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Virtual rehabilitation: What are the practical barriers for home-based research?

Kate Threapleton¹, Avril Drummond¹ and Penny Standen²

Abstract

Virtual reality technologies are becoming increasingly accessible and affordable to deliver, and consequently the interest in applying virtual reality within rehabilitation is growing. This has resulted in the emergence of research exploring the utility of virtual reality and interactive video gaming interventions for home use by patients. The aim of this paper is to highlight the practical factors and difficulties that may be encountered in research in this area, and to make recommendations for addressing these. Whilst this paper focuses on examples drawn mainly from stroke rehabilitation research, many of the issues raised are relevant to other conditions where virtual reality approaches have the potential to be applied to home-based rehabilitation.

Keywords

Home-based, rehabilitation, virtual reality, gaming technology, interactive video gaming, commercial gaming, virtual rehabilitation

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Introduction

Technology is developing rapidly and the interest in applying virtual reality (VR) technologies within rehabilitation is growing. As well as enabling the development of complex and expensive VR systems for use in controlled clinical environments, recent technological advances have also led to the emergence of more affordable and accessible systems for use in a range of settings. Consequently, therapists are now beginning to evaluate VR systems that can be delivered and subsequently self-managed by patients within their own homes.^{1–4} This is an emerging research area, and whilst home-based VR applications may offer a range of benefits for rehabilitation, they also bring a new level of challenges for researchers to overcome. This paper highlights the practical issues that may be encountered when conducting VR research within patients' homes and suggests approaches to addressing these.

VR refers to systems or devices that allow users to interact with computer-generated scenarios, objects and events.⁵ This may range from high-end systems where a user is immersed within a virtual environment via a head-mounted device, to non-immersive lower-cost systems displayed on flat-screen monitors.^{6,7} This paper focuses specifically on lower-cost VR systems that are more likely to be used within a home environment and

includes interactive video gaming and commercial gaming systems, such as the popular Nintendo Wii (Nintendo, Kyoto, Kyoto Prefecture, Japan) or Microsoft Kinect (Microsoft Corp, Redmond, Washington, USA). Whilst such mass-market gaming systems have not been designed for clinical or therapeutic use, their accessibility and potential for clinical application has led to increased interest in their use within rehabilitation.^{1,5,8–13} For example, soon after the release of the Wii console there were reported examples of its use within clinical settings and care homes, with the term 'Wii-hab' emerging as a result.¹⁴ Advances in commercial gaming systems have also facilitated the development of bespoke lower-cost interactive gaming systems specifically for rehabilitation where customised hardware and/or software have been used in conjunction with commercial devices.^{2,3,15–18}

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A key appeal of virtual rehabilitation is its potential to increase the frequency and intensity of guided therapy that patients are able to receive compared with standard approaches,¹⁹ without creating additional burden on therapists' already heavily constrained time.^{9,20,21} As the population ages and staffing pressures consequently mount,⁹ VR may enable more patients to participate in controlled programmes of therapy at home. The inherent properties and flexibility of VR have the potential to increase patients' engagement, motivation and adherence to therapy, especially when undertaking repetitive tasks or exercises that they may otherwise find mundane.^{22,23} If patients are more able to self-manage their own rehabilitation and determine when activities are undertaken, they might feel more able to fit this around factors such as fatigue or other commitments, such as hospital appointments, care needs or social activities.⁸ VR also reduces the need for transportation to clinical settings to undertake rehabilitation, and has the further advantage of being able to deliver immediate feedback to patients regarding their task performance.⁶

Research into the use of VR and gaming interventions in rehabilitation settings is still in its relative infancy, but has received significant attention in the field of motor recovery after stroke.^{1,5-7,9,10,14,24,25} The findings regarding its effectiveness have, however, so far been mixed.^{7,9,10,24} A recent Cochrane systematic review found limited but promising evidence to suggest that VR interventions are effective in upper limb rehabilitation after stroke compared with standard approaches.⁹ However, the reviewed trials tended to be somewhat small and exploratory, had varied outcome measures, and the interventions used differed greatly in terms of setting, type and dose of intervention delivered.⁹ Where positive effects have been shown, the reviews found that the evidence was limited in both size and quality, and concluded that, although VR may be promising, there is a need for ongoing high-quality research in this area to more clearly determine the potential benefits for rehabilitation.^{7,9} This is further echoed by calls for researchers to understand what the 'active ingredients' are in VR interventions, such as in relation to dosage, in order to produce carefully designed trials to determine their effectiveness.¹⁴

