

Application of commercial games for home-based rehabilitation for people with hemiparesis: Challenges and lessons learned

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Application of commercial games for home-based rehabilitation for people with hemiparesis: Challenges and lessons learned

Objective: To identify the factors that influence the use of an at-home virtual rehabilitation gaming system from the perspective of therapists, engineers, and adults and adolescents with hemiparesis secondary to stroke, brain injury, and cerebral palsy.

Materials and Methods: This study reports on qualitative findings from a study, involving seven adults (2 female; mean age: 65 ± 8 y) and three adolescents (1 female; mean age: 15 ± 2 y) with hemiparesis, evaluating the feasibility and clinical effectiveness of a home-based custom-designed virtual rehabilitation system over two months. Thematic analysis was used to analyze qualitative data from therapists' weekly telephone interview notes, research team documentation regarding issues raised during technical support interactions, and the transcript of a post-study debriefing session involving research team members and collaborators.

Results: Qualitative themes that emerged suggested that system use was associated with three key factors: 1) the technology itself (e.g. characteristics of the games, and their clinical implications, system accessibility, and hardware and software design); 2) communication processes (e.g. preferences and effectiveness of methods used during the study); and 3) knowledge and training of participants and therapists on the technology's use (e.g. familiarity with Facebook, time required to gain competence with the system, need for clinical observations during remote therapy). Strategies to address these factors are proposed.

Conclusion: Lessons learned from this study can inform future clinical and implementation research employing commercial video games and social media platforms. The capacity to track compensatory movements, clinical considerations in game selection, the provision of kinematic and treatment progress reports to participants, and effective communication and training for therapists and participants may enhance research success, system usability and adoption.

Introduction

Virtual environments accessible through commercial gaming systems are appealing for home-based rehabilitation because of their therapeutic advantages ^{1,2}. Motion capture systems, for instance, can provide real-time feedback about users' movements, which can assist in reducing undesirable compensatory patterns ³⁻⁵. The kinematic data these systems generate can be used offline by rehabilitation professionals to create reports about client performance ⁶. Well-designed game mechanics that incorporate novelty, activity variety, visually pleasing graphics, and cooperative or competitive social interactions can augment engagement ⁷ and effort ⁸. In healthy participants, game mechanics, such as attractive environments ⁹, the ability to individualize and to adjust the degree of task difficulty based on the skills and performance of the user ^{10,11}, and increased autonomy (user's ability to self-regulate aspects of the task) during practice ^{12,13}, have been shown to reliably increase engagement and lead to superior acquisition/retention of novel motor skills by increasing the amount and quality of practice. These experimental studies have demonstrated that well-designed games can improve learning through both indirect means (i.e., increased engagement leads to more practice) and direct means (i.e., increased engagement leads to a higher quality of practice). Thus, a promising area of research is exploring how/if these learning benefits extend to rehabilitation.

Meta-analytic evidence suggests that virtual environments are beneficial for rehabilitation, through demonstrated effectiveness over conventional therapy or no therapy for improving upper limb and daily living function ¹, and equivalent to or greater than conventional therapy across the full range of outcome levels (i.e. addressing body structure/function impairments, activity limitations and participation restrictions) in domains, such as balance and mobility, upper extremity function, activities of daily living ². However, these effects are not universal. Some

large trials have shown that as a supplement to conventional therapy, virtual rehabilitation was comparable to other forms of recreational activity ¹⁴. To improve the opportunity for benefit, both therapists and clients should be consulted on system design and implementation; this collaboration can increase therapeutic value, adoption, compliance, and enjoyment ^{15,16}.

This article presents qualitative findings drawn from a clinical trial examining feasibility and effectiveness of a custom-built virtual gaming system for rehabilitation for hemiparesis (ClinicalTrials.gov Identifier: NCT02290353). Our objective was to identify factors affecting the use of the system to inform future virtual rehabilitation research, based on feedback from participants with hemiparesis secondary to stroke, brain injury and cerebral palsy, as well as research team therapists and engineers.

Materials and Methods

System Description

FEATHERS (Functional Engagement in Assisted Therapy through Therapy Robotics) is a bimanual rehabilitation system designed for individuals with hemiparesis. The hardware depicted in Figure 1 was selected for its cost-effectiveness (camera and controllers <\$120 USD), accessibility, and ease of home setup. The system consists of a PlayStation® Eye camera (similar to a webcam), two PlayStation Move controllers (the outer shell and button layout was modified ergonomically to better accommodate limited hand function and to adjust the plane of movement to be more therapeutic), and a laptop or personal computer running Microsoft© Windows. Design details and usability testing were described previously ^{17,18}. The camera tracks and maps the activity of the controller with the smallest movement to the computer's screen cursor in order to promote use of the hemiparetic arm. Both controllers must be moving to enable cursor

movement. This requirement prevented users from employing only their non-paretic arm to interact with the system. If a user did not have enough hand function to grasp a controller, a custom-built hand strap was employed to secure the device to the user's hand.



