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The Feasibility of Mixed Reality Gaming as a Tool for Physical Therapy Following a Spinal Cord Injury

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Summary

Physical therapy, often a tedious and non-social experience, has a low retention rate. For Spinal Cord Injury (SCI) patients in particular, dropping out leads to further physiological and emotional problems. This study seeks to determine how Skyfarer—a mixed reality game for SCI patients with chronic shoulder pain—can serve as an effective tool to improve players' physical health. We also examined whether Skyfarer can make physical therapy a social experience: SCI patients can play with their friends and family, which could further improve players' emotional health. In order to assess these possibilities, we recruited individuals with and without SCI to participate in our study and evaluated the physical and immersive experiences of both the disabled and able-bodied players through semi-structured interviews. We coded this qualitative data using six ideals from the Transtheoretical Checklist and analyzed the game's effectiveness as a physical therapy tool, along with its ability to cultivate a social experience. Parameters considered were subjects' physical exertion levels, immersion levels, and the predicted adherence levels for each group. Our results indicate that both SCI and non-SCI players found the game effective and engaging, suggesting that Skyfarer can serve as a successful and social alternative to conventional physical therapy. Mixed reality storytelling technology remains in a nascent phase, but this study shows that video games have the power to transform the way we approach healthcare and rehabilitation.

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Introduction

Video games are not necessarily thought of as healthy (1). However, the field of mixed reality and health-focused serious games is starting to change this perception. Interactive video games, designed to target a certain aspect of a player's physiology or psychology, can actually create positive change in a player's health (2). As our world changes and entertainment technology becomes more central and accessible in our lives, interactive entertainment is also changing our world by providing effective, engaging solutions to healthcare challenges.

Conventional treatments for behavioral and physical health, including medications and face-to-face therapies, are costly (3). Meanwhile , physical therapy methods for physiological rehabilitation are often time consuming, lack adherence, and can be isolating (4, 5). On the other hand, video games are low cost, often socially shared experiences that can appeal to a wide range of backgrounds (6, 7). Games have been used as interventions in healthcare-related settings for over two decades with positive effects, and despite some stigma associated with them (8, 9), mixed reality and virtual reality (VR) games have shown great promise as tools to improve health (10, 11, 12).

By integrating exercises that can help create physical or behavioral change, some games have been shown to improve players' health and change their levels of motivation, allowing them to get better more efficiently (13, 14). Studies have shown the power of harnessing interactive entertainment to rehabilitate players' emotional (9, 15) and physical functioning (9, 15, 16). One study in particular tested how a VR game, called DEEP, could be used as a more effective form of both treatment and prevention for children with anxiety disorders, which is one of the most common mental health problems for that demographic (15). The game measured the players' diaphragm expansions and used this to determine the force with which the player moved in the game. Slower breathing allowed for easier movement and thus provided an incentive for such deep breathing, which, in turn, is an evidence-based technique for lowering anxiety levels (15). Dr. Herbert Benson is credited with some of the first research that exposed the connection of slow breathing and lower stress, which he explains in his paper, "The Relaxation Response" (31). In this study, Benson noticed that his participants showed lower levels of lactate in their bloodstream (a sign of calmness) when they participated in 20 minutes of meditation. During