Although the current evidence is mixed, as VR technologies develop to become increasingly affordable and accessible it is likely that they will continue to grow in popularity within rehabilitation settings.⁹ There has been increasing interest from patients as well as clinical interest in the potential therapeutic benefits that commercial games systems may offer for rehabilitation.^{11,26,27} The first major randomised controlled trial (RCT) in the UK investigating the effectiveness of the Wii for home-based upper limb rehabilitation after

stroke (Trial of Wii™ in Stroke – TWIST) found that although the Wii was positively received by participants, it did not prove more effective than standard upper limb exercises and also had higher associated costs.²⁸ However, the majority of participants in this study valued the potential therapeutic benefits of the Wii, and perceived their upper limb function as having improved following its use. Further to this, some also reported improvements in their mental well-being.⁸

Despite the potential benefits of using VR and gaming technologies within rehabilitation, and recent evidence to suggest that VR and gaming interventions are acceptable to deliver in the community,^{8,28} research into this area remains potentially problematic. Where home-based trials have been conducted, aside from detailing what equipment was used, there has often been insufficient detail provided regarding the practicalities of how the equipment was installed, accommodated and accepted within participants' homes and whether any key issues were encountered during this process.^{25,29,30} Delivering any intervention within a home environment may entail a variety of complexities and challenges, since the home environment cannot be easily controlled, recorded or monitored, and is subject to wide variation. Added to this, rehabilitation research is likely to involve target populations who are likely to be relatively inexperienced in the use of new technologies, and may also be living with assistive or care needs.

This paper aims to outline the practical challenges for consideration in using VR technologies in the home environment and in planning future research in this area. This is a guide for researchers interested in developing and testing VR and gaming systems for rehabilitation outside of the clinical setting, and is intended to bridge the current gap in the literature in relation to the practical issues that may arise. It is hoped that this sharing of the issues encountered and lessons learned from research into VR in home-based rehabilitation will improve the quality of future research and generate findings to add to the evidence base for its effectiveness.

Recruitment issues

Although rehabilitation research encompasses a multitude of conditions and spans a broad range of age groups, research involving patients with, for example, stroke or Parkinson's disease typically involves an older target population. Whilst therapists may be inclined to view age as a barrier to engaging with technology, it is important not to assume that this accurately reflects older patients' own perceptions, nor that older adults will be unwilling to take part in research of this nature.³¹ Older patients with little experience of using

computers previously have found using gaming as part of their rehabilitation enjoyable,^{8,10,29} and age has been found in one study not to correlate with the frequency of use of a home-based VR gaming intervention.²

However, preconceptions of which patients are or are not likely to be interested in using technology may still influence who is initially screened and invited to take part in the research, even if this is not relevant to the inclusion or exclusion criteria of the study. With VR and gaming, ‘younger’ participants may be assumed to be more suitable for these studies, and thus there will be implications for the representativeness of findings. For example, in one systematic review of the use of commercial gaming consoles for stroke rehabilitation, it was reported that most participants were aged in their 50s or 60s,¹⁰ whilst the average age of stroke survivors is higher.¹² Over the recruitment period, it is therefore advisable to continually monitor how participant screening is being undertaken according to the stipulated inclusion or exclusion criteria within the protocol, and to ensure that potential participants, such as older patients, are not being unnecessarily excluded from taking part.