Figure 1. FEATHERS System. Included: laptop computer, a PlayStation Move camera, and two ergonomically modified PlayStation Move wireless hand-held controllers.

The software consists of two applications: 1) *FEATHERS Motion* synchronizes controller/cursor movement, while collecting data about the user's hand movements as a means of quantifying motor performance and progress ^{6,19}. 2) *FEATHERS Play* introduces interactivity through a private Facebook group for client-therapist communication, high score sharing, competition with friends and accessing technology support from the research team. Therapist, client and caregiver input during two focus group studies ^{15,16} suggested that this online "community" would improve engagement, leading to greater gains in motor function.

Participants

Participants with upper extremity hemiparesis were recruited from local hospitals, rehabilitation clinics, child development centers, community stroke recovery groups, and through online postings. Figure 2 presents inclusion/exclusion criteria, participant flow diagram and reasons for study withdrawal. Fifty-seven percent (4 of 7) of adults and 33% (1 of 3) of adolescents did not complete the study. Preliminary inclusion screening took place over the phone, and was confirmed through clinical observation by a physical or occupational therapist during the initial assessment appointment at the clinic. Participants were able to maintain control over the adapted Playstation controllers and were observed to participate effectively in game play involving bilateral movement in all directions within the frontal plane. Participants (and parents/caregivers, as appropriate) provided written informed consent; the University of British Columbia Clinical Research Ethics Board provided ethics and protocol approval.

