Serious Games-based System to Train Weight Shifting and Balance after Stroke at Home

Description of a Pilot Study and Preliminary Experience

M. Pajaro-Blázquez, A. Dueñas-Ruiz, B. Ferrer-Gonzalez, A. Moreno-Conde, F. Jódar-Sánchez and C. Parra
Technological Innovation Group, Virgen del Rocío University Hospital, Manuel Siurot Avenue, s/n, 41013 Seville, Spain

Keywords: Serious Games, Telerehabilitation, Stroke.

Abstract: Serious games specifically designed for rehabilitation have the potential to improve motor deficits and can be used to enhance functional recovery after stroke. Serious games provide a repetitive and structured game-based training while monitoring user performance and progress. In this paper, we present a description of an ongoing pilot study of a serious games-based system to train posture, balance and weight shifting after stroke at home. We also present a preliminary description of three patients enrolled in the pilot study that are successfully accomplishing an in-home training program showing good adherence, acceptance and satisfaction with the technology.

1 INTRODUCTION

Overall, in year 2010, an estimated 16.9 million cases of incident stroke took place worldwide, 33 million prevalent stroke cases, 5.9 million stroke deaths, and 102.2 million disability-adjusted life years lost (Feigin et al., 2014). Stroke affects physical, cognitive and emotional functioning, but there are interventions that can be done to reduce the impact of post-stroke effects. Despite adequate treatment, stroke survivors experience a broad range of lasting deficits that can impact their cognitive, visual and motor systems. Moreover, at six to twelve months after stroke, only 60% of the patients are independent in personal care, 30% to 40% present depression and 50% need help either with shopping or housework (Cheeran et al., 2009). Given the increasing figures of such events, this poses a large burden to the National Health Service Providers that have become overly saturated and are forced to shorten the duration of the rehabilitation service. Stroke has an enormous socioeconomic impact also on the patient's families that often feel left alone by the health service providers. Patients that should continue the therapy outside the hospital actually drop out mostly due to high costs (Langhorne & Duncan, 2001).

New technology presents potential benefits for therapy and can represent an effective way of providing intensive and structured rehabilitation at a distance (telerehabilitation) to people with lasting motor impairments after stroke (Loconsole, Bannò, Frisoli, & Bergamasco, 2012). The field of game-based rehabilitation for stroke is growing into a significant area spurred by the growth in the use of video games and of new methods for their development (Fernández-Baena, Susín, & Lligadas, 2012). There are a number of studies published related to the use commercial games for stroke rehabilitation (Crosbie, McNeill, Burke, & McDonough, 2009; Hung et al., 2014; Pedro & De Paula Caurin, 2012), but efforts in the field of customizing and creating specific games for rehabilitation are increasing because commercial games does not fit properly to the demands and characteristics of these patients (Sandlund, McDonough, & Häger-Ross, 2009). Serious Games are aimed at improving motor deficits while monitoring and evaluating patient progress, and offer game-based rehabilitation environments that motivate the patient during training (Webster & Celik, 2014). The virtual environment of serious games can provide safe and customizable training, which may be tailored to a patient's interest and physical abilities. Serious games technology allows

Pajaro-Blázquez M., Dueñas-Ruiz A., Ferrer-Gonzalez B., Moreno-Conde A., Jódar-Sánchez F. and Parra C..
Serious Games-based System to Train Weight Shifting and Balance after Stroke at Home - Description of a Pilot Study and Preliminary Experience.
DOI: 10.5220/0005190401350142
In *Proceedings of the 2nd International Congress on Neurotechnology, Electronics and Informatics* (VirtRehab-2014), pages 135-142
ISBN: 978-989-758-056-7

monitoring user performance to analyze results over time (Deutsch et al., 2012). In this field, previous studies reported the effectiveness of balance training performed with video game-based therapy with Wii Fit for improving balance and for reducing disability in patients in the subacute phase after stroke (Morone et al., 2014).