An additional factor influencing recruitment may be the specific inclusion or exclusion criteria in relation to the use of technology, such as the need for participants to have a suitable internet connection or sufficient physical space in order to use the VR or gaming device.^{3,16,18} As part of the participant screening process, it is essential to have clear guidance on any such criteria, and to be able to efficiently assess whether the home environment of a potential participant is suitable. Any equipment that requires particular resources or parameters for it to be used effectively at home is likely to exclude some otherwise suitable patients from participating, and thus recruitment timeframes are likely to be longer as a result. For example, Kiselev et al.³ developed a home-based VR system to deliver falls prevention exercises to older adults. Due to the system specifications, participants were only included in the pilot RCT if they could already use a computer, had a high-speed internet connection, and had sufficient space to be able to accommodate the hardware at home. The pilot RCT aimed to recruit 30 participants; however, only five were attained within the given timeframe. Key reasons cited for the low recruitment rate were the lack of high-speed internet connection and lack of space for the system. Such a high-speed internet connection is not likely to be essential for most systems used, although it may enable patient monitoring to be carried out more efficiently and may thus help to reduce the number of home visits required to monitor progress. This may offer benefits in relation to study costs and resources, especially where therapists’ availability is limited or there is a wide geographical spread of participants.

Equipment set-up

There are likely to be many factors affecting how the research equipment can be set up and accommodated within a participant’s home. Some interventions may simply require a gaming device that can be used with the patient’s existing television,¹⁸ whereas others may have more extensive requirements. Standen et al. provided participants with an all-in-one desktop PC in a study of upper limb rehabilitation after stroke.² Whilst this ensured that there were no compatibility issues with the software, and a large monitor was available for all participants, it also required sufficient space for the equipment on a suitable table for the duration of the intervention. The majority of participants were able to accommodate this, although some needed a suitable table to be provided along with the equipment.

Similarly, a pilot study utilising a modified Microsoft Kinect system to deliver a home-based exercise intervention for older adults also provided participants with an all-in-one PC.¹⁶ This equipment was supplied after a previous survey of older adults showed that, even though the majority owned a desktop computer, they were typically too old to be compatible with the Kinect system. However, in some cases setting up the all-in-one PC proved problematic due to its size and bulk. Although the participants were willing to accommodate the equipment for the duration of the intervention, many did not regard it as an acceptable long-term solution and would have preferred a system that could be integrated with an existing computer monitor, PC or television.¹⁶

Resolving issues concerning equipment set-up may result in additional unforeseen demands on time and cost, and could result in delays before interventions can commence. Even in cases where set-up appears straightforward, there may be ongoing issues with, for example, the appropriate height of tables and chairs. Accommodating the equipment could also involve the need to rearrange other household items, or may impede the participants’ daily activities and the needs of other family members.³² If existing televisions or monitors are compatible with the system being used, these may not be large enough or positioned correctly. VR or gaming systems that respond to movements from the whole body, such as the Kinect or Sixense STEM system (Los Gatos, California, United States), typically require a large furniture-free space at a particular distance from the equipment in order to respond accurately. Many homes simply do not have this space to accommodate such systems. Patients may also have had to accommodate various items of assistive equipment into their homes, such as commodes, wheelchairs or walking aids, or may have had to adapt to downstairs living. It is important for researchers to be

sensitive to any changes that patients have already had to make to their home environment, and to be aware that accommodating additional research equipment may not be acceptable to all participants.²⁸ Some participants may also want to store the equipment in between usage if space is limited; however, this may or may not be possible for the system, and will involve more time being spent repeatedly setting up the equipment.^{4,32} Potential costs to participants may be a further consideration, such as in cases where additional electricity usage poses a concern (e.g. ‘pay as you go’ electricity meters).

As well as factors such as the size of the equipment and the space required in the home, general aesthetics may also be a factor affecting participant acceptance of the intervention. Prototypes/bespoke equipment produced specifically for research purposes are likely to have been developed within a constrained level of resources and timeframe, where the focus on aesthetics is therefore of lower priority. Participants may therefore perceive such equipment as being ‘clunky’, ‘bulky’ or ‘ugly’ compared with commercially available systems and this may affect their acceptance of it within their home. Further to this, it is also plausible that the overall appearance of the equipment may affect how scientifically rigorous or ‘seriously’ the invention is viewed by participants, which may in turn affect their engagement with the intervention.