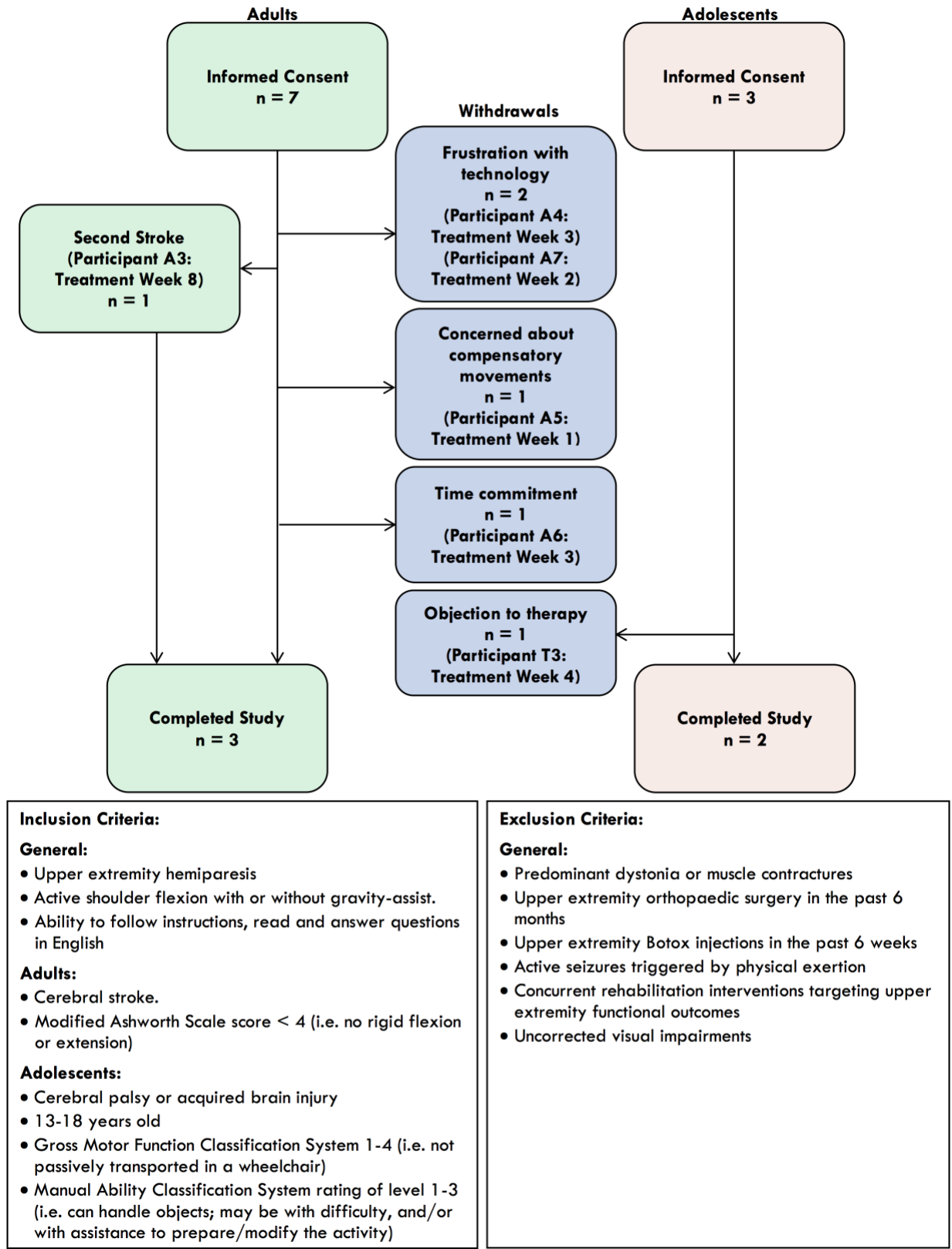


Figure 2. Participant Flow Diagram and Inclusion/Exclusion Criteria

Table 1 provides sample demographics, including Motricity Index (MI) scores (upper extremity subtest only, which rates pinch grip, and elbow flexion and shoulder abduction muscle force as a proxy for arm function) ²⁰.

<i>Participant</i>	<i>A1</i>	<i>A2</i>	<i>A3</i>	<i>A4^a</i>	<i>A5^a</i>	<i>A6^a</i>	<i>A7^a</i>	<i>T1</i>	<i>T2</i>	<i>T3^a</i>
<i>Sex</i>	F	M	M	M	M	F	M	M	M	F
<i>Age</i>	73	78	68	59	57	63	60	16	13	16
<i>Diagnosis</i>	Stroke	Stroke	Stroke	ABI	Stroke	Stroke	Stroke	CP	ABI	ABI
<i>Years Since Injury</i>	5	2	4	35	2	2	2	16	4	15
<i>Affected Side</i>	Left	Right	Left	Left	Left	Right	Left	Right	Left	Right
<i>Motricity Index U/E Score</i>	60	85	66	71	48	55	76	65	61	100

^a Participants who withdrew. A=Adult, T=Teen, F=Female, M=Male, ABI = Acquired Brain Injury, CP = Cerebral Palsy, U/E=Upper Extremity. A Motricity Index Score of 1 indicates complete paresis and 100 indicates normal strength.

Table 1. Demographic and Clinical Descriptive Information

Intervention

Over two months, participants were asked to play Facebook videogames for 30 minutes/day, five days/week, using the FEATHERS system. In terms of meeting this weekly goal (≥ 150 min/week) for the participants that completed the study: A1 accomplished it in 5/8 weeks; A2 in 4/8; A3 in 4/8; T1 in 0/8; and T2 in 0/8. A treating physical or occupational therapist and an engineer visited the participant's home to set up the system and train the participant on its use, and returned only if technical difficulties could not be resolved by phone. During the initial home

setup, the amount of arm movement required to interact with the system was adjusted based on each participant's motor skills.

The treating therapists made weekly telephone calls to gather participants' experiences with the system (e.g. clinical/technical issues), monitor which games were played, and assess participant confidence and motivation in carrying out their treatment programs. Therapists wrote down a combination of verbatim participant quotes, and summary notes (e.g. impressions, action plan, etc.) based on their interactions with participants. The Brief Action Planning Guide ²¹ was used to guide these interviews and to collaboratively problem-solve with participants when low confidence or motivation was identified. The Brief Action Planning Guide uses motivational interviewing principles to support individuals to develop concrete action plans related to their health ²¹. Weekly individualized digital progress reports, which included information about time (minutes) spent playing (daily totals and weekly average) and distance moved (meters) by each controller during play (daily and weekly totals), were sent to participants and discussed during telephone check-ins.

Data Analysis

The treating therapists' weekly telephone interview notes and research team documentation about issues raised during home visits and technical support calls for all participants were reviewed using thematic analysis ²². In addition, a post-study knowledge exchange session allowed 12 research team members (i.e. 6 biomedical/mechanical/physics engineers E1-E6 [5 males, 1 female], 3 occupational/physical therapists Ther1-Ther3 [3 females], 1 rehabilitation clinic director/physical therapist D1 [female], 1 clinic administrator ADM1 [female], and 1 knowledge broker/physical therapist K1 [female]) involved at the various stages of the FEATHERS project to share their opinions about the factors affecting the use of the system.