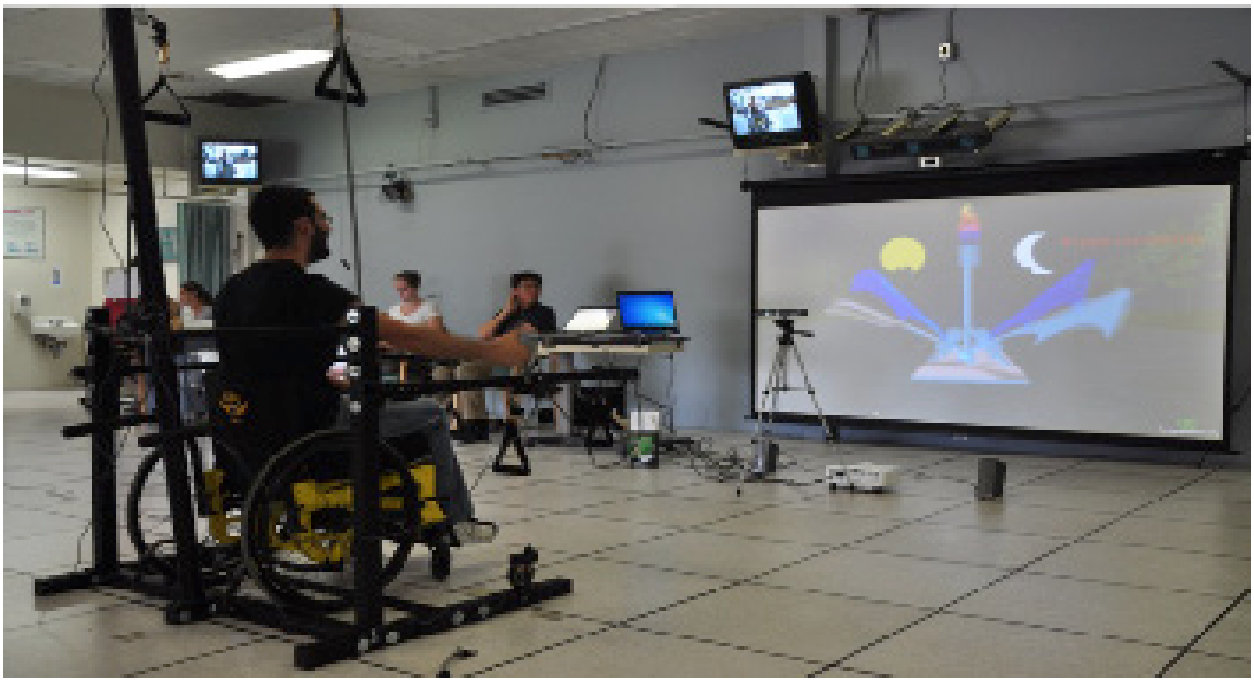

Figure 1: Skyfarer Setup. In this early version of the game, a participant in the adjustable rig uses resistance bands to complete shoulder movements that correlate, in the game, to the flying of one's ship through the sun and the moon.

the meditation session, the participants' breath slowed to 10 to 11 breaths per minute, and they had less air entering and leaving their lungs, which was linked to the participants having lower levels of lactate and therefore anxiety (31). In line with this research, the DEEP VR game was created with a focus on slowing players' breathing as a way to reduce their anxiety levels. The game's health effect was tested via a pilot study at Cinekid Medialab that was conducted with 86 children between 8 and 12 years of age. The participants played DEEP for 7 minutes each and filled out a pre- and post-test survey between sessions to measure self-reported anxiety, self-reported positive and negative affect, and how much the children liked the game. Results of this study showed that a majority of the players liked the game and experienced no signs of nausea—suggesting that VR games are an accessible and enjoyable tool for child psychological therapy. Although there was no significant change in the positive and negative affect ratings between the pre- and post-test session, this could be due to the fact that the study was taking place in a fun, high-energy environment and the levels of positive affect were high to begin with. There was, however, a significant decrease in self-reported anxiety after playing the game, suggesting that DEEP does have the potential to reduce anxiety in children and could be used as an effective therapeutic tool (15).

Past research has also shown that serious games are able to improve physical health. In one study, long-term care patients with upper extremity dysfunction played the bowling task of the popular video game Nintendo Wii (16). The control group participated in a standard exercise routine while the intervention group completed four weeks of physical therapy sessions using the Wii bowling game, in addition to their normal exercise routine. The study found that the intervention group was less likely to complain of shoulder stiffness and pain, indicating an improvement in upper-extremity function over the control group. Further results indicated that the intervention group subjects not only improved their physical capability and reduced their pain, but also experienced a higher level of enjoyment and engagement in their physical therapy over the control group.

Many SCI patients become disabled in an instant—through a fall or car crash or gun violence—and suddenly lose their ability to participate in their favorite physical and outdoor activities. As a result, they may end up increasing media consumption, and in particular, playing more video games in order to connect to the world and stay entertained without leaving their home or wheelchair (17, 18, 19). Conventional physical therapy is a lifelong necessity for individuals with SCI, but it is not as engaging as playing video games (20). Rather, physical therapy is often seen as an isolating and disengaging experience, and therefore many patients are reluctant to participate in it (5). This can lead to further health problems, such as obesity, cardiovascular disease, pressure ulcers, and depression (5). A particular

