



Porto Potenza Picena – 17 May 2019

Introduction - Clinical up to date

ER²
SCHOOL



2° European R²S² **Robotic Rehabilitation Summer School**

13-18 May 2019. Porto Potenza Picena (MC), Italy

Advanced devices and rehabilitation protocols in Virtual Reality and remotely supervised (home) treatment

Marianna Capecci

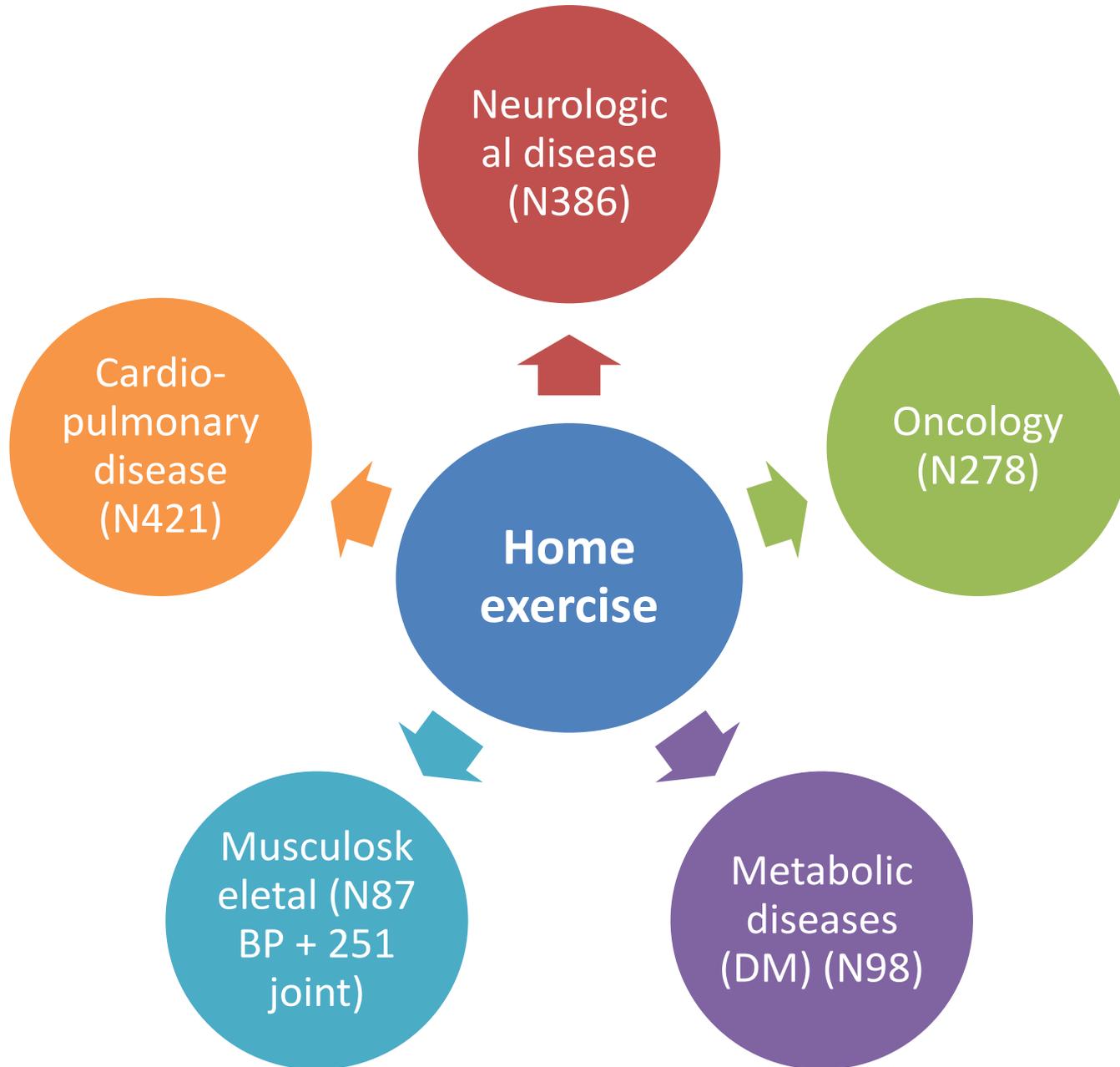


UNIVERSITÀ
POLITECNICA
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on Pubmed «home-based exercises» and ... at may 2019



Adherence to «Home exercises»

- **Adherence to long-term therapy in chronic diseases averages to 50 %** [Geneva: World Health Organization; 2003.]
- **Low-back pain:** reported adherence to home-based exercise is between 50 [Friedrich M, et al '96] and 70% [Medina-Mirapeix F, et al '09].
- **COPD:** participants registered 43.3% diary registrations/ week and 56.2 training sessions/week [Hoas et al '16]
- **Stroke:** large longitudinal study, stroke survivors were sedentary 81% of the day at 1, 6 and 12 months after stroke and more so as impairment increased [Tieges Z et al '15 Billinger S, '14]
- **Parkinson's Disease:** 61% sedentary [van Ninvegen J Neurol 2011]

FACTORS THAT CAN IMPAIR ADHERENCE

PATIENT-RELATED FACTORS :

- Clinical (disease severity.. poor self-efficacy,..)
- Demographic (gender, age)
- Cognitive/Psychological (dementia, depression, stigma)
- Organizational (inability to fit exercises into daily life) [Medina-Mirapeix F, et al '09; Slade '14],

CARE PROVIDERS' STYLE:

- lack of monitoring or feedback [Slade '14; Jordan JL, '11]

PHYSIOTHERAPY PROGRAM CHARACTERISTICS:

- absence of supervision during learning sessions,
- 'one size fits all' program design, The complexity of the program
- Motivation
- The burden of exercising [Medina-Mirapeix F, et al '09; Slade '09; Jordan JL, '11]

Strategies to enhance adherence from patients' perspectives

1) INCREASING THE ATTRACTIVENESS OF EXERCISE PROGRAMS

- Young athletic patients desired evolving programs (new exercises, increased difficulty) to improve performance and increase the challenge)