The potential of serious games to help deliver rehabilitation at home still needs to be explored as a tool to provide telerehabilitation. Although the telerehabilitation is a viable alternative way of delivering rehabilitation services, a systematic review of telerehabilitation services for stroke concluded that the evidence was insufficient to draw conclusions on the effects of the intervention on mobility, health-related quality of life or participant satisfaction with the intervention. Moreover, no studies evaluated the cost-effectiveness of telerehabilitation (Laver et al., 2013).

We hypothesize that using an in-home virtual reality system that aims to train posture and balance at home is feasible and that the regularly training with the system may improve balance, endurance and motor function after stroke. The goal of this paper is to describe the ongoing pilot study to evaluate the use of a serious games-based rehabilitation system constituted by a multi-level rehabilitation platform and to give a preliminary description of the experience of three patients with post-stroke hemiparesis enrolled in the study that are using the system at home.

2 MATERIAL AND METHOD

2.1 Recruitment and Study Population

Patients are recruited from the rehabilitation department of the Virgen del Rocío University Hospital (Seville, Spain). Patients meeting the inclusion criteria are fully informed and included in the study after signing the informed consent form. The inclusion criteria are as follows: age over 18 years old, history of stroke ≥ 3 months, signed informed consent, presence of caregivers, Minimental State Examination score > 20, training 2 weeks at the hospital, Functional Ambulation Classification > 3, ability to walk for six minutes, Berg Balance Scale > 21, enough working space at home for the use of the REWIRE system and WiFi connection. The exclusion criteria are as follows: previous neurological progresive disease, pain that impossibility the use of the platform, psychiatric illness, emotional deficit, vision impairments. The pilot study received the aproval of the Ethical Committe of our institution prior patient enrollment

2.2 Multilevel Platform

The REWIRE project develops and tests an innovative rehabilitation platform based on a virtual reality , which allows patients, discharged from the hospital, to continue intensive rehabilitation at home under remote monitoring by the hospital itself. The main idea is to assemble off the shelf components in a robust and reliable way to get a multilevel platform system that enable to be deployed massively at the patients' homes. The platform is constituted of three hierarchical components: a patient station (PS), deployed installed at home, a hospital station (HS) and a networking station (NS) at the health provider site.

The **PS** is based on video-based tracking (through a mix of 2D and 3D cameras) and virtual reality. The patients perform their training or " serious games" at home through a Kinect and force platform systems (Tymo plate by Tyromotion, Graz, Austria). The patient sees himself/herself or an avatar interacting in real time with a virtual game. Game variety of scenarios, balanced scoring system, quantitative exercise evaluation, audio-visual feedback aims at maximum patient's motivation. A robust and reliable auto-calibration and spatial synchronization with the graphics is developed. Patient's daily activity is monitored by a Body Sensor Networks (Lifestyle system) and his activity is profiled through eigenbehavior (Krause, Lusseau, & James, 2009). Environmental, physiological and motion data are combined to tune the rehabilitation exercise level, to assess potential risks and advice clinicians on the therapy.

The **HS** main role is the definition and monitoring of the treatment. Data mining in the **NS** discovers common features and trends of rehabilitation treatment among hospitals and regions. A virtual community is setup to educate and motivate patients (Wüest et al., 2014).

2.2.1 Serious Games

A set of ten serious games is available for the intervention. Each game offers different difficulty levels, ranging from 1 (lowest degree of difficulty) to 5 (highest degree of difficulty).

1. "Balloon popper": the goal of the game is to pop the balloons that appear on the screen. To pop the balloons, the patient should move the hips in all directions (shifting the weight) to reach the balloons.

To score points, the patient should pop red balloons. If the patient pops blue balloons instead, an “X” icon appears on the screen showing that he/she made an error. A big blue hand represents the patient’s movements as an avatar.

2. “Bubbles”: The objective of this game is to pop the bubbles that appear inside a cauldron. The patient is represented as a wooden stick. The hips are used to pop the bubbles (Figure 1).