problem for SCI patients is that manual wheelchair users frequently suffer from shoulder pain due to overuse and car transfer functions (21). This pain can further prevent patients from participating in physical therapy, further lowering their quality of life (22). Both the Center for Disease Control and Prevention and US Health and Human Services have called specific attention to SCI patients, stressing that pioneering approaches be used to ameliorate the health problems and disabilities that accompany SCI, such as chronic shoulder pain (25). Skyfarer, a mixed reality, action-adventure video game, has been developed as an innovative approach to help address exercise adherence in SCI patients (23, 24). The game consists of a customizable exercise rig with GameTrak technology to sense and capture movement data. When playing Skyfarer, the participants engage in exercises sets, personalized to their needs, using resistance bands and free weights. In the virtual environment, these exercise sets are completed in order to prepare, propel, and launch a ship through the sun and the moon. The exercises are targeted to improve long-term muscle strengthening and to specifically reduce the chronic shoulder pain that often accompanies spinal cord injuries. This is accomplished by incorporating STOMPS (Strengthening and Optimal Movements for Painful Shoulders) protocol movements into the game, which have been shown in a prior study to reduce shoulder pain by 71% (26).

In this study, we examined the experiences of SCI and non-SCI participants who played Skyfarer, exploring how the game affects the physical and emotional states of its players, how immersive the game is, and how likely the players are to use the game again. I used this data to evaluate the game's feasibility as both a physical therapy tool and, as a game that that non-SCI participants can also partake in, a tool that cultivates a motivating and social experience around physical therapy. Through coding and analyzing qualitative data of post-test session interview transcripts, I evaluated and compared the impact of Skyfarer on both the bodies and minds of SCI and non-SCI players. Our results indicated that the majority of participants in both groups were physically worked out, engaged, and would play Skyfarer again. This suggests the potential of Skyfarer in making physical therapy a social and motivating experience that could replace or complement conventional methods.

This study would be the first in showing whether and how Skyfarer could be used as a physical therapy tool, and adds to the very limited discourse to date on how video games and virtual reality technology can actually benefit the physical and emotional health of their players. The field of VR and video games for health is only in its beginning stages, and this promising study on Skyfarer paves the way for new experimental, technology-based therapies and treatments to enter the healthcare field, thereby opening up possibilities for transforming and innovating society's approaches to rehabilitation.

Results

We investigated the potential of Skyfarer transforming SCI patient physical therapy into an engaging and social experience. Both SCI and non-SCI individuals played the game, as shown in **Figure 1**, and then they participated in post-test session interviews. The demographics of the

Participants	Age/Gender/Race	Physically challenged?	Fully immersed?	Would use in future?
Non-SCI 1	25, Female, White	**Yes,** shoulder workout	**Yes,** entered world of game	**Yes,** for workouts
Non-SCI 2	23, Female, South Asian	**Yes,** could replace gym workout	**Yes,** lost track of time	**Yes,** at gym
Non-SCI 3	19, Male, White	**No,** too much like a game	**No,** no narrative	**No,** only for rehab players
SCI 1	50, Male, Black	**No,** not tired	**No,** no narrative	**Yes,** in clinic or home
SCI 2	26, Male, Hispanic	**Yes,** fatigue in arms	**Yes,** didn't want to stop playing	**Yes,** in clinic or home
SCI 3	31, Male, Hispanic	**Yes,** sweat	**No,** game didn't talk to player	**Yes,** in clinic or home
SCI 4	37, Male, White	**Yes,** feels exerted	**Yes,** distracted and entertained	**Yes,** in clinic or home
SCI 5	Not provided	**Yes,** body feels awake	**Yes,** distracted and engaged	**Yes,** in clinic or smaller version at home

Table 1. Participants' demographics and comments expanding on their physical and immersion experiences playing the game, along with their comments on whether or not they would play Skyfarer in the future

Figure 2: Skyfarer Opinions. A comparison of how many SCI versus non-SCI participants were challenged, how many were immersed, and how many would use Skyfarer again (%).

players interviewed along with important comments and answers about their experiences playing the game are shown in **Table 1**. I then coded the interview transcripts in order to discern both groups of players' immersion and engagement levels, how their bodies and minds felt during the game, and whether or not they would use the Skyfarer technology in the future as either a means of exercise or to replace typical physical therapy for chronic shoulder pain. Side-by-side comparisons of how many SCI and non-SCI individuals were physically challenged, immersed, and would utilize Skyfarer in the future are shown in **Figure 2.**

Analysis of coding according to the six heuristic ideals revealed that a majority of SCI and non-SCI players were physically challenged by Skyfarer, were immersed in the experience, and would use it again in the future (**Figure 2**). Specifically, four of the five SCI participants found Skyfarer physically challenging. Two of these participants noted that they felt their blood circulating—one even noticed sweat—while another participant cited arm fatigue post-workout (**Table 1**). After playing, an SCI patient (VR 14) commented on his/her experience: "I felt good, quite an exercise…I feel like I woke up…my blood is actually circulating better." In the non-SCI group, two out of the three participants (**Figure 2**) found Skyfarer physically challenging, saying that they felt their muscles working and that they were getting a comprehensive shoulder workout (**Table 1**).