2) IMPROVING PATIENT PERFORMANCE

- Following a model,
- Providing feedback

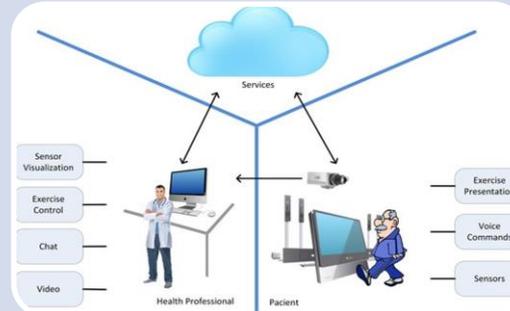
3) FAVORING THE FEELING OF BEING SUPPORTED BY CARE PROVIDERS

- By sport professionals.
- By other patients

EXPECTATIONS REGARDING NEW TECHNOLOGIES TO ENHANCE ADHERENCE

- Reminder tools (anonymous reminder (short message service, email, watch).
- **Exchange tools** (Patients were mainly favorable to social networks)
- **Tools for improving performance** (tools to help patients with exercises by following a model (movie of exercises or virtual coach rather than audiotape or static pictures) **or providing feedback** (telerehabilitation or exergames) -

Practical supplies



Home Health and Wearable Device Innovation



EXERCISE PROVIDING SYSTEMS

Without Additional resorces:

**EXERGAMING
(VIRTUAL REALITY)**

EXERCISE PROVIDING SYSTEMS

**With Additional resorces
TELE-REHABSYSTEMS**

REWIRE PLATFORM (Held 2016)

HAAPI (Wolf, 2015)

www.actionobservation.it
(Sale Capecci Pelosin 2016)

MONITORING SYSTEMS

With Additional resorces

Accelerometers/inertial sensors/ magnetometers/ GPS/ skin conductance measures

Without Additional resorces:
smartphone and smartwatch

Video based assessment:

i.e. RGB-D cameras

REVIEW ARTICLE

Exergaming for individuals with neurological disability: a systematic review

Maziah Mat Rosly^a, Hadi Mat Rosly^b, Glen M. Davis OAM^{c,d}, Ruby Husain^a and Nazirah Hasnan^e

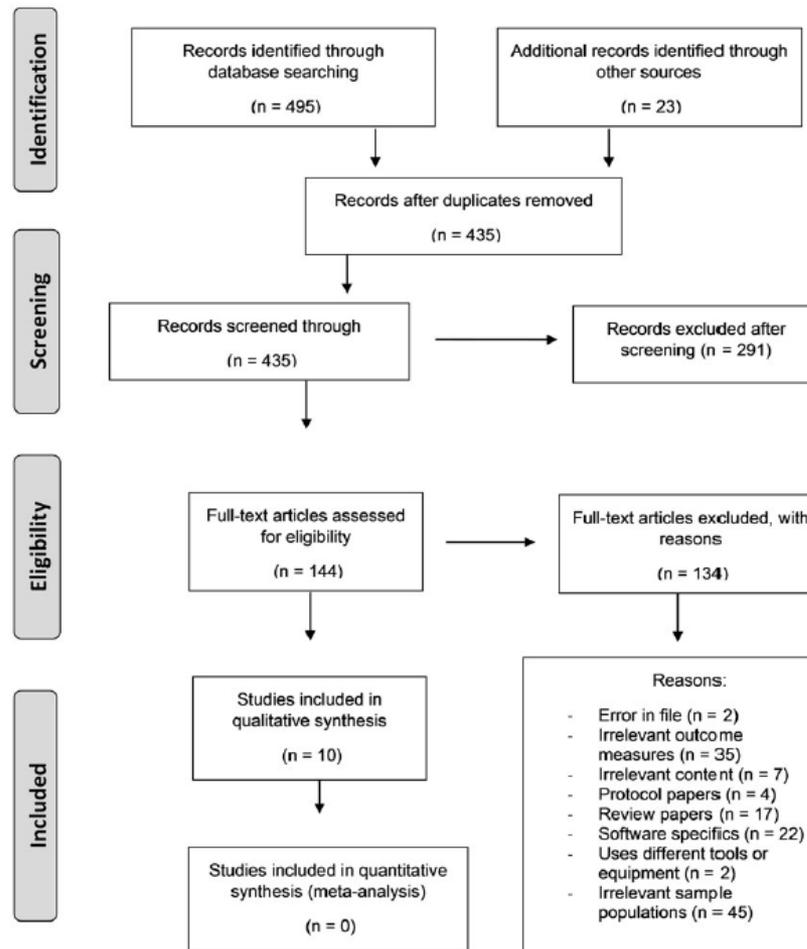


Figure 1. Data extraction and synthesis.

Table 2. Exergaming studies.