3. “Fire fighter”: In this game a 3D avatar man inside a barn will represent the patient. To score points, the patient should step over a fire that appears around him/her (in eight different directions). To extinguish the fire, the patient needs to stay a determined amount of time over the flame. If the patient does not extinguish it, the hay bales that are in the barn may burn and the patient will lose points.

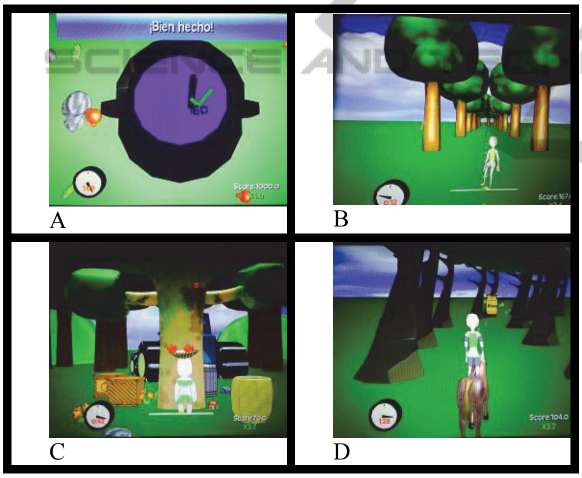

Figure 1: Videogames screenshots: A. Bubbles; B: animal hurdler; C. Fruit catcher; D. Horse runner.

4. “Animal hurdler”: The purpose of this game is to raise the leg when some small worms approach to the 3D avatar man. Depending on the side of the worm approaches, the patient will need to raise the right or the left foot (Figure 1).

5. “Fruit catcher”: The objective of the game is to catch apples falling from the top of the tree. In “Fruit catcher” the patient will be represented as a 3D avatar man represented in front of a tree with a basket on the head. To catch the fruit, the patient should shift the body weight or step to the sides. The patient will score points when the fruits fall into the basket placed over the avatar´s head (Figure 1).

6. “Hay collect”: The objective of this game is to shift the body weight to the left or to the right, and score points collecting the hay bales scattered around the field. In this game the patient´s avatar is driving a tractor travelling forward automatically. The score decreases when the patient does not collect the bales or if the avatar hits against rock formations.

7. “Scare crow”: The objective of this game is that the patient increases his balance and equilibrium. In this game, a scarecrow placed in a crop field represents the patient. Birds come from the sky to alight upon you. If the patient moves when the birds are approaching to the avatar, the birds will be scared and the patient looses points.

8. “Pump the wheel”: In this game the patient should raise both legs alternately, as previously described in “Animal hurdler”. The patient is represented by a 3D avatar man that operates a pump connected to an empty flat of a tractor that is in front of the avatar. Patient operates the pump rising and lowering the legs at both sides alternatively. A blue arrow indicates which leg the patient has to lift and the height necessary to achieve points.

9. “Horse runner”: The patient has to stand up to run faster and getting floating honey jars (it give you points) and to sit down to run slower and avoiding branches (Figure 1). An avatar of a man who is on the top of a horse represents the patient. The horse is running in the woods and advances automatically.

10. “Butterfly catcher:” The objective of this game is to catch butterflies appearing from one side of the screen to the other. A floating butterfly net represents the patient, who has to use the body movements to catch butterflies (moving the hips). If the patient catches dragonflies instead of butterflies, he/she looses points.

2.3 Intervention

Description of the recruitment and intervention protocol of the pilot study is presented in Figure 2.

2.3.1 Two-Week Training at the Hospital

Patients complete a two-week training program at the hospital to instruct patients and caregivers in the use the REWIRE platform (Figure 3). Caregivers are encouraged to observe hospital training sessions. It is required that one or more caregivers attend at least one session in order to learn to assist in the system

