclusion

To conclude, this report detailed the design, implementation, and findings of the evaluation study on the VGP developed by TWGHs. A protocol with standardised usage frequency, duration, and content of VR trainings was set for general rehabilitation purposes. Findings from this study showed that a universal set of VR training was feasible and acceptable for local elders and PWDs, including those with functional impairment, mobility limitation, cognitive impairment, intellectual disability, and visual impairment. Benefits to upper-limb dexterity and cognitive function were observed despite partial compliance to the protocol. The findings informed the future planning and application of VR training to elders and PWDs in different settings. With the experience from the VGP, recommendations for future practice were made accordingly in terms of hardware, software, usage protocol, and research.

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Evaluation Report of VRehab Generation Programme

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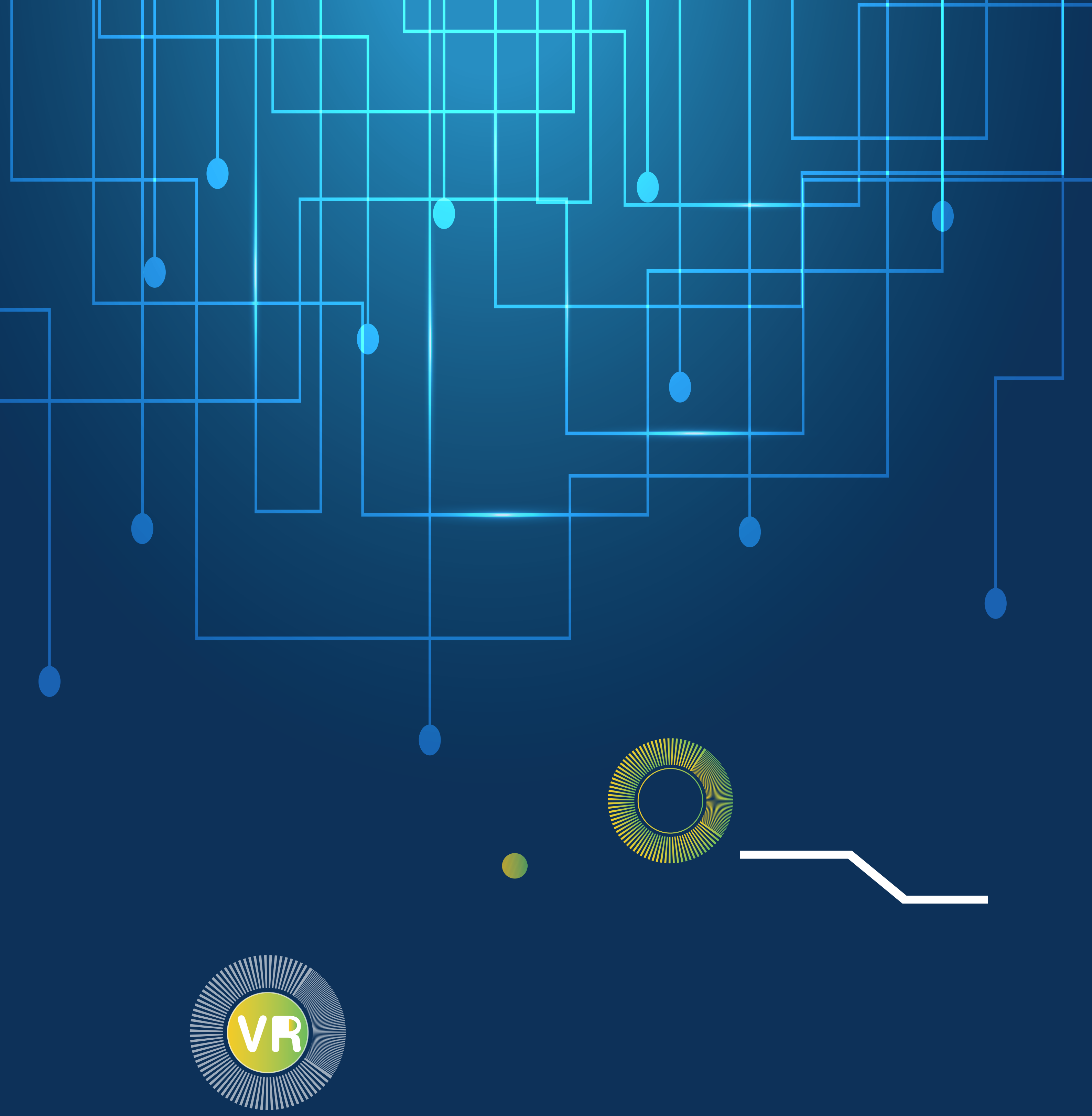

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