It is therefore recommended that open discussions concerning the equipment and the potential implications of its use within the home are held early in the recruitment process. This can help to manage and set realistic expectations. Photographs of the equipment could be helpful as part of this process to provide a guide of what equipment is involved and the amount of space required. During the participant screening process it is advisable to establish a detailed checklist of the essential requirements that need to be met in order for an intervention to commence, such as the amount of floor or table space required, specifications of existing televisions or monitors, need for carer support with equipment, etc. Any requirements that may not easily be fulfilled (such as having high-speed internet connection) should form part of the exclusion criteria for the study. However, as discussed above, such stipulations are likely to have an impact on recruitment rates. Early screening of participants’ needs could also help to streamline the initial set-up and training phase by identifying potential issues prior to issuing equipment, for example whether using a computer mouse or touchscreen to navigate the software will be problematic for the participant, and an alternative joystick or other accessible controls will be required.³³

Transporting and delivering the equipment to participants could also pose further difficulties. Access to a

car is generally a necessity, and suitable nearby parking both at the workplace and at the participant’s home needs to be available. Handling heavy equipment may pose problems, especially for a lone researcher and/or where there are parking restrictions. In some cases a trolley, or more than one researcher, may be required to help move equipment. There may also be issues of safety surrounding both the transportation of the equipment and the researchers’ own personal safety. Issues to consider include the potential risk of theft or damage to the equipment and the need for adequate insurance cover. These issues may add a level of complexity and further cost to the intervention and need to be included in the research budget.

Participant training

Careful consideration should be given to the training that participants will be given to support their use of VR and gaming interventions, as the participant needs to understand not only how to optimally perform the exercise/therapy, but also how the associated system is used. The level of training required may depend on the participant’s level of functioning, prior experience with computers/technology, and familiarity with rehabilitation. Participants may need ongoing training or reassurance throughout the intervention to support their independent use of the equipment.² Written instructions are a useful tool to provide prompts about set-up and use of the equipment, as well as more detailed instructions on handling common difficulties.^{2,25,30} Written materials should be accessible, using pictures and illustrations to avoid lengthy sections of text.

Carers and relatives may also play a role in the participant’s engagement with the intervention.⁸ The TWIST trial reported that carers were more likely to be involved in the Wii intervention where participants were less physically able, and often helped with setting up the equipment for the participant.⁸ Some also played a role in motivation, supporting the patient to continue with the intervention throughout its duration.⁸ Although it is beneficial to involve carers with the training process where possible, the level of their involvement should be directed by the participant, as maintaining and asserting ownership of the intervention might be important factor for some participants that may influence the level of support they are willing to receive.⁸

Other factors to consider are the possibility that carers may not have a great deal of experience or interest with computers themselves, and thus may not be able to provide support.⁸ Carers’ overall level of interest in the intervention or research may also influence participants’ adherence and motivation, and could be a factor in early abandonment due to lack of

engagement. A further factor may be the research therapists' own engagement with or interest in technology. Wider research has indicated that, for clinical staff, previous experience with technology is associated with a more positive attitude towards the use of technology for rehabilitation purposes.³⁴ In the TWIST trial it was reported that some therapists involved in delivering the intervention had no prior experience of use of the Wii.⁸ Those therapists with little experience may not feel confident in delivering the intervention or able to offer technical support for minor issues. Training and ongoing support for the research team is important not only to ensure that they are confident with the intervention and using the associated technology, but also that the intervention is delivered in a consistent manner across all participants.

Adherence and monitoring

As with other research interventions, the use of VR and gaming interventions needs to be flexible in relation to participants' other commitments and routines. Researchers may need to delay commencing the intervention if there are conflicts of timing with, for example, planned holidays, hospital stays, bouts of illness, etc. Whereas one study reported that a participant missed 1 week of a 5-week VR intervention due to a scheduled holiday,³⁰ another reported that a participant was able to accommodate the intervention by taking the Wii with them on holiday.⁸ Seasonal changes may also affect recruitment uptake or adherence, as participants may, for example, prefer to spend more time outside during the summer months.²⁹ Depending on equipment availability, participants may also need to wait to commence the intervention if the equipment is already in use at the time of joining the study. Where there are delays to commencing the intervention, there is also a risk of participants losing interest in the interim and subsequently withdrawing from the study.