A majority—three out of five—of the SCI participants found Skyfarer immersive (**Figure 2**). These participants said they were engaged in the world of the game, so they were not focused on the difficulty or tediousness of their exercises (**Table 1**). Along these lines, an SCI participant (VR 06) said, "It makes you want to keep going. It's a great way to motivate people…you get distracted by the visual and don't really realize you're working out at the time." Of the three Non-SCI participants, two found Skyfarer immersive (**Figure 2**)—saying specifically that they were invested in the exercises in a way that they have not ever experienced working out conventionally, that they lost track of time, and that they felt they had entered the world of the game (**Table 1**). A non-SCI participant (STU 2) said: "Without the stimulus of playing a game, even if I was watching a TV show on the treadmill, I think I still end up checking my watch a lot. That wasn't something I felt inclined to do during the game…I was invested in completing the tasks. That was cool and it was fun." Those who were not immersed in Skyfarer—across both SCI and Non-SCI participant groups—said this was due to the game's lack of narrative, and one participant cited the game's lack of verbal communication with the player (**Table 1**).

When asked whether they would use Skyfarer for physical therapy workouts in the future, all SCI participants said yes, many adding how Skyfarer would give them motivation to work out while keeping them engaged and entertained (**Table 1**). When asked how Skyfarer would impact and transform his/her current rehabilitation process, a SCI patient (VR 14) said: "I give up easily working out so this would help me stay focused and in a friendly mood and have a nice half hour without quitting." Two SCI participants said that they wish they had access to Skyfarer earlier in their rehabilitation process because it would have alleviated some of their depression post-injury. They noted that it would have also made them more willing to work out, which may have prevented the deterioration of their injured bones. Overall, all the SCI participants communicated a sentiment that incorporating Skyfarer into the physical therapy experience, whether at home or in a clinical setting, would improve their moods, motivation, and engagement levels, and eventually contribute to an overall better quality of health (**Table 1**). Two of the non-SCI participants said that they would use Skyfarer in the future (**Figure 2**) and that it would make their workouts more enjoyable.

Methods

Participants

Eight participants, five SCI and three non-SCI

players, were chosen from a sample of a larger study (N=40). The study was still enrolling participants at the time of this manuscript preparation, therefore only the data that was already collected was analyzed and is a partial sample. SCI players were recruited from an associated rehabilitation facility and players without SCI were recruited from University of Southern California (USC) through emails, flyers, and social media.

Of the eight participants, seven provided demographic information. The demographic profile of identified participants included an age range of 19-50, two females, and five males. Participants also varied in race and ethnicity. Three participants were White, two were Hispanic, one participant was Black, one was South Asian, and one declined to share.

The following inclusion and exclusion criteria were used: volunteers with SCI had to be at least 18 years of age and between 2 to 20 years post SCI. To be recruited, these individuals had to either have paraplegia from SCI, with an SCI level thoracic or lower according to the American Spinal Injury Association Impairment Scale (AIS A, B, or C, which means no motor function below the level of SCI or less than 3/5 in key muscles), or tetraplegia from SCI (cervical level C5-C8 and AIS classification A, B, or C). There was also a requirement that potential participants could not have shoulder pain that prevents them from engaging in daily activities or that requires immediate medical attention. This means a total score on the Wheelchair User's Shoulder Pain Index (WUSPI) of 10 or less. Individuals with positive impingement signs, as signified by a positive Hawkins-Kennedy test or pain during arc and shoulder abduction or flexion; bicep tendonitis, as shown by a positive Speed's test; adhesive capsulitis or cervical radiculopathy; along with a history of shoulder injury, surgery, orthopedic, or neurological disorders that would impact arm function, except for SCI, could not participate. The criteria for individuals without SCI were that they must be at least 18 years old, and they could not have any painful injury (marked by a 7 or greater on a 10 point) that is self-reported during an initial evaluation. Health professionals at an associated rehabilitation facility completed recruitment, pre-screening, and assessment of individuals with SCI.