Author/year/country/ level of evidence	Study design/population/ mean age (in years)	Intervention/position	Instrument/tools	Key outcome measures	Intensity	Conclusion
Widman et al.,[24] 2006, USA Level 4	Cross-sectional study <i>n</i> = 8 Spina bifida adolescents ♂: 4 age, μ : 17.5 \pm 0.9 ♀: 4 age, μ : 15.5 \pm 0.6	Nintendo Gamecube GameCycle Position: sitting	Metabolic Cart (Medgraphics) Polar heart rate monitor Borg Scale of Perceived Exertion	<i>EE/HRR/RPE</i> (<i>N</i> = 6) achieved \geq 50% <i>VO</i> ₂ <i>R</i> (<i>N</i> = 7) achieved \geq 50% of <i>HRR</i> All achieved <i>RPE</i> \geq 12	Moderate	GameCycle was able to produce moderate intensity arm cranking work out
	Prospective study <i>n</i> = 8 Spina bifida adolescents ♂: 4 age, μ : 17.5 \pm 0.9 ♀: 4 age, μ : 15.5 \pm 0.6	Nintendo Gamecube GameCycle 16 weeks home training (three days/week, 20 min per session)	Polar heart rate monitor	Work output (<i>W</i>) (<i>N</i> = 6) Mean arm crank work output increased by 12% (<i>p</i> < 0.015).		Subjects were able to reach training zone intensity when program deployed at home. Mean arm crank work output improved.
Hurkmans et al.,[42] 2010, Netherlands Level 5	Cross-sectional study <i>n</i> = 8 Cerebral palsy adults ♂: 5 ♀: 3 Age, μ : 36 \pm 7	Nintendo Wii Wii Tennis Wii Boxing Position: standing	Cosmed K4b ² (portable indirect calorimeter) Modified Borg Scale of Perceived Exertion	<i>METS</i> Tennis: 4.5 \pm 1.1 Boxing: 5.0 \pm 1.1 <i>RPE</i> (modified Borg) Tennis: 3.5 \pm 1.2 Boxing: 5.4 \pm 1.9	Moderate	Wii Tennis and Boxing produced moderate intensity exercise according to WHO guidelines
Hurkmans et al.,[43] 2011, Netherlands Level 5	Experimental study Chronic stroke <i>n</i> = 10 \geq 6 month Tennis: (age: 33–68) μ : 48 ♂-3 ♀-4 Boxing: (age: 33–74) μ : 56 ♂-5 ♀-3	Nintendo Wii Wii Tennis Wii Boxing Position: standing	Cosmed K4b ² (portable indirect calorimeter) Polar T61 Modified Borg Scale of Perceived Exertion	<i>METS</i> Tennis: 3.7 \pm 0.8 Boxing: 4.1 \pm 0.7 <i>RPE</i> (modified Borg) Tennis: 4.1 \pm 1.2 Boxing: 5.3 \pm 2.7	Moderate	Wii Tennis and Boxing produced moderate intensity exercise according to WHO guidelines
Howcroft et al.,[44] 2012, Canada Level 5	Experimental study Cerebral Palsy children <i>n</i> = 17 ♂: 10 ♀: 7 Age, μ : 9.43 \pm 1.51	Nintendo Wii Wii Bowling Wii Tennis Wii Boxing DDR (Dance Dance Revolution) Position: standing	Cosmed K4b ² (portable indirect calorimeter) Polar heart rate monitor	<i>METS</i> Wii Bowling: 2.14 \pm 0.68 Wii Tennis: 2.60 \pm 0.78 DDR: 3.20 \pm 1.04 Wii Boxing: 3.36 \pm 1.50	Light for Wii Bowling and Tennis Moderate for DDR and Wii Boxing	DDR and Wii Boxing were able to achieve moderate intensity exercise
Burns et al.,[38] 2012, USA Level 5	Cross-sectional study Spinal cord injury adults, Chronic paraplegia <i>n</i> = 9 Age: 18–69, μ : 34 \pm 8	Nintendo GameCube GameCycle (level resistance increased every 3 min till volitional exhaustion) Position: sitting	Oxycon Mobile (portable spirometric system) Polar heart rate monitor	<i>EE/HRR</i> GCE: all achieved \geq 50% <i>VO</i> ₂ <i>R</i> and \geq 50% of <i>HRR</i>	Moderate	GCE as a potential tool for exercising in moderate intensities that satisfy ACSM guidelines among individuals with paraplegia
	XaviX XaviX Tennis (15 min of gameplay, level of resistance increased by adding 1 lbs every 3 min, up to 4 lbs) Position: sitting	Oxycon Mobile (portable spirometric system) Polar heart rate monitor	<i>EE/HRR</i> XTSE: 33% (<i>N</i> = 3) participants achieved \geq 50% of <i>VO</i> ₂ <i>R</i> and \geq 50% of <i>HRR</i>	Moderate	About one third of participants achieved moderate intensity exercise with the XaviX Tennis	
Rowland et al.,[45] 2012, USA Level 5	Case study <i>n</i> = 3 (2 Cerebral palsy)	Nintendo Wii Wii Tennis Wii Bowling	Polar heart rate monitor VMax Encore 29C	<i>METS</i> DDR: 1.2–2.1	Light	<i>EE</i> were of light intensity (<i>METS</i> < 3) and <i>HR</i> values did not meet the ACSM guidelines of achieving at

(continued)

Table 2. Continued

Author/year/country/ level of evidence	Study design/population/ mean age (in years)	Intervention/position	Instrument/tools	Key outcome measures	Intensity	Conclusion
Robert et al.,[39] 2013, Canada Level 5	and 1 spina bifida) ♂: 2 ♀: 1 Age: 19–21 Cross-sectional study Cerebral palsy children <i>n</i> = 10 ♂: 4, ♀: 6 <i>n</i> = 10 able-bodied, ♂: 5, ♀: 5 Age: 7–12	DDR (Dance Dance Revolution) *all three done in sitting position Nintendo Wii Wii Jogging Wii Bicycling Wii Snowboarding Wii Skiing Position: standing	(Portable metabolic unit) Polar heart rate moni- tor (RS400)	Wii: 1.4–1.9 %HRR DDR:29–36% of HRR Wii: 29–36% of HRR HRR Wii Jogging: >40% HRR at >50% of total gameplay Wii Bicycling: >40% HRR at >30% of total gameplay	Moderate	least 40% of HRR (light intensity) No significant difference between groups in % of time spent with HRR > 40%. Exercise intensity for Wii Jogging and Bicycling are of moderate level which met ACSM standards
Neil et al.,[41] 2013, Israel Level 5	Cross-sectional study Stroke and able-bodied <i>n</i> = 10; stroke (μ age: 61 \pm 7.3) <i>n</i> = 10; able-bodied (μ age: 54.4 \pm 12.6) Age:19–75	Nintendo Wii Sony Playstation 2 EyeToy Wii Canoeing Wii Sword Fighting EyeToy Wishy Washy EyeToy Kung Foo Position: standing	Borg Scale of Perceived Exertion	RPE All games on both respective consoles achieved RPE rating score between 11 and 13	Light to moderate	Light to moderate level intensity, re- commended for self-paced or startup exercise for sedentary individuals
Kafri et al.,[40] 2014, USA Level 5	Cross-sectional study <i>n</i> = 11; post-stroke <i>n</i> = 8; able-bodied Age: 25–75	Nintendo Wii Wii Boxing (standing) Wii Boxing (sitting) Wii Run (standing) Wii Penguin (standing)	Cosmed K4b ² (portable indirect calorimeter) Polar heart rate monitor	METS/HRmax% Wii Boxing (sitting) stroke: 2.73/60% Wii Boxing (standing) stroke: 3.08/63% Wii Run stroke: 3.23/65% METS/HRmax% KBoxing stroke: 3.46/ 65%	Moderate Moderate	EE was lower for post-stroke than able-bodied but still enough to meet moderate intensity and HRmax% me ACSM standards
Roopchand-Martin et al.,[46] 2014, Jamaica Level 5	Case study Spinal Cord Injury adults <i>N</i> = 2, ♂: 2 Age: 19, 23	Nintendo Wii Wii Boxing Position: sitting	Polar heart rate monitor	HR Wii Boxing HR > 50% of HRR	Moderate	Achieved training HR, moderate intensity training