Participants' use of the technology will need to be appropriately monitored for the duration of the intervention. Clear procedures should be in place as to how monitoring will be conducted and recorded, and the monitoring strategies will need to be both convenient to the participant and feasible for the research team. The level of support required is likely to vary between participants. Regular visits and phone calls to participants can provide general support and encouragement,^{2,16} and may be especially important where participants live alone or do not have family nearby.⁸ However, whereas some participants may welcome weekly phone calls and/or visits, others may find this too intrusive or unnecessary. Likewise, travel to a research clinic for monitoring may be time-consuming, tiring and ultimately inconvenient for a participant,

even if transport is provided. Remote monitoring of participants' use of the equipment may be possible with some more sophisticated VR systems,³⁵ but this data can only be of value if it is of a type that can then be easily utilised in a meaningful way.²³

Monitoring is important to ensure the VR intervention continues to provide an appropriate level of challenge tailored to individual participant needs and progressed across the duration of the intervention; for example, introducing the participant to new games that have varying levels of challenge at different time points over the course of the intervention.³⁰ This is particularly important where repetitive exercises are involved, to prevent boredom and/or frustration and maintain adherence.^{2,6} Games that are hard to play are likely to be seen as frustrating, and games with little challenge as boring.⁸ Other specific issues that may need to be identified as part of monitoring include under- or overuse and/or incorrect use of the equipment to optimally and safely perform the therapy, and any other issues that the participants may be unlikely to alert the researchers to independently. In one series of exploratory studies to trial the use of a home-based gaming system for upper limb exercises after stroke, participants were reviewed on a weekly basis at a clinic by a research therapist to ensure the exercise movements were performed correctly and with no risk of potential injury.^{25,29,30} Participants were instructed to use the games 'as much as they liked' at home over a 5-week intervention duration, with the system imposing a 5-minute break for every 15 minutes of play to prevent overuse. Some participants, however, reported that they felt this imposed break was irritating or overly long.^{25,29,30}

Whilst patients' ability to self-manage can be an advantage of using VR and gaming interventions, there may be issues regarding how accurately rehabilitation activities are carried out when researchers are not present to oversee this. For example, with an intervention involving a gaming element, it may be that the participant becomes more concerned with 'successful' gameplay rather than the quality of movements they are making, and thus it is possible that maladaptive or compensatory patterns of movement may result.^{5,22} This is especially relevant for systems that are unable to provide real-time feedback to participants regarding whether they are correctly performing the exercise (such as commercial devices like the Nintendo Wii). Participants may also find that the standard feedback provided by commercial devices is not motivational where they are likely to struggle to score well on the games.³⁶ As with any therapy regime that patients undertake independently, the importance of the quality of the exercise should be stressed across all training and monitoring. Involving carers can also be another useful approach to limit the occurrence of compensatory movements. Although carers cannot be expected

undertake the role of a therapist, they can be advised and trained on key areas relevant to the intervention, such as managing correct posture, especially where the participants' proprioception is impaired.

In terms of the types of data obtained as a result of monitoring, it may not be possible to track all potentially relevant aspects of a patient's use of the equipment. Some commercial systems may only be able to provide limited information, such as overall scores achieved, whereas more detailed information, such as total time spent engaged with the activity over time, may be somewhat harder to track. Whilst some systems may be capable of generating a vast array of data, only some of this will have potential clinical relevance and utility.

In some cases, patterns in the data may help to identify cases where the equipment has been used in a different way than was intended, for example, where performance scores appear better than expected. Anecdotal feedback in one trial highlighted that on occasion a participant had tried the intervention using their unaffected upper limb to see how well they could perform 'normally'.² Depending on the frequency and extent to which these altered patterns of use occur, they may or may not impact on the findings of the trial, but such outliers may need to be identified in the data. Similarly, family members might be curious to try using the system, particularly if it involves a gaming element. Although the intervention should be focused on the participant, it might be unrealistic to expect that interested family members will not be tempted to 'have a go' themselves, especially if they are supporting the participant in their rehabilitation. This level of interest from family members been shown to help encourage and motivate participants across the intervention duration.² It may therefore be pragmatic to preempt such instances by including guest user profiles within the system that will allow them to use it without their data being misidentified as belonging to the participant,^{2,25,29} rather than instructing them not to use it at all. It is, of course, difficult to ensure that the participant and/or family members will always remember to use these alternative user profiles and that they will not accidentally alter the individual settings for the participant.