Because participants' perspectives were represented through qualitative data gathering processes described earlier, the meeting was established to gather the diverse perspectives of the team members. A verbatim transcript of the session's audio recording, a clinical and technical perspective presentation presented by research team members, and the meeting minutes were therefore also included in the data set used for the thematic analysis. Feedback and notes from a treating physical therapist (Ther4) that was involved in the project but that was not able to attend the knowledge exchange session were also included in the data set for the thematic analysis. Three authors, including a biomedical engineer (BV) that was part of the project since its inception, an occupational therapist (AS) that participated in the project by providing assessments and treatment to participants, and a mechanical engineer (biomedical specialization) (RB) student who was not involved in the project, independently carried out the coding of the data. The data were provided as digital files in text form, and the coders came to an agreement on the themes and subthemes during a face-to-face meeting. The question that guided analysis was: What factors affect the use of the FEATHERS system for in-home rehabilitation that could inform future in-home gaming interventions?

Results

Figure 3 summarizes the main themes and subthemes described below, and provides potential strategies to mitigate identified challenges.



Figure 3. Thematic Map of Qualitative Findings, including Main themes (large circles), subthemes (small circles), and specific factors (rectangles) that were identified. In addition, recommendations (arrows) are marked with a star symbol.

Technology

Games. Therapists identified game selection as an important consideration for choosing to use the system, given the large number of Facebook games available. Although the FEATHERS Facebook application enabled therapists to personalize game recommendations for each participant, some games failed to load, leading to frustration:

Engineer 3 (knowledge exchange session): "...there really needs to be quite a bit of thought that goes into [game selection]; there should be a strict list of criteria for games that work."

In addition to the operational function of games, the selection of games was also complicated by the need for clinical judgment with respect to its utility for a given participant. The decision to access thousands of existing commercial Facebook games through the FEATHERS system paradoxically limited the therapists' and engineers' management of the movement parameters, therapeutic value and accessibility of the games:

Therapist Ther4 (research team documentation regarding issues): "It looks like Facebook was maybe not a great platform for this system since there is no control over the games."

These control parameters relate to elements of the game environment, such as the size of text, the complexity of instructions, the type of interaction required to play (e.g. keyboard strikes, mouse clicks, cursor movement), and pop-up ads. Participants and a therapist reported frustration over ads and in-game purchases, respectively.

Participant A2 (research team documentation regarding issues): "Games with ads are constantly frustrating."

Therapist Ther4 (research team documentation regarding issues): "The [games] that [participant] has liked so far only let you do a few levels for free then ask for your credit card number, which I advised him not to give out."

This in-game marketing was seen as a particular challenge for maintaining the flow of a therapy session, and given the cognitive impairment associated with brain injuries, for protecting the participant from financial risk.

The games available on Facebook ranged from card and knowledge trivia games with no time pressure and static backgrounds (e.g. solitaire) and pattern matching games (e.g. Candy Crush, which requires constant visual scanning and is time dependent), to action games with actively changing visual backgrounds, which involve collecting tokens while slaying enemies (i.e. requiring divided attention), and simulation games requiring a player to build a virtual town (strategic planning, extended period of play, trade and purchase decisions required). Such involved task analysis to anticipate potential challenges for participants, and clinical judgment to match the games to meet the cognitive and motor abilities and therapy goals of participants is resource-dependent, and challenging to sustain over time as the social media platform adds new games. Game elements considered in identifying games for participants included the complexity of physical movement required to interact with objects (i.e. cursor movement only, cursor movement and mouse click, click and drag, aiming a virtual pointer, keyboard input), the range of motion required, and in which quadrant(s) of the screen the movements will target, the difficulty level of the game's entry point and availability of more challenging levels, the degree of visual clutter, the nature of auditory feedback or background music (which may be distracting to users), game duration, the nature of scoring or other performance feedback (e.g. positive or negative), the complexity of instructions provided by the system, and cognitive requirements (e.g. visual discrimination, matching, sequencing, visual scanning, memory demands, understanding game-specific symbols or object functions, turn taking, strategizing).

Accessibility. The system's camera required participants to sit at least 1.35 meters away from the computer screen, which created issues with game visibility:

Therapist Ther4 (research team documentation regarding issues): "When [participant] sits far enough away for the proper controller position he can no longer read text on the screen (like game instructions or card suits)...even with his glasses on."