Abbreviations: AVG: active video game; HR: heart rate; HRR: heart rate reserve; HRmax: maximum heart rate; RPE: rating of perceived exertion; EE: energy expenditure; METS: metabolic equivalents; VO₂R: reserve oxygen uptake; ♂: male; ♀: female; μ : mean; *n*: sample size; GCE: GameCycle Ergometer; XTSE: XaviX Tennis System Exergaming; DDR: Dance Dance Revolution; ACSM: American College of Sports Medicine; WHO: World Health Organization.

Virtual Reality: A New Rehabilitative Approach in Neurological Disorders

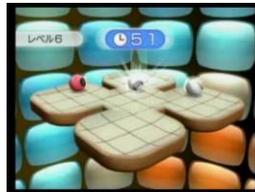
Di Biagio Laura¹, Ferretti Matteo², Cingolani Daniele, Buzzatti Luca, Capecchi Marianna and Ceravolo Maria Gabriella

Author Proof

Subjects; Seven PD patients with balance impairment (**H&Y:3**) received:

- 2-week Nintendo-Wii Balance rehabilitation followed by 2-week training on stabilometric platform (**Group Wii-P**) (4) or
- the same treatments in the opposite sequence (**Group P-Wii**). (**3**)

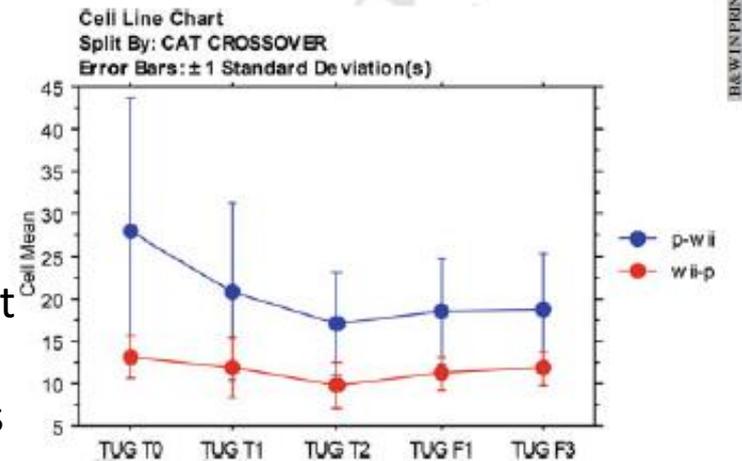
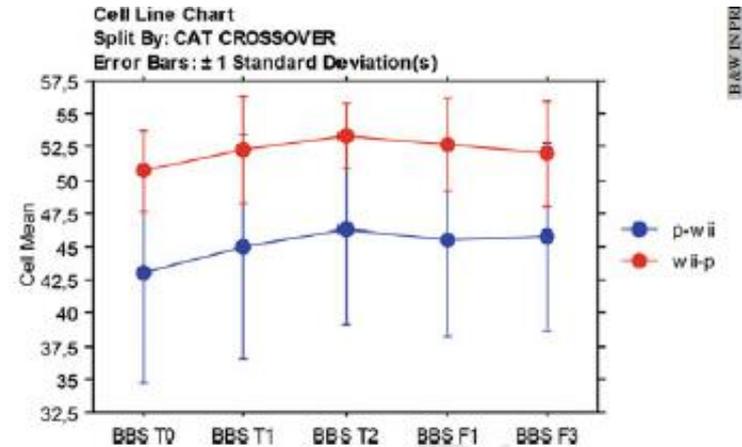
Each week consisted of 5 daily one-hour sessions.



Nintendo-Wii Balance: PENGUIN; BUBBLE; MARBLES

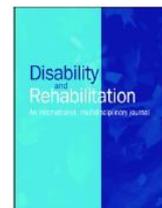
ASSESSMENT: 10mwt; tug; bbs.

Assessment timing: at enrolment (T0), after the first 2-week treatment (T1), after the second 2-week treatment (T2), at one month (F1) and three months (F3) of first treatment end.





IMPLICATIONS FOR REHABILITATION



- **Exergaming can be deployed as physical activity or exercise using commercially available game consoles for neurologically disabled individuals in the convenience of their home environment and at a relatively inexpensive cost**
- **Moderate-to-vigorous intensity exercises can be achieved during exergaming in this population of persons with neurological disabilities.**
- **Exergaming can also be engaging and enjoyable, yet achieve the recommended physical activity guidelines proposed by ACSMTM or WHO for health and fitness benefits.**
- **Exergaming as physical activity in this population is feasible for individuals with profound disabilities, since it can be used even in sitting position for wheelchair-dependent users, thus providing variability in terms of exercise options.**
- **In the context of comprehensive rehabilitation, exergaming should be viewed by the clinician as “at least as good as” (and likely more enjoyable) than traditional arm-exercise modalities, with equivalent aerobic dose-potency as “traditional” exercise in clinic or home environments.**

Virtual reality

A realistic three-dimensional image or artificial environment that is created with a mixture of interactive hardware and software, and presented to the user in such a way that the any doubts are suspended and it is accepted as a real environment in which it is interacted with in a seemingly real or physical way.