Materials and Procedure

The technology associated with the Skyfarer game is a mixed reality game system (**Figure 1**) built through the Unity3D game engine. The game's technology has 3D models, which each have textures, a musical score, and game mechanics, including movement boundaries and goals to allow for the participant to accurately perform STOMPS (Strengthening and Optimal Movements for Painful Shoulders) exercises. A portable exercise frame device (of a medium cost) was incorporated to provide self-adjustable resistance to the user, who is seated. The resistance is both concentric and eccentric. The last part of the Skyfarer technology includes low-cost GameTrak sensors. These provide for tracking of biomechanical input to help give feedback in real time and also allow for estimating resistance level control. Resistance settings can be manually saved as data on the individual's calibration profile. The data collected during the study was stored using USC REDCap (Research Electronic Data Capture).. which is a free, web-based application that helps create databases and surveys for research studies very quickly.

The general procedure of the Skyfarer study was as follows: first the volunteers were recruited and evaluated through exams at the associated rehabilitation facility (including shoulder screening examinations and muscle tests of important AIS muscles) to make sure that they met the inclusion criteria and did not fall into the exclusion category. Then, if a volunteer passed the screening or was a non-SCI participant, he/she read the informed consent document of the study, and, if it was agreed to, the volunteer came to the USC Creative Media and Behavioral Health Center and was scheduled for a 90-minute test session. When the participant arrived at his/her appointment, they were re-consented for USC's portion of the study. Demographic information was collected through a questionnaire. Next, the participant began the test session. The participant placed him/her self into the middle of the rig, with its side arms adjusted according to the wingspan of the participant, and the participant was calibrated to the game. The study coordinator helped with calibration and explained the instructions of the game. The participant then played Skyfarer once, which includes three repetition sets of the four core exercises from STOMPS, and the study coordinator recorded session notes while observing the participant. After the test session, the participant engaged in a post-test interview that included questions about the participant's experience in the game. The participant was given the chance to talk about his/her experience in the game, including his/her opinions, complaints, and praise. Participants were compensated for their time via an Amazon gift certificate. USC's Institutional Review Board approved the study.

NVivo computer software was used to code the interview data in order to examine if and how the experience of Skyfarer differed for participants, with a focus on comparing how the SCI and non-SCI participants' bodies felt during and after the game, their motivation and presence, and whether they could see themselves playing this game in the future. NVivo is a qualitative analysis computer-software (downloaded from the web) that helps its users organize, code, and interpret qualitative data. Each of the eight participants'

post-test session interviews were coded in NVivo using six heuristic ideals, from the Transtheoretical Heuristic Checklist, a method developed by the USC Creative Media and Behavioral Health Center to develop and evaluate interactive entertainment interventions for health and happiness (27). Words and lines from the interview transcripts were grouped and placed into these six categories, according to which ideal(s) the qualitative data correlated to the most. The six ideals coded were Cognitive Challenge (interactions with executive function and whether the game is adaptive to individual players); Affect Regulation (the potential to increase wellbeing and decrease stress); Dialectical Engagement (exploration of the game's feedback and messaging); Somatic Gratification (how the body feels during the game); Sociological Validity (how the game would be utilized beyond the study); and Semiotic Integrity (a general category for overall game experience, impact, and meaning). NVivo was first used to find the 30 most frequently used words across all interviews in order to understand the big picture the data was presenting. Data was then analyzed and coded data to determine the number of SCI and non-SCI participants that were physically challenged by Skyfarer, how many players were immersed in it, and how many would use it again in the future. Each participant's answers were noted, along with his/her additional comments.