Equipment usability, reliability and maintenance

Equipment usability, reliability and maintenance are vital aspects contributing to the success of the research. If a participant is unable to engage with the intervention at the recommended frequency due to usability issues or equipment failures,³ this will have implications for feasibility as it will be quickly abandoned by participants. Equipment failures may also threaten data recording, storage, and retrieval for the research,³ as well as the remote transfer of data.

Research involving prototypes/bespoke systems may entail a greater likelihood of equipment breakages and usability issues than that involving commercially available devices. Appropriate usability testing should be undertaken ahead of feasibility, pilot or efficacy studies. However, to ensure that prototypes are sufficiently robust for repeated use outside the laboratory, appropriate pre-testing should also be carried out in the environment for which the intervention was devised.³ Thus, interventions aiming to provide home-based therapy should be pre-tested within domestic environments to identify and resolve any immediate technical and installation issues. Factors affecting the optimal setup, calibration and performance of different systems are more easily monitored and controlled within a laboratory setting, such as the height and distance of the device in relation to the user and environmental interference,³⁷ but may not be as readily controlled within home environments.^{2-4,16} Home-based testing is also beneficial where larger items of equipment are required in order to assess how it is best to package and transport these items safely.

The user interface and graphics for prototypes/bespoke systems may also be viewed as basic and/or less sophisticated compared with commercial counterparts. Whilst this in itself may not be an issue, especially for novice users, these systems are more likely to be in the early stages of development and therefore might have greater associated usability issues, for example, menu options that are hard to navigate, have distracting colours/graphics, small text, or use jargon. Equally, for the hardware/equipment it may be necessary to ensure that on/off switches are easy to locate, or that it is easy to charge or replace batteries where relevant. Prototypes/bespoke systems should nevertheless offer a clear advantage in that they are being designed for a specific end user in relation to their needs. It is therefore vital that, throughout the design process and usability testing, there is appropriate feedback from the end users, such as patients and clinical groups.³² Even with appropriate pre-testing, problems may however still arise that were not apparent during the early development phases.³ Finally, any pre-testing within patients' homes must also be covered by appropriate ethical and governance approvals.

Should technical problems be encountered during participants' use of equipment, there must be appropriate capacity and resources to respond to this in a timely manner. Participants should be provided with a contact telephone number,² and if staffing levels mean that technical support is unavailable outside of normal working hours, then a dedicated phone line with messaging facilities should be provided which is checked regularly and remotely. However, participants may not always use this facility to alert the researchers

when technical issues arise,² and therefore it should not be used as a means to reduce the overall levels of monitoring required. It is also important to record the types of difficulties encountered by participants, from equipment failures to general usability issues, so that they might be resolved in future iterations of the system. For any issues that cannot readily be resolved, additional technical support will be required. Such issues could result in the equipment being removed from the participant's home until the problem can be fixed, and/or replacement equipment being provided. Availability of spare equipment will help to prevent delays, although this will have implications for the research budget. In some cases it may be necessary for a person with technical expertise to visit the participant's home to rectify any issues. It will be necessary for this person to be named on the required research governance approvals prior to the trial starting, so that the required authorisations are in place to conduct visits to participants. It will also be necessary to factor in additional costs for such maintenance visits, including staff time and travel, during the study planning stages.

Safety and insurance

Evidence to date suggests that VR interventions are safe for home use.^{8,10} However, it is the researchers' responsibility to ensure patient safety when using the issued equipment, and any equipment supplied to participants must be safe as well as reliable. Although participants are able to buy any commercially available gaming systems for their personal use at home without any input or guidance from a therapist, the nature of that same system changes when used within the context of research.

Research governance bodies may also raise different safety concerns regarding the use of commercially available systems as used in their 'off-the-shelf' capacity compared with bespoke systems produced specifically for the research. In-depth information may be requested about the specifications of the hardware involved, how it has been assimilated, and by whom, for the purposes of the research. Whilst this level of detail should not be an issue for the research team to provide (and should be prepared as part of the development phase), it may result in delays in the processing of research governance approvals. Details of the study's insurance provision should also be checked in relation to use of equipment within a patient's home, for example, coverage for any damage resulting to the participant's home as the result of use of the equipment (such as if it should fall onto items, damage surfaces, etc.).