Key Elements of a Virtual Reality Experience

Virtual World

- A virtual world is a three-dimensional environment that is often, but not necessarily, realized through a medium (i.e. rendering, display, etc.) where one can interact with others and create objects as part of that interaction. In a virtual world, visual perspectives are responsive to changes in movement and interactions mimic those experienced in the real world.

Immersion

- [Virtual reality immersion](#) is the perception of being physically present in a non-physical world. Two common types of immersion include: *Mental Immersion* – A deep mental state of engagement, with suspension of disbelief that one is in a virtual environment. *Physical Immersion* – Exhibited physical engagement in a virtual environment, with suspension of disbelief that one is in a virtual environment

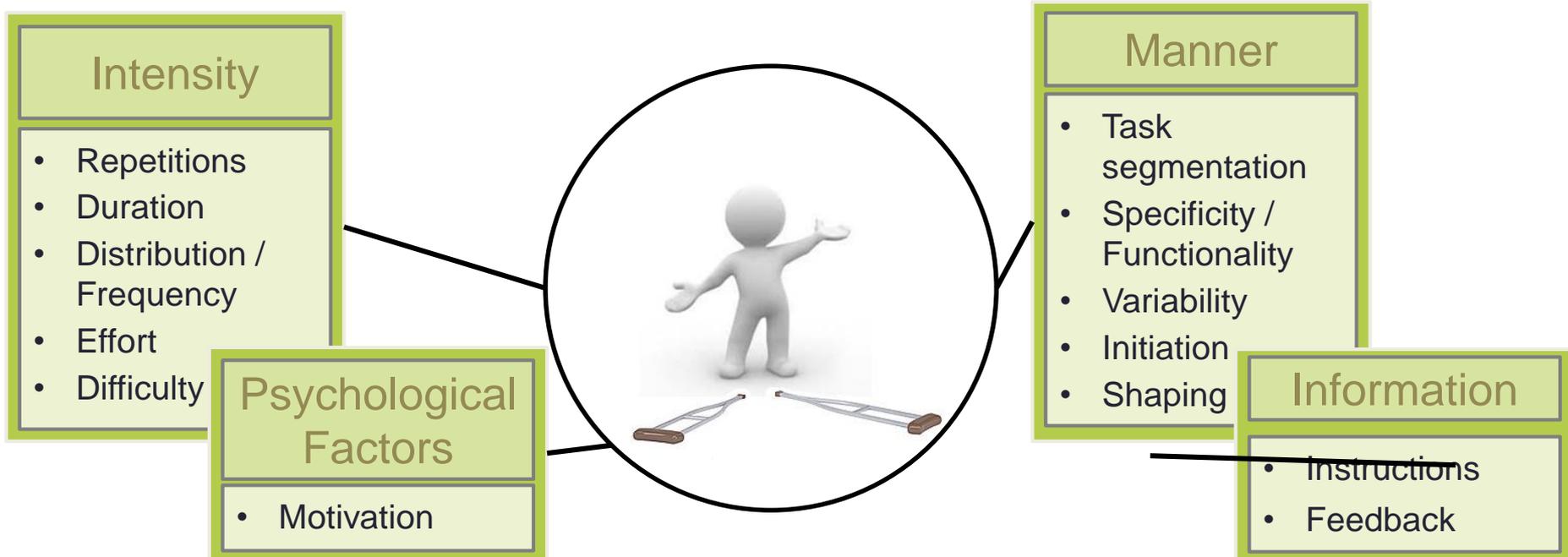
Sensory Feedback

- Virtual reality requires as many of our senses as possible to be simulated. These senses include vision (visual), hearing (aural), touch (haptic), and more. Properly stimulating these sense requires sensory feedback, which is achieved through integrated hardware and software (also known as inputs).

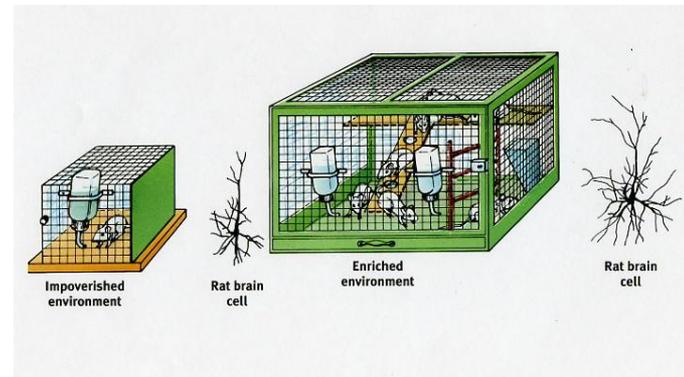
Interactivity.

- The element of interaction is crucial for virtual reality experiences to provide users with enough comfort to naturally engage with the virtual environment.

Key Factors for Recovery



The advantages
of Virtual reality



Zhang X et al. Brain Res. (2017)

Types of Virtual Reality



Non-immersive simulations

are the *least* immersive implementation of virtual reality technology.

In a non-immersive simulation, only a subset of the user's senses are stimulated, allowing for peripheral awareness of the reality outside the virtual reality simulation



Semi-immersive simulations

provide a *more* immersive experience, in which the user is partly but not fully immersed in a virtual environment.

Semi-immersive simulations closely resemble and utilize many of the same technologies found in flight simulation.



Fully-immersive simulations

provide the *most* immersive implementation of virtual reality technology.