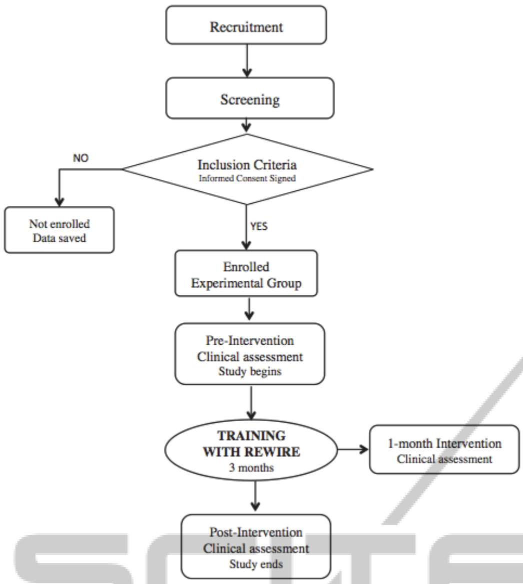

Figure 2: Pilot study flowchart.

Figure 3: Patient 1 performing a session during the two-week hospital training.

utilization. At the end of the hospital training, patients are able to set up the equipment correctly and to complete a programmed session through the PS. Patients are also instructed to solve simple issues that may arise during sessions without assistance. Assistance from caregivers is allowed to solve potential issues if necessary.

Through the hospital training subjects are also instructed in the use of the Lifestyle system.

During these two-week training, a physical therapist defines subject's motor and function ability in order to program and customize sessions to patient clinical characteristics.

At the end of these two weeks of training, patients complete the usability questionnaire Technology Acceptance Model (TAM). The TAM questionnaire comprises 24 items (divided into four sections detailed, Table 3) that are scored using a 7-point Linkert scale ranging from "strongly disagree" (scored as 1) to "strongly agree" (scored as 7). This questionnaire explains the perceived usefulness and usage intentions about a technology (Davis, Bagozzi, & Warshaw, 1989; Davis, 1989; Venkatesh, Davis, & College, 2000).

2.3.2 Three-Month Training at Home

After completing the two-week hospital training, the REWIRE system is installed at patient's home to start three-month intervention training. Three to five sessions per week for a period of twelve weeks (ranging from 36 to 60 session) are programmed for every patient. The clinical team involved in the investigation decides the number of sessions per week for each patient, according to clinical criteria. The length of each session time is 20 to 25 minutes of actual training (time spent playing games). In addition, subjects are allowed to rest as much as they need between games.

2.3.3 Communication Between the Patient and Clinicians

The PS includes a tool that allows for communication between participants and clinicians involved in the investigation through the HS. This tool allows to participate in a forum for patients and clinicians, to send direct messages to the therapist and to make a video calls. Direct phone calls are allowed in case of incidences during the session that interfere with the training performance. The number of phone calls made and time required for the assistance are recorded to evaluate the usability and costs at the end of the study.

2.3.4 Displacement to the Patient's Home

The therapist is expected to go to the patient's home in eight different scheduled visits (V):

- V1: the first day at the beginning of the in-home training program to install the REWIRE system.
- V2-V7: to provide the Lifestyle system at the beginning of the monitoring period, and to collect the systems when done.

- V8: to collect the REWIRE system at the end of the three-months training period.

Additional visits may be necessary in case of technical problems that cannot be solved through the PS or phone call. Number of additional visits to patient's home required and time expended during the visits is registered.

2.3.5 Outcome Measures

Clinical outcome measures are listed in table 1.

The Lifestyle System is a sensor-based wearable system used to evaluate movement during activities of daily living (ADLs). The system is composed of 5 IMUs (Inertial Measure Unites) that allow evaluating movements to assess changes in the ADLs. The objective is ubiquitous lifestyle evaluation using ambulatory monitoring under real-life conditions, in order to provide a multi-parametric overview of motor functions (upper limb, gait, and posture) and physical activity in the patient's daily environment. The sensors have to be worn in the morning and carried continuously during the day. At the end of the day they can be taken out and attached to the Lifestyle Station through dedicated mini-USB connector. Three assessments with the lifestyle system will be carry out: the first week, the seventh and the last week. During every evaluation, subjects wear the sensors for 5 days a week, 8 consecutive hours per day.

Two clinicians with experience in clinical assessments measurements performed the evaluation three times:

- T 0- before intervention: clinical assessments and activity monitoring with the lifestyle system.