This observation varied across participants based on factors, such as the size of the text or objects on the screen, and the need for visual discrimination in order to operate the game. Other participants shared positive feedback about the intervention's convenience as a home-based activity:

Therapist Ther4 (weekly telephone interview notes): "[Participant] thinks the program helps, and being at home to do [it] at any time is a benefit."

Travelling to a clinic can be a barrier for some patients, and the ability to self-schedule one's therapy activities was perceived positively. Participants were also interested in observing functional changes resulting from the intervention that would transfer to activities of daily living, and relayed their satisfaction with the treatment:

Therapist Ther3 (research team documentation regarding issues): "[Participant] thinks her improvement in arm strength while driving may be due (at least in part) to this program."

Participant A6 (weekly telephone interview notes; participant withdrew from study): "Well, everything I'm doing is helping with my mobility. I notice I can move my arm much more easily now."

Participant T1 (weekly telephone interview notes): "I feel like I'm accomplishing something when I play".

These participant perceptions were volunteered without therapist feedback on functional improvements, and may have strong implications for motivation and adherence to treatment.

Hardware and Software. Technical issues with the FEATHERS system were major contributors to participants' frustration. The controllers required setup and maintenance throughout the treatment period, leading to longer-than-anticipated sessions:

Participant A6 (research team documentation regarding issues; participant withdrew from study): "Be upfront with participants about how much time participating in the study will take each week. Realistically, it's taking much more than 30 min/day, five days/week during the setup phase for most participants."

The nature of these challenges related to issues with charging the controllers, Bluetooth wireless connection, controllers' buttons malfunctions and tracking inaccuracies. Another significant limitation recognized by therapists and participants was that compensatory trunk movements could not be monitored:

Therapist Ther3 (knowledge exchange session): "I would feel more confident and comfortable in giving a system like this if I know that it's measuring something like compensatory movements. Because I don't feel comfortable knowing that if I'm not able to watch somebody for eight weeks they might be doing this [showing compensatory movement]."

Without the capacity to monitor movements, participants may use shoulder hiking, trunk rotation, or even sidestepping as movement strategies to produce cursor movement on the screen. The drawbacks of this compensatory movement are reduced therapeutic benefit resulting from failing to target desired movements, and risk of reinforcing maladaptive movement patterns. This limitation led to one participant withdrawing from the study:

Therapist Ther4 (research team documentation regarding issues): "[Participant] said he is having too much difficulty moving his left arm without moving his body and he doesn't want to reinforce maladaptive compensation patterns."

Communication. A lack of communication about who to contact for technical support limited the provision of timely solutions: The following approach was proposed to improve clarity for participants and to ensure they felt comfortable connecting with support:

Therapist Ther3 (knowledge exchange session): “I feel [participants] would be more prone to access [tech support] if they met the main tech person in the home visit and in person and just say I’m your go-to guy if you have tech issues, here’s the number, let’s practice calling it...”

Participants also demonstrated preferences in methods of communication:

Therapist Ther3 (knowledge exchange session): “I’ve had very few people using Facebook [to communicate with their therapist]; they would end up calling.”

In fact, only two comments were posted by participants through the Facebook application: one to request hardware support, and one to express satisfaction with a specific game. This lack of engagement through the social media platform was accommodated through direct telephone communication. In order to foster better communication by telephone, one therapist found weekly progress reports to be an effective conversation starter:

Therapist Ther3 (knowledge exchange session): “[Participants] thought that was really cool to see, like ‘wow, my arm moved that far, how strange that my unaffected arm moved that much further than my affected arm, let’s talk about that.’ ”

However, some participants who reported feeling dissatisfied with their efforts during the week saw the report as a sign of failure:

Participant T1 (research team documentation regarding issues): “I hate that these reports come in because then you guys see how shallow the data is... Granted it's 100% my fault but I feel like you guys are just looking down like ‘Really? Really?’ ”

This variability in participant response to the various communication methods available highlights the need for a client-centered approach that meets individual preferences.

Knowledge and Training

Participant Knowledge and Training. Differences were observed in participants' familiarity with Facebook:

Engineer E3 (knowledge exchange session): "What surprised us was that mainly for older participants, teenagers not so much, had difficulty. Often this was their first time being introduced to Facebook, navigating the interface."

This lack of familiarity necessitated additional training. In addition to the challenges with using Facebook, the research team did not anticipate some participants' challenges in navigating the FEATHERS software and managing the hardware, which also limited exploration of available games:

Engineer E3 (knowledge exchange session): "From an engineer's side, it's ridiculously simple, you plug it in, turn on the controllers and that sounds great, but this isn't always so simple from the consumer side... It took them about three weeks to a month for them to really feel comfortable with turning on the system, plugging it in, playing the game."