In a fully-immersive simulation, hardware such as head-mounted displays and motion detecting devices are used to stimulate all of a user's senses. Fully immersive simulations are able to provide very realistic user experiences by delivering a wide field of view

Virtual reality for stroke rehabilitation

Kate E Laver Belinda Lange Stacey George Judith E Deutsch Gustavo Saposnik Maria Crotty

Cochrane Systematic Review - Intervention Version published: 20 November 2017

Background Virtual reality and interactive video gaming have emerged as recent treatment approaches in stroke rehabilitation with commercial gaming consoles in particular, being rapidly adopted in clinical settings. This is an update of a Cochrane Review published first in 2011 and then again in 2015.

Objectives Primary objective: to determine the efficacy of virtual reality compared with an alternative intervention or no intervention on upper limb function and activity.

Secondary objectives: to determine the efficacy of virtual reality compared with an alternative intervention or no intervention on: gait and balance, global motor function, cognitive function, activity limitation, participation restriction, quality of life, and adverse events.

Search methods We searched the Cochrane Stroke Group Trials Register (April 2017), CENTRAL, MEDLINE, Embase, and seven additional databases. We also searched trials registries and reference lists.

Selection criteria Randomised and quasi-randomised trials of virtual reality ("an advanced form of human-computer interface that allows the user to 'interact' with and become 'immersed' in a computer-generated environment in a naturalistic fashion") in adults after stroke. The primary outcome of interest was upper limb function and activity. Secondary outcomes included gait and balance and global motor function.

Data collection and analysis Two review authors independently selected trials based on pre-defined inclusion criteria, extracted data, and assessed risk of bias. A third review author moderated disagreements when required. The review authors contacted investigators to obtain missing information.

Results We included **72 trials that involved 2470** participants. This review includes 35 new studies in addition to the studies included in the previous version of this review. Study sample sizes were generally small and interventions varied in terms of both the goals of treatment and the virtual reality devices used. The risk of bias present in many studies was unclear due to poor reporting. Thus, while there are a large number of randomised controlled trials, the evidence remains mostly low quality when rated using the GRADE system. Control groups usually received no intervention or therapy based on a standard-care approach. Primary outcome: results were not statistically significant for upper limb function (standardised mean difference (SMD) 0.07, 95% confidence intervals (CI) -0.05 to 0.20, 22 studies, 1038 participants, low-quality evidence) when comparing virtual reality to conventional therapy. However, **when virtual reality was used in addition to usual care (providing a higher dose of therapy for those in the intervention group) there was a statistically significant difference between groups** (SMD 0.49, 0.21 to 0.77, 10 studies, 210 participants, low-quality evidence). Secondary outcomes: when compared to conventional therapy approaches there were no statistically significant effects for gait speed or balance. Results were statistically significant for the activities of daily living (ADL) outcome (SMD 0.25, 95% CI 0.06 to 0.43, 10 studies, 466 participants, moderate-quality evidence); however, we were unable to pool results for cognitive function, participation restriction, or quality of life. Twenty-three studies reported that they monitored for adverse events; across these studies there were few adverse events and those reported were relatively mild.

Virtual reality for stroke rehabilitation

Kate E Laver, Belinda Lange, Stacey George, Judith E Deutsch, Gustavo Saposnik, Maria Crotty

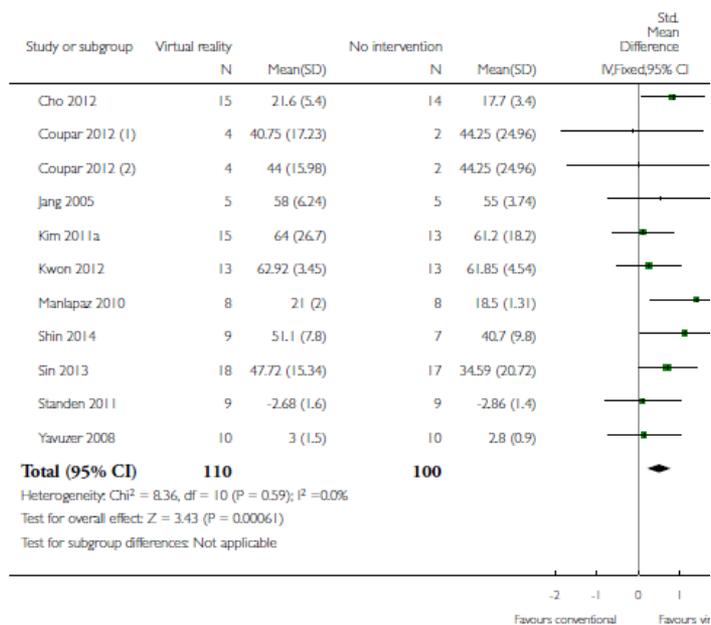
Cochrane Systematic Review - Intervention Version published: 20 November 2017

Analysis 3.1. Comparison 3 Additional virtual reality intervention: effect on intervention, Outcome 1 Upper limb function (composite measure)

Review: Virtual reality for stroke rehabilitation

Comparison: 3 Additional virtual reality intervention: effect on upper limb function post intervention

Outcome: 1 Upper limb function (composite measure)