Discussion

The results of this study, as outlined above, signal that Skyfarer is physically challenging, immersive, and enjoyed by a majority of both SCI and non-SCI patients in this study sample. In line with previous research studies on the benefits of VR games on physical health, this study found that a mixed reality, specially designed video game can benefit the physiology of its players (14, 13,16, 28, 29, 30). The majority of both test groups claimed that they felt physically worked out, although the extent varied between test groups. SCI participants seemed to be more physically challenged by Skyfarer, claiming sweat, fatigue, and an increase in circulation post-workout, while the non-SCI participants said that while they could feel their muscles working, they did not feel exerted. The majority of both test groups said that they would use Skyfarer in the future, adding to data that supports Skyfarer as an effective tool for both SCI and non-SCI participants. This suggests that Skyfarer could serve as an alternative to traditional physical therapy methods and could easily be turned into a social experience for SCI patients—allowing them to complete their physical therapy exercises with their able-bodied family and friends taking turns in playing the game or playing on a console alongside each other. And if a multiplayer aspect were incorporated into the game in the future, Skyfarer would easily foster a supportive community around the SCI rehabilitation process. These results also support a growing body of studies (8, 9) that show how specifically designed VR games change not only the physical health, but also the mental health, of the players. In Skyfarer, most of the participants across test groups found the game entertaining and engrossing, mood boosting and motivating. Overall, the data shows that Skyfarer has the power to change the health behavior of its players, encouraging them to improve their physical health by making their physical therapy an engaging, fun, and potentially social experience. It seems that Skyfarer would likely be used by participants at home, in a gym, or in a clinical setting, and according to participant feedback, would be useful early in the rehabilitation process to alleviate the depression and bone deterioration that happens immediately post-injury.

Although this study only examines a small sample size (n=8), these early results are the first to show that Skyfarer is a valuable tool to challenge and immerse both SCI and non-SCI players, is effective in benefiting their physical and emotional health, and could and would be played by both SCI and non-SCI individuals. Future research involving more participants could investigate the feasibility of having Skyfarer replace traditional SCI patient physical therapy practice through a multiyear controlled study, and should also account for how demographic variables create differences in the game's effect on the player. The results from this study, however, do suggest the feasibility of Skyfarer creating a social experience around physical therapy and the viability of incorporating Skyfarer into a physical therapy practice. Above all, this study shows the potential of interactive entertainment technology, especially video games and mixed reality, to change our bodies and our minds, and perhaps even reform our traditional healthcare system.

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References

1. Gotsis, M. "Games, Virtual Reality, and the Pursuit of Happiness." IEEE Comput. Graph. Appl. 29.5 (2009): 14–19.
2. Kovess-Masfety, V., Keyes, K., Hamilton, A., Hanson, G., Bitfoi, A., Golitz, D., Pez, O. "Is time spent playing video games associated with mental health, cognitive