Therapist Ther3 (knowledge exchange session): "The majority of participants would only do maybe one of the games through the 8 weeks because they just felt that it was too overwhelming to have to learn another game, they just felt that they didn't have the time."

This increased cognitive demand for participants highlights the need for simple user interfaces, increased time to become familiar with the system, and ongoing support. Therapists perceived that participants needed additional training time to feel confident:

Engineer E2 (knowledge exchange session): "We realized because it's a three-hour home setup, they don't get all of it, so we need to give them some time to play around, see how it goes and make sure they learn how to use it."

This graded approach for training and familiarization was seen as a useful strategy to monitor comprehension and skills in using the system. Even though participants only played Facebook games, some adolescents showed interest in being able to play third-party console or/and

computer games (outside of Facebook) that were familiar to them, and that had more sophisticated graphics and complex stories:

Therapist Ther3 (knowledge exchange session): "...we did see from teens that, in particular, they grew tired of the short repetitive games and would rather play games where it is an ongoing complex story or it is not as repetitive. One teen was like: if I could just play Madden [American Football third-party console game] on this [FEATHERS system] I would be happy."

At the time of the study, this integration with additional third party games that required more than moving a mouse cursor and clicking was not possible.

Therapist Knowledge and Training. Problematically, therapists had access to the FEATHERS system hardware only during an initial research team meeting, and briefly during home visits. This amount of time to become familiar with the technology and to understand how to apply it clinically was inadequate:

Therapist Ther1 (knowledge exchange session): "With any other therapy we would try it in clinic first, and therapists become familiar with it and learn how to use it, the clients learn how to use it and then they go home with it. So we kind of skipped that step in the process in a rush to try and test the home-based system."

Limited time for observation of participant game play also impacted therapists' clinical selection of appropriate games for each participant:

Therapist Ther3 (knowledge exchange session): "...limited structure or time for the therapist to actually watch the participant play the games, observe this and see what it looks like and see how the fit is in that initial home visit. I think part of it was that it was such a long home visit that it was tough to fit it all in and still have them absorb what's going on and learn."

This inadequate opportunity for clinical observation was seen to hinder therapists' ability to select appropriate Facebook games, to anticipate how to grade the degree of challenge of those activities over time, and to provide adequate guidance with respect to compensatory strategies and desired movements to optimize therapeutic benefit.

Discussion

Technology

Games. The third-party gaming software presented advantages and disadvantages. The ability to choose any game from the Facebook catalogue enabled customization of clients' treatment programs to meet their personal preferences, familiarity with the system, and physical and cognitive abilities. Research with healthy adults suggests that increased choice may lead to superior motor learning ¹³. However, by using games designed for typical gaming populations, therapists lose the capacity to adjust software parameters to grade the degree of challenge ²³. Providing an optimal challenge is important for rehabilitation, because clients' therapeutic needs change as they progress in their recovery and become more familiar or skilled with treatment activities ²⁴. Unwanted pop-up ads and in-game purchases were also detrimental for the therapy process as frustrating distractions. Individuals with cognitive impairments, and those unfamiliar with in-application advertising, may experience confusion or incur unintended financial costs.

Maintaining a comprehensive list of games that can be matched to clients' abilities and preferences throughout the treatment program, and that mitigate the influence of in-game marketing, is essential. Task analysis of movement and cognitive requirements (e.g. visual clutter, speed of tracking, static versus dynamic backgrounds, complexity of instructions), and categorical groupings of games by difficulty level (e.g. speed, task requirements), and genre (e.g. action, strategy, building) supported therapists' clinical judgment of game suitability for clients at the outset, but the practice was not maintained throughout the study. Enabling full-screen viewing capability was identified by participants as another important consideration when creating the list of games. Although a theory-based selection process for commercial games used for rehabilitation has not been identified in the literature ²⁵, clinical decision-making frameworks

have been developed to support system and game selection based on therapist and client needs, system and game characteristics, and motor learning theoretical concepts^{26,27}. These frameworks aim to address clinical decisions related to the extent to which software and task parameters can be controlled and modified over time, the movements and movement speed required, the therapeutic goals addressed, the cognitive demands of the activity, the extent to which cognitive demands can be controlled independently of the physical demands, and the type of performance feedback afforded to users^{26,27}. Future studies should utilize these frameworks to improve system and game selection to better match the needs and abilities of users.