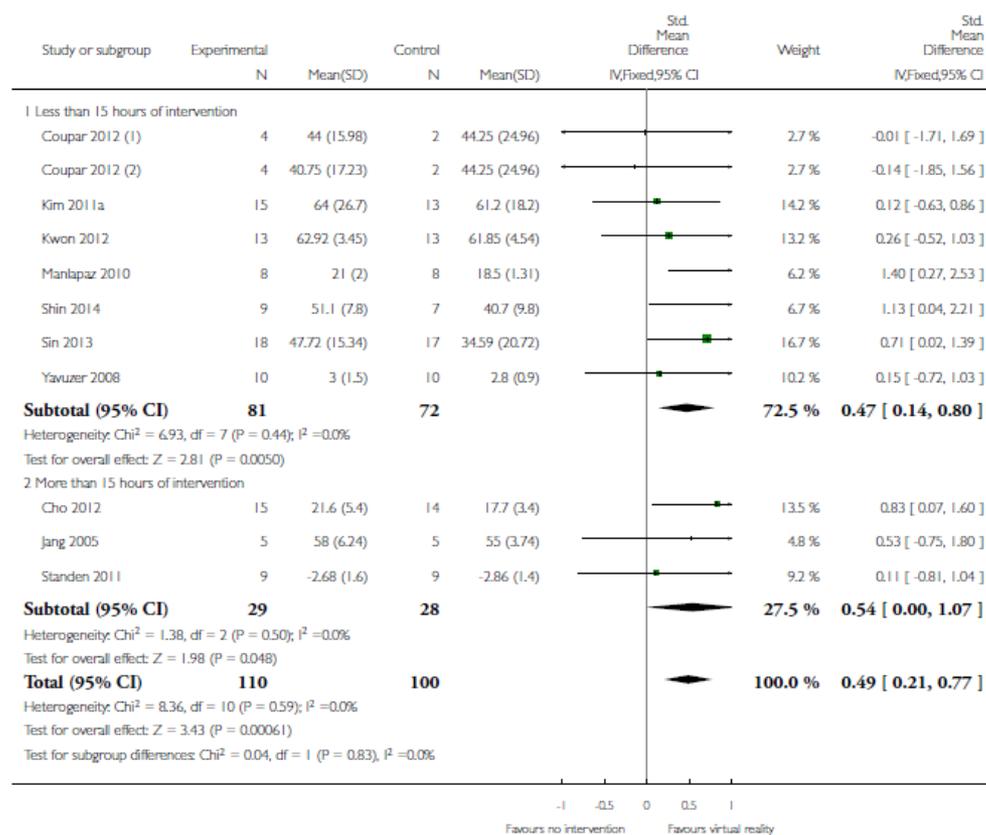
- (1) Low intensity training
- (2) High intensity training

Analysis 4.1. Comparison 4 Additional virtual reality intervention: effect on upper limb function post intervention: subgroup analyses, Outcome 1 Dose of intervention.

Review: Virtual reality for stroke rehabilitation

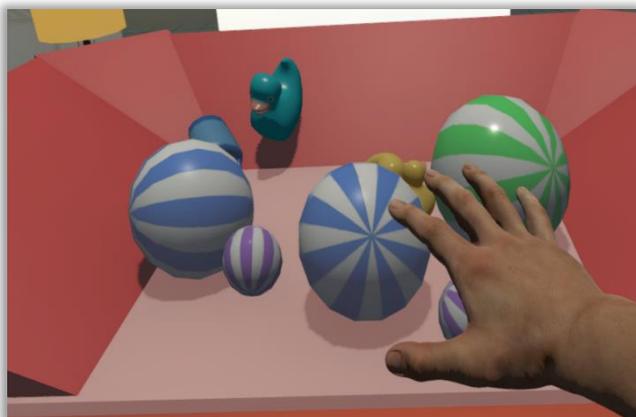
Comparison: 4 Additional virtual reality intervention: effect on upper limb function post intervention: subgroup analyses

Outcome: 1 Dose of intervention





Magic Glass



A multicentric
feasibility study
Of an immersive
virtual reality
delivered at
Home on chronic
stroke pts

Software



Magic Glass



- Based on mirror therapy



Telerehabilitation: Review of the State-of-the-Art and Areas of Application

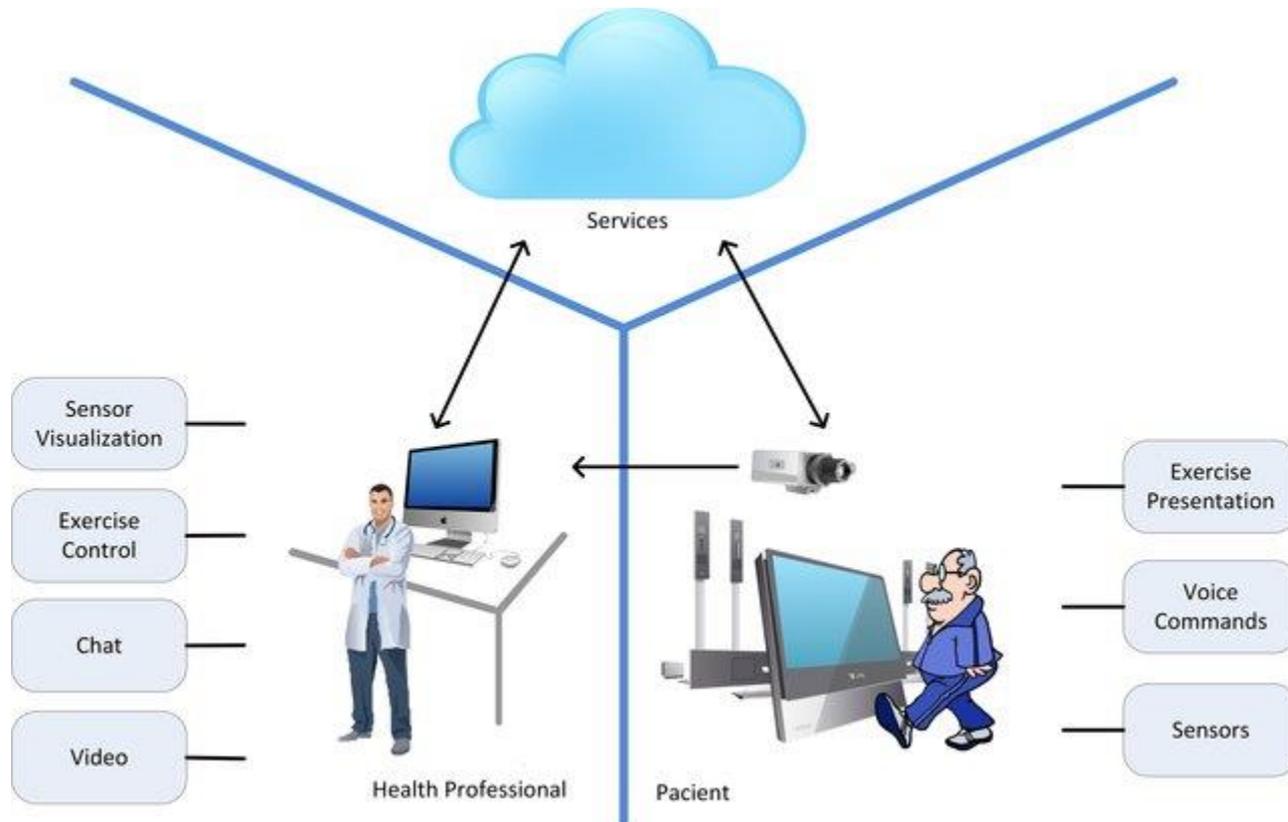
Telerehabilitation has been defined as “**the delivery of rehabilitation services via information and communication technologies**” [Brennan D, Tindall L, Theodoros D, et al. A blueprint for telerehabilitation guidelines. International journal of telerehabilitation. 2010;2(2):31–34.]