- T 1- one month after the beginning of the intervention: clinical assessments and activity monitoring with the lifestyle system (seventh week).

- T 3- at the end of the 3-months intervention: clinical assessments and activity monitoring with lifestyle system.

3 PRELIMINARY RESULTS

Fifteen eligible candidates were identified to participate and completed the screening evaluation. Nine out of fifteen patients were not enrolled (one patient due to marked proprioception impairments, one patient due to severe aphasia, two patients did not have enough available space at home to use the platform, two refused to participate, one did not have internet connection at home, and two because of absence of caregiver). Six patients signed the informed consent, agreed to participate and were enrolled in the study. After signing the informed consent, one patient dropped out because the primary caregiver was admitted to the hospital with a serious illness. Three patients are performing the in-home training phase (age, gender and diagnosis described in Table 2) on the date of this article submission. Baseline outcome measures of the three patients are described in Table 3. The other two patients already completed the two-week hospital training.

Table 1. List of clinical outcome measures evaluated in this pilot study. Abbreviations: NIHSS, National Institute of Health Stroke Scale; MMSE, Minimental State Examination; ZüMAX, Zurich Maximental Status.

DOMAIN	MEASUREMENT INSTRUMENTS
Stroke deficit severity	Fugl Meyer (lower limb) NIHSS
Motor Function	**Berg Balance Scale** (primary outcome measure) Six Minutes Walking Test Ashworth
Cognitive deficit	MMSE ZüMAX
Functional level	Barthel Index Modified Rankin Scale Timed Up and Go
Quality of Life	EuroQol Quality of Life Scale (EQ5D) Stroke Impact Scale -16 (SIS-16)
Questionnaires	TAM (Technology Acceptance Model) Patient Doctor Relationship

An average of 6.16 phone calls per week made by the patients were registered to date.

Phone calls made by patients were due to main three reasons (ordered by frequency):

- Technical problems related to the games during the session.
- To ask questions about the installation of the system components
- To inform a short period missing sessions due to vacation, illness or other personal reasons.

Table 2. Clinical characteristics of three patients included in the pilot study. Abbreviations: MMSE, Minimental State Examination; FAC, Functional Ambulation Category.

	Patient 1	Patient 2	Patient 3
Age	32	72	65
Gender	Female	Female	Male
Diagnosis	Left hemispheric Ischemic Stroke	Left hemispheric Ischemic Stroke	Right hemispheric Ischemic Stroke
Months since stroke	3	8	7,5
MMSE	35	25	32
FAC	5	3	3

Table 3. Baseline outcome measures and description of the training of three patients included in the pilot study. Abbreviations: 6MWT, Six Minutes Walking Test; m, meters; BBS, Berg Balance Scale; TAM, Technology Acceptance Model; SD: Standard deviation.

	Patient 1	Patient 2	Patient 3
BBS	55	42	38
6MWT (m)	414	136	171
TAM Questionnaire			
- Perceived Ease of Use	6	6.3	6.9
- Perceived Usefulness	6.2	6.5	6.7
- Attitude Toward Using	7	5	7
- Behavioral Intention to Use	5.5	4.5	7
6 weeks-training			
- Sessions per week	3.5 (3-5)	4.66	3.33
- Session duration (minutes) (means ± SD)	37.01 ± 13.65	30.86 ± 8.07	29.72 ± 6.17

The phone calls made by the staff involved in the study to contact patients were needed due to the following reasons (ordered by frequency):

- Resolution of technical problems related the system functioning.
- To schedule programmed therapist visits.
- To schedule visits to make the assessments.

A total of 16 visits to the patients home were required during the first 6-weeks training, included expected scheduled visits and additional visits, involving an overall time of 23.75 hours (including time for displacement and time spent at patients home), with an average of 3.80 ± 5.29 hours per week.