Accessibility. Accessing rehabilitation can be difficult because of challenges in mobility, cost, travel, and availability of services²⁸. Low-cost home-based virtual/gaming rehabilitation systems are attractive because of their potential to increase the intensity and frequency of treatment sessions. Home-based programs also enable participants to choose when to participate. Participant reports related to improvements in arm mobility, independence and a sense of accomplishment reflect the potential of the system as a treatment tool, which likely impacted motivation²⁹. Even though the low hardware cost of our system could aid in increasing the accessibility of home-based therapy, the number of hours that therapists and engineers had to spend visiting and fixing issues with participants resulted in a large time/cost investment. In order for the system to be accessible and cost effective as a treatment tool, ease of use and reliability of the software and hardware components must first be enhanced, as described in the following section.

Hardware and software. Technical issues were influential on participant retention and overall success of the intervention, and represent a common barrier to virtual rehabilitation adoption^{30,31}. This at-home feasibility study built on a previous usability study with clients and therapists

^{17,18}, which identified certain system limitations (e.g. the visual complexity of some application features, variable robustness of controller tracking, and inability to monitor compensatory trunk movements). Refinements were made to the system to address the first two issues, based on project time constraints that prevented the refinement of the software to support trunk movement monitoring. Whole-body motion-tracking technology and remote video observation may be feasible options to pursue in future iterations.

For optimal accessibility, computer-based rehabilitation systems need to be designed with the end user in mind ^{17,32}. While initial focus groups and usability testing informed the design and refinement of the current FEATHERS system, the visual difficulties associated with distance requirements of the system's camera that some participants faced became evident during this study. In this context, using commercial gaming software failed to address the specific needs of therapy clients.

Most of the technical issues that arose (e.g. in-game marketing, and hardware/software malfunctions that included motion-tracking inconsistencies and uncharged controller batteries) were not observed during the usability session that involved a single game. For some participants, the extended troubleshooting led to frustration and lack of motivation to continue. These issues also resulted in therapists and engineers spending more time teaching participants how to use the system. In previous studies, Glegg et al. ^{23,33} identified time to learn and to use the technology as two of the most significant barriers for therapists in the adoption of virtual reality rehabilitation. In another study on perceptions of the barriers and opportunities for use of assistive technology, patients and carers identified “ease of use” as the most important consideration in the design of assistive technology ³⁴. Many of our findings are consistent with this previous research. These lessons are important for future home-based rehabilitation projects,

as short-term success in a controlled research environment may not translate into favorable outcomes in home-based multi-session treatment programs where participants are responsible for managing the technology themselves.

Communication

Participants' preference for telephone over Facebook-based communication was surprising given our previous client focus group findings suggesting that the interactivity of social media platforms was seen as a motivator to participation and facilitator of communication¹⁵. This outcome might have resulted from the reduced at-home training time provided by the research team, which focused more on how to operate the controllers and games than on how to use the application's communication features. More training in the use of the Facebook application and reinforcement of the available communication channels may help to improve access to support. A larger and more homogeneous cohort may also facilitate greater online community participation; while not all participants will be motivated to engage in online communication, a critical mass of active group members may help to build momentum and demonstrate the utility of the forum for others. Initiating communication through the social medium platform days or weeks prior to initiating the therapy program may also provide participants the opportunity to become familiar with the platform without the added cognitive burden of learning about the gaming system. Video conferencing could also be used to communicate more effectively about solutions to technical problems³⁵, which would reduce the time commitment and frustrations of participants. A larger sample and direct feedback from participants would be required to determine the perceived value of online client-therapist and client-client interaction in the context of home-based gaming rehabilitation.

In contrast to participants' perceptions about Facebook's lack of utility as a communication tool, weekly reports were found to be effective for communicating about participant progress and adherence. Many participants appreciated receiving this feedback, but in some cases it reinforced feelings of disappointment and frustration. Evaluating adherence should be part of routine therapy assessments; however, special attention should be given to how adherence feedback is communicated³⁶, and should be individualized based on client preferences. Future studies should investigate the impact of design and content of progress reports on program adherence. Identifying optimal strategies to deliver negative results without impacting motivation should also be considered.

Knowledge and Training

Participant knowledge and training. Participants' ability to navigate Facebook and the gaming technology was an important participation barrier. This finding was particularly true for older adults, who were less familiar with Facebook, computers, and gaming. Lack of familiarity with Facebook may have also hindered potentially facilitatory interactions among participants, or between participants and the research team. The initial participant training appeared inadequate to foster sufficient competence or confidence with the technology. The lack of retention of the information presented was partly related to the length of the session and the volume of information introduced. Increasing training time across two or more sessions may significantly increase participant knowledge, motivation, and efficacy, as was observed with one participant. Future research is warranted to explore the optimal design of training programs for these technologies.