and social skills in young children?" Soc Psychiatry Psychiatr Epidemiol 51.3 (2016): 349-57.
3. Rowan, K., McAlpine, D., & Blewett, L. "Access and Cost Barriers to Mental Health Care by Insurance Status, 1999 to 2010." Health Affairs (Project Hope). 32.10 (2013): 1723–1730.
4. Jack, K., McLean, S. M., Moffett, J. K., & Gardiner, E. "Barriers to treatment adherence in physiotherapy outpatient clinics: A systematic review." Manual Therapy. 15.3 (2010): 220–228.
5. Kehn, M., & Kroll, T. "Staying physically active after spinal cord injury: a qualitative exploration of barriers and facilitators to exercise participation." BMC Public Health. 9 (2009): 168.
6. Hawn C. "Take two aspirin and tweet me in the morning: how Twitter, Facebook, and other social media are reshaping health care." Health Aff. 28.2 (2009): 361–8.
7. Read, J.L., & Shortell, S.M. (2011). "Interactive games to promote behavior change in prevention and treatment." J Am Med Assoc. 305.16 (2011).
8. Ceranoglu, T.A. "Video Games in Psychotherapy." Review of General Psychology. (2010).
9. Granic, I., Lobel, A., & Engels R.E. "The benefits of playing video games." American Psychologist. 69.1 (2014): 66–78.
10. Pietrzak, E., Pullman, S., & McGuire, A. "Using Virtual Reality and Videogames for Traumatic Brain Injury Rehabilitation: A Structured Literature Review." Games Health J. 3.4 (2014): 202–214.
11. Cherniack, E.P. "Not just fun and games: applications of virtual reality in the identification and rehabilitation of cognitive disorders of the elderly." Disabil. Rehabil. Assist. Technol. 6.4 (2011): 283–9.
12. Rizzo et al. "Virtual reality applications for addressing the needs of those aging with disability." Stud. Health Technol. Inform.163 (2011): 510–6.
13. Colomer, C., Llorens, R., Noé, E., & Alcañiz, M. "Effect of a mixed reality-based intervention on arm, hand, and finger function on chronic stroke." Journal of NeuroEngineering and Rehabilitation. 13.45 (2016).
14. Szturm, T., Peters, J. F., Otto, C., Kapadia, N., & Desai, A. "Task-specific rehabilitation of finger-hand function using interactive computer gaming." Archives of Physical Medicine and Rehabilitation. 89.11 (2008): 2213-2217.
15. Rooij, M., Lobel, A., Harris, O., Smit, N., & Granic, I. "DEEP: A Biofeedback Virtual Reality Game for Children At-risk for Anxiety." Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '16. (2016): 1989–1997.
16. Hsu, J.K., Thibodeau, R., Wong, S.J., Zukiwsky, D., Cecile, S., & Walton, D.M. "A 'Wii' bit of fun: The effects of adding Nintendo Wii Bowling to a standard exercise regimen for residents of long-term care with upper extremity dysfunction." Physiotherapy Theory and Practice. 27.3 (2011): 185-193.
17. Rodrigues, M.P.C., Pinto Cauchioli, M., & Araujo, T. "Internet as a support for people with spinal cord injuries: usage patterns and rehabilitation." Paidéia (Ribeirão Preto). 22.53 (2012): 413-421.
18. Goodman, N., Jette, A.M., Houlihan, B., & Williams, S. "Computer and internet use by persons after traumatic spinal cord injury." Arch Phys Med Rehabil. 89.8 (2008): 1492–8.
19. Mattar, A.A.G., Hitzig, S.L., & McGillivray, C.F. "A qualitative study on the use of personal information technology by persons with spinal cord injury." Disabil Rehabil. 37.5 (2015): 1362–71.
20. Nas, K., Yazmalar, L., Şah, V., Aydın, A., & Öneş, K. "Rehabilitation of spinal cord injuries." World Journal of Orthopedics. 6.1 (2015): 8–16.
21. Haubert et al. Car Transfer and Wheelchair Loading Techniques in Independent Drivers with Paraplegia. Front. Bioeng. Biotechnol. 3 (2015): 139.
22. Alami, S., Desjeux, D., Lefèvre-Colau, M. M., Boisgard, A. S., Boccard, E., Rannou, F., Poiraudeau, S. "Management of pain induced by exercise and mobilization during physical therapy programs: views of patients and care providers." BMC Musculoskeletal Disorders. 12 (2011): 172.
23. Gotsis, M., Frangoudes, M., Lympouridis, V., Maneekobkunwong, S., Turpin, D., & Jordan-Marsh, M. "Skyfarer: a mixed reality shoulder exercise game." ACM SIGGRAPH 2013 Studio Talks on - SIGGRAPH '13. (2013): 1.
24. Gotsis, M., et al. "Skyfarer: Design Case Study of a Mixed Reality Rehabilitation Video Game." HCI International. (2014): 699–710.
25. Phillips, W.T., Kiratli, B.J., Sarkarati, M., Weraarchakul, G., Myers, J., Franklin, B.A.,…Froelicher, V. "Effect of spinal cord injury on the heart and cardiovascular fitness." Curr Probl Cardiol. 23 (1998): 641-716.
26. Mulroy, S. J., Thompson, L., Kemp, B., Hatchett, P. P., Newsam, C. J., Lupold, D. G., Haubert, L. L.,… Gordon, J. "Strengthening and Optimal Movements for Painful Shoulders (STOMPS) in Chronic Spinal Cord Injury: A Randomized Controlled Trial." Physical Therapy. 91.3 (2011): 305-324.
27. Gotsis, M. Jordan-Marsh, M., Baron, D.A., & Hashemian, Y. "A transtheoretical heuristic for design and evaluation of interactive entertainment for health and happiness." Poster session presented at the Jacquelyn Perry Research Symposium. (2014).
28. Chang, C., & Chang, Y. "A gaming system for shoulder rehabilitation." International Journal of Computer

Research. 22.2 (2015): 133-153.
29. Joo, L.Y., Yin, T.S., Xu, D., Thia, E., Kuah, C.W.K., & Kong He, K. “A feasibility study using interactive commercial off-the-shelf computer gaming in upper limb rehabilitation in patients after stroke.” Journal of Rehabilitation Medicine. 42.5 (2010): 437-441.
30. Widman, L. M., McDonald, C. M., & Abresch, R. T. “Effectiveness of an upper extremity exercise device integrated with computer gaming for aerobic training in adolescents with spinal cord dysfunction.” The Journal of Spinal Cord Medicine. 29.4 (2006): 363-370.
31. Benson, H. “The relaxation response.” Mind/Body Medicine: How to Use Your Mind for Better Health. (1993): 233-257.