4 DISCUSSION

This paper describes the pilot study protocol and the requirements to support and monitor the use of a serious game-based system to train patients after stroke at home. Three patients enrolled to date are successfully training at home with the system, showing good adherence to treatment and motivation, as shown by the successful completion of the programmed sessions. Satisfaction and good acceptance from users is reflected by the positive results obtained in the TAM questionnaire at the beginning of the intervention. Phone assistance was often required at the first stage of the in-home training phase, but was progressively decreasing due system modifications and adaptation successfully implemented and to increase experience of the patients in the use of the system.

This study goes a step beyond others studies reported with the system because we described the successfully transference of the training to the patients home. Wüest et. al. (Wüest et al., 2014) described the results of 13 elderly participants that completed thirty-six sessions of twenty minutes with five exergames of the REWIRE project for twelve weeks. They found a significant improvement with moderate to large effect sizes in Berg Balance Scale ($P = 0.007$, $r = 0.51$) in the 7-m Timed Up and Go ($P = 0.002$, $r = 0.56$) after training, and in the Short Physical Performance Battery ($P = 0.013$, $r = 0.48$). Wüest et al. described that subjects evaluated positively the usability of the virtual reality training intervention, assessed by the TAM questionnaire. In contrast with Wüest et al. study protocol, which involved the presence of an instructor during the sessions, in our pilot study subjects complete the sessions independently at home through the virtual platform that allows monitoring the results at the hospital through the HS. In the protocol of this pilot study, individualized sessions are programmed from the HS and are progressively adapted to subject progresses and adherence. In addition, subjects enrolled in our study present post-stroke residual hemiparesis, increasing the challenge of the use of virtual games at home.

The main challenges faced at the beginning of the study were: frequency of system fails due to a number of reasons related to the performance and completion of the scheduled sessions, interaction between the patient and objects captured by the kinect at home and kinect calibration malfunctions. All issues were successfully solved after some fine-tuning adjustments and some modifications made by the engineers and therapist participating in the study, increasing the system robustness and allowing to perform the home program.

Study staff dedicated a significant amount of time to attend phone calls and solve issues after installing the system at home, especially during the first two weeks. Although for the first weeks the phone was the more efficient communication tool, it is expected that all the consultations and issues will be solved through the communication tool of the REWIRE platform during the following weeks. Similarly, the time spent on subjects-home visits was variably distributed among weeks, including some weeks where no visit was required and others weeks that required significant in-person assistance at patients home.

Although ideally, all stroke rehabilitation exercises should be performed with therapist-assisted daily practice; it is not feasible in most of the health care systems due to the high cost of the demand of therapists (Webster & Celik, 2014). The final results of this study will analyze the cost associated with the intervention and its benefit in terms of clinical improvement and quality of life related to health compared to conventional rehabilitation in the hospital.

5 CONCLUSIONS

A multilevel rehabilitation platform to train balance deficits at home has been successfully installed at patients home. Preliminary experience shows good adherence, satisfaction and good acceptance from users, although close contact and feedback with the hospital is still needed to solve initial issues. Further studies with larger samples are needed to demonstrate the benefits of these virtual systems for stroke rehabilitation.

ACKNOWLEDGEMENTS

This work was partially supported by the REWIRE project (www.rewire-project.eu), funded by the European Commission under the FP7 framework with contract 287713.

Author Disclosure Statement

No competing financial interests exist.

REFERENCES

Cheeran, B., Cohen, L., Dobkin, B., Ford, G., Greenwood, R., Howard, D., … Wolf, S. (2009). The future of restorative neurosciences in stroke: driving the translational research pipeline from basic science to rehabilitation of people after stroke. *Neurorehabilitation and Neural Repair*. doi:10.1177/1545968308326636

Crosbie, J. H., McNeill, M. D. J., Burke, J., & McDonough, S. (2009). Utilising technology for rehabilitation of the upper limb following stroke: the Ulster experience. *Physical Therapy Reviews*. doi:10.1179/108331909X12540993897892

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*, 319–340. doi:10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*, 982–1003. doi:10.1287/mnsc.35.8.982