Despite the challenges the adults faced in learning to use the technology, their enjoyment tended to be greater than the adolescents. This difference may relate to the types of games available and

their visual quality, as some adolescents were interested in using the system with other favored third-party games with more sophisticated graphics. While active video games may be appropriate for both age groups, customized game selection and different training protocols may be required to meet their interests and learning needs. Involving participants in selecting and grading activity difficulty may support engagement and motivation ¹³.

Therapist knowledge and training. Affording therapists increased support to familiarize themselves with the system's operation and its clinical application was another recommendation from this study. Over three quarters of respondents on a recent Canadian survey of therapists reported an interest in learning more about how to use virtual reality/active video games in practice, regardless of their experience level with the technology ³⁰. Therapists' low self-efficacy ratings suggested that targeted training is necessary ³⁰. Clinical skills requiring support include selecting appropriate systems, clients and games, grading activities, evaluating outcomes, and integrating theoretical approaches (e.g. motor learning principles) to gaming-based treatment ^{30,33}. Therapists in the current study reported that selecting games was not simple or intuitive; the sheer quantity of games made this process more overwhelming. A task analysis of games' demands and therapeutic implications may support therapists in ongoing game recommendations. Affording time for therapists to make clinical observations of participants throughout the intervention period through videoconferencing or periodic home visits is also necessary to enhance clinical decision-making.

Limitations

The primary limitations of this study were its small sample size (3 adults and 2 adolescents completed the study), high dropout rate (4 adults and 1 adolescent) and low compliance (participants that completed the study did not meet their intended dosage). These issues limit the

generalizability of the results, as larger samples, from each age and clinical group, that represent those that did and did not meet their intended dosage would be needed to provide a clearer picture of the factors that affect the use of home-based gaming technology for the targeted populations. As a secondary analysis of clinical trial data, the study provides a range of stakeholder perspectives and multiple data sources, but may be missing important viewpoints that might have been raised with a more targeted methodology, such as direct interviews or focus groups that explicitly addressed the research question.

The chronicity of the participants' health conditions may also have implications for the findings presented here. For example, adherence to treatment may be influenced by factors, such as a person's perceptions of their capacity to progress in their recovery over time (biasing toward lower adherence and enjoyment of the treatment experience). Fatigue during the acute phase of recovery from stroke and brain injury, and cognitive sequelae, such as confusion, agitation and executive functioning deficits, may limit engagement in or enjoyment of the treatment program. In addition, more pronounced physical impairments during the acute phase may influence participants' ability to participate successfully in commercial gaming-based therapy activities, thus negatively influencing their attitudes. Research on the use of commercial gaming is required across the spectrum of rehabilitation phases (in accordance with patients' abilities and its therapeutic utility), to gain a stronger understanding of the extent to which these, and other considerations influence the experiences of patients in this context.

Participant-therapist dynamics may also have impacted the participant experience differently as the result of employing more than one treating therapist in the study. While factors, such as a therapist's communication style, may influence participant confidence or motivation differently, logistics required that two treating therapists share the role. However, the presence of two

therapists enabled them to problem-solve and to exchange learning about their clinical experience.

While this study was conducted in Canada, it describes home-based rehabilitation, which aims to make therapy more accessible by addressing barriers related to geographical distribution. As such, its findings are relevant to other urban/suburban (and possibly rural) settings into which such systems could be installed. Success of such home-based programs may vary across settings, however, depending on the extent of infrastructure that exists to support processes, such as equipment set-up and funding, remote communication, and access to therapists. While occupational and physical therapists in Canada generally view the use of active video games for rehabilitation positively³⁰, attitudes may differ in other health care settings. National or institution-specific regulations (e.g. HIPAA) regarding the country in which data is stored may hinder the use of corporately owned platforms (e.g. Facebook) as a communication medium.

Finally, this study employed a custom built system, which limits the generalization of the results. Nevertheless, given that the system integrated commercial platforms (e.g., PlayStation Move controllers and camera, Facebook games and apps, and personal computers) the results may provide insight to researchers interested in integrating similar commercial technologies for rehabilitation.

Conclusion

The main themes (Technology, Communication, and Knowledge and Training) and the lessons learned from this study provide an initial framework for strengthening future clinical and technology implementation research with respect to issues with using commercially available motion tracking systems and social media services, capacity to track compensatory movements, selection of games, provision of kinematic and adherence reports, and methods of communication and training of therapists and participants.

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