- Telerehabilitation can be considered as a branch of telemedicine.
- Its use has rapidly grown
- In general, telerehabilitation reduces the costs of both health care providers and patients compared with traditional inpatient or person-to-person rehabilitation.
- Furthermore, patients who live in remote places, where traditional rehabilitation services may not be easily accessible, can benefit from this technology.
- However, certain disadvantages of telerehabilitation, including skepticism on the part of patients due to remote interaction with their physicians or rehabilitators, should not be underestimated.
- Conclusions: This review evaluated different application fields of telerehabilitation, highlighting its benefits and drawbacks. This study may be a starting point for improving approaches and devices for telerehabilitation. In this context, patients’ feedback may be important to adapt rehabilitation techniques and approaches to their needs, which would subsequently help to improve the quality of rehabilitation in the future. The need for proper training and education of people involved in this new and emerging form of intervention for more effective treatment can’t be overstated.

[Peretti et al. JMIR Rehabil Assist Technol 2017;4(2):e7]

Tele-rehabilitation

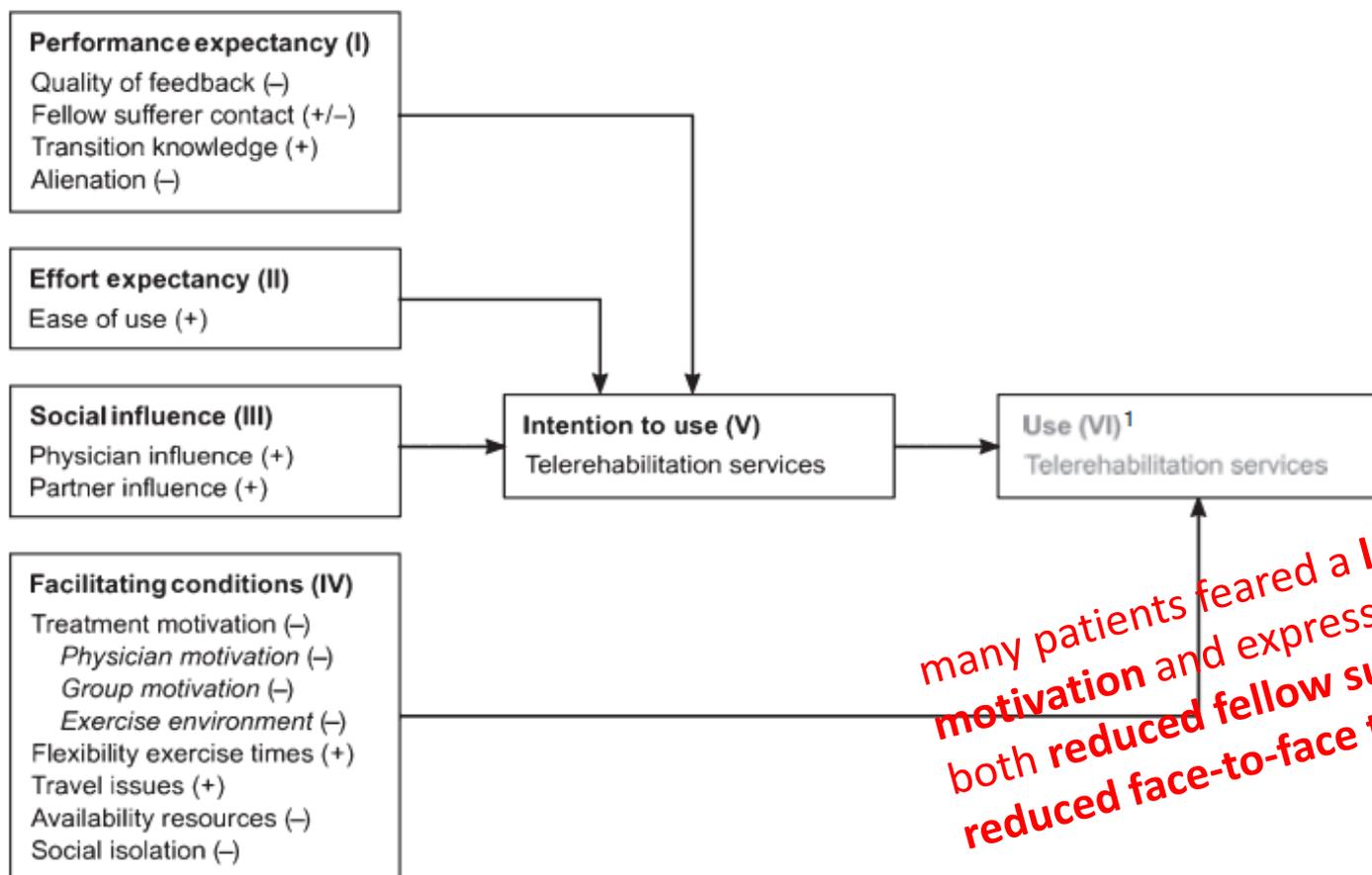
TeleRehabilitation System Architecture



An exploration of chronic pain patients' perceptions of home telerehabilitation services

Karlijn Cranen MSc,* Constance H. C. Drossaert PhD,† Evelien S. Brinkman MSc,† Annemarie