Equipment should be safeguarded and installed carefully so that it does not become a hazard, either when in use or when stored in between sessions. All power leads

and cables should be secured, which may entail taping leads down so that they do not trail across floor space. Extension leads or sockets with surge protection may be used to offer additional safeguarding for the equipment. Any identified safety concerns should be discussed with the participant and/or carer, along with how these risks will be minimised. It is advisable to document that due care has been taken over equipment set-up, including any particular precautions that have been taken and discussed with the participant. Such documentation may also record any appropriate electrical safety testing or inspection where necessary. Itemising all equipment supplied to the participant may help to avoid potential confusion over ownership upon collection. At the end of the intervention all equipment should be thoroughly checked for wear and tear before it is reissued to the next participant. Infection control should also be addressed, and equipment should be adequately sanitised before it is reissued. Where this is not possible, for instance if there are components that are difficult to clean such as Velcro straps, these should be replaced between participants.

Assessments

Completing blinded outcome measures may prove difficult for trials of home-based VR interventions. The most practical arrangement for participants will be to complete the assessments at home. However, if there are multiple assessment points, then the equipment may still be present in the participant's home at follow-up and thus easily visible. Assessors are therefore likely to be unblinded to treatment allocation. Even when all equipment has been removed prior to completing assessments, the participant may wish to discuss their experience of the VR technology during the assessments. Even if strategies are used, such as reminding the participant not to disclose their treatment allocation to the blinded assessor,¹ it is not known how well breaches of blinding are recorded and reported in the literature, and therefore it is difficult to gauge how successful these strategies are. Completing assessments in participants' homes may also involve further issues not directly linked to the use of technology, such as the possible need to use measures originally designed and standardised for use within controlled clinical settings rather than in community settings. Of course, the suitability of the setting and issues concerning blinding might be easily overcome by conducting the assessments within a clinical setting. This approach has been reported within the literature for home-based research.^{18,29,30} However, participant transportation needs and costs would then need to be considered.

Planning checklist

It is clear from the above that there are a great many factors to consider in relation to the home use of VR and gaming interventions in rehabilitation research. We have therefore compiled a checklist of key issues that are likely to arise (see Appendix A). This is intended as an initial guide to help researchers identify the practical considerations involved in carrying out research using VR and gaming technologies within patients' homes. This may be adapted to suit particular research needs, and it is envisaged that it will be updated in response to ongoing feedback from future studies.

Summary

The use of VR and gaming in home-based rehabilitation research may present a unique set of challenges. Addressing these practical issues can help to improve the quality of research that will ultimately inform the efficacy of VR in rehabilitation. As technology advances, it is hoped that current constraints will lessen, and that new devices will emerge that can offer solutions to current limitations.

Technological change can, however, also present new challenges for research.^{9,14} Technology is capable of expanding far beyond the rate at which research can advance to fully explore its utility.¹¹ Consequently, it is important that the research lessons learned do not have to be repeated as new devices emerge. Findings concerning the acceptability and utility of equipment for home-based rehabilitation need to be applied to both current and subsequently emerging devices.

Similarly, at the same time as technological advances are taking place, the population is also changing. Future generations will become increasingly computer and technology literate, and thus it is likely that age will no longer be seen as a barrier to participating in VR research.² Less technical support is likely to be required to deliver home-based interventions in the future, which may offer benefits in terms of cost and resource savings.

As well as being relevant to research studies, the issues identified in this paper have clear implications for the potential clinical implementation of VR technologies. Clinical services are unlikely to utilise any technologies that are either difficult, costly, or time-consuming to use or monitor, or that are prone to technical problems.²¹ If these interventions are to move from research into clinical practice it will be necessary to provide comprehensive and affordable training to key staff.²¹ Therapists who find the systems and devices difficult to engage with, or to adapt to individual patients' needs, are unlikely to employ this type of technology in the course of their daily clinical work.²³ It is also unlikely that service providers will

have the necessary resources and time to implement home-based interventions if accommodating additional equipment will be problematic for the patient or will require a raft additional of resources. Equally, patients and carers are unlikely to adhere to an intervention if the equipment is not user-friendly, reliable, or easily accommodated within their home.