Deutsch, J. E., Brettler, A., Smith, C., Welsh, J., John, R., Guarrera-Bowlby, P., & Kafri, M. (2012). Nintendo Wii Sports and Wii Fit Game Analysis, Validation, and Application to Stroke Rehabilitation. *Topics in Stroke Rehabilitation*. doi:10.1310/tsr1806-701

Feigin, V. L., Forouzanfar, M. H., Krishnamurthi, R., Mensah, G. A., Connor, M., Bennett, D. A., … Naghavi, M. (2014). Global and regional burden of stroke during 1990-2010: Findings from the Global Burden of Disease Study 2010. *The Lancet*, *383*, 245–255. doi:10.1016/S0140-6736(13)61953-4

Fernández-Baena, A., Susín, A., & Lligadas, X. (2012). Biomechanical validation of upper-body and lower-body joint movements of kinect motion capture data for rehabilitation treatments. In *Proceedings of the 2012 4th International Conference on Intelligent Networking and Collaborative Systems, INCoS 2012* (pp. 656–661). doi:10.1109/iNCoS.2012.66

Hung, J.-W., Chou, C.-X., Hsieh, Y.-W., Wu, W.-C., Yu, M.-Y., Chen, P.-C., … Ding, S.-E. (2014). A Randomized Comparison Trial of Balance Training by Using Exergaming and Conventional Weight-Shifting Therapy in Patients with Chronic Stroke. *Archives of Physical Medicine and Rehabilitation*. doi:10.1016/j.apmr.2014.04.029

Krause, J., Lusseau, D., & James, R. (2009). Animal social networks: an introduction. *Behavioral Ecology and Sociobiology*, *63*(7), 967–973. doi:10.1007/s00265-009-0747-0

Langhorne, P., & Duncan, P. (2001). Does the organization of postacute stroke care really matter? *Stroke; a Journal of Cerebral Circulation*, *32*, 268–274. doi:10.1161/01.STR.32.1.268

Laver, K. E., Schoene, D., Crotty, M., George, S., Lannin, N. A., Sherrington, C., … Na, L. (2013). Telerehabilitation services for stroke. *The Cochrane Database of Systematic Reviews*, *12*, CD010255. doi:10.1002/14651858.CD010255.pub2

Loconsole, C., Bannò, F., Frisoli, A., & Bergamasco, M. (2012). A new Kinect-based guidance mode for upper limb robot-aided neurorehabilitation. In *IEEE International Conference on Intelligent Robots and Systems* (pp. 1037–1042). doi:10.1109/IROS.2012.6386097

Morone, G., Tramontano, M., Iosa, M., Shofany, J., Iemma, A., Musicco, M., … Caltagirone, C. (2014). The efficacy of balance training with video game-based therapy in subacute stroke patients: A randomized controlled trial. *BioMed Research International*, *2014*. doi:10.1155/2014/580861

Pedro, L. M., & De Paula Caurin, G. A. (2012). Kinect evaluation for human body movement analysis. In 2012 4th IEEE RAS EMBS International Conference on Biomedical Robotics and Biomechatronics BioRob (pp. 1856–1861)doi:10.1109/BioRob.2012.6290751

Sandlund, M., McDonough, S., & Häger-Ross, C. (2009). Interactive computer play in rehabilitation of children with sensorimotor disorders: A systematic review. *Developmental Medicine and Child Neurology*. doi:10.1111/j.1469-8749.2008.03184.x

Venkatesh, V., Davis, F. D., & College, S. M. W. (2000). Theoretical Acceptance Extension Model : Field Four Studies of the Technology Longitudinal. *Management Science*, *46*, 186–204.

Webster, D., & Celik, O. (2014). Systematic review of Kinect applications in elderly care and stroke rehabilitation. *Journal of Neuroengineering and Rehabilitation*, *11*, 108. doi:10.1186/1743-0003-11-108

Wüest, S., Borghese, N. A., Pirovano, M., Mainetti, R., van de Langenberg, R., & de Bruin, E. D. (2014). Usability and Effects of an Exergame-Based Balance Training Program. *Games for Health Journal*, *3*, 106–114. doi:10.1089/g4h.2013.0093