Improved documenting and increased sharing of findings concerning research into home-based VR and gaming interventions is important, including the approaches that have worked well as well as the practical difficulties encountered. VR and gaming interventions also need to be developed with appropriate user feedback from both patients and key service providers, throughout the processes of research design, testing and subsequent evaluation.²³ This feedback is vital to the development of interventions for home-based therapy that participants will find acceptable. As in this context, it is not just the therapeutic benefit that the intervention can offer, but the many other varied factors that can influence the participant's overall experience with the system. This can range from the user interface design, to the impact the system may have on their home environment, such as the space and resources necessary for it to operate.³²

It is likely that there will be differing issues surrounding the implementation of VR and gaming interventions in the context of research compared with clinical practice. VR and gaming technologies have the potential to offer a wealth of benefits for rehabilitation in the future. The task of researchers at present is to focus on how this technology is delivered and received within research setting, so that the full therapeutic potential of this technology can be reached in practice.

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Appendix A: Practical checklist for home-based VR rehabilitation research

Practical checklist for home-based VR rehabilitation research

1. Trial Set-up Phase

– Equipment provision

- How many full sets of equipment will be required, considering:
 - What is the provisional budget for equipment?
 - How many participants can concurrently undertake the intervention?
- What spare equipment is required in case of breakages?
 - e.g. monitors
- Are additional items such as extension leads, surge protection, batteries, tape to secure leads, sanitising wipes, etc. required?
- Has electrical or safety testing been carried out on the electrical equipment?
- Has the equipment been security marked in case of theft – e.g. with Smartwater?

– Researcher/Therapist Training

- What level of training will be required to deliver the intervention?
- Who will deliver and monitor the training?
- Will training also be required for assessments?

– Transportation

- Are protective bags and/or boxes required to transport the equipment?
- Will help be needed to load/unload equipment – e.g. trolleys, parking provision?

– Insurance

- Do those transporting the equipment need business use on their car insurance?
- Is the equipment insured for breakages or theft, during transport or while in the participant's home?
- Does insurance cover damage to the participant's home?

2. Screening

In addition to study inclusion and exclusion criteria, the following factors may also need to be considered to determine participant suitability:

- Does the participant have the required resources at home? e.g.:
 - Are there tables, chairs, TV/monitor of appropriate size and height? Is there high-speed internet connection?

(continued)

Continued

Practical checklist for home-based VR rehabilitation research

Is there sufficient free space to undertake the intervention activities?

What resources can be provided by the research team if required?

→ e.g. suitable chairs, chair risers, monitor risers, portable tables

Is there suitable access to the participant's property?

→ e.g. parking, distance from parking to the home, stairs, lifts etc.

3. Equipment Set-up & Storage

Ensure equipment is left safe and secure and that the participant is consulted during the set-up process:

Have potential safety concerns been discussed with participant?

→ e.g. trip hazards, overuse

Have any electrical leads been secured so that they are not trailing?

Has appropriate equipment storage been discussed with the participant?

→ e.g. will they need to pack the equipment away when not in use, and will they be able to manage this unaided?

Is it appropriate for participants to sign documentation to confirm what equipment has been supplied?

4. Participant Training & Monitoring

– Participant support

Will accessible written instructions be helpful?

→ e.g. FAQ, what to do if problems occur

Is there a specific phone line that participants can call for help?

→ how will this be managed and by whom – e.g. five days a week, in usual work hours?

How should the researchers respond when issues are reported?

→ what additional technical support can be provided?

→ can spare equipment be provided in the event of faults or breakages?

→ what are the acceptable timeframes within which to respond to an issue?

→ how will researcher availability affect this? What is the potential impact of staff annual leave?

– Monitoring and data collection

Should field notes be taken on each participant visit?

→ e.g. to record any individual equipment set-up, visit duration, observed issues and how they were addressed

What is an acceptable schedule to monitor participant progress?

→ e.g. weekly or fortnightly phone calls and/or visits

Will any data recorded by the VR system need to be manually collected at specific intervals?

How will participant adherence be monitored?

→ e.g. will the participant need to self-report adherence or can this be recorded by the VR system?

How will participants be cued to recommended session durations with the intervention?

→ e.g. will the participant need to monitor time or can the VR system provide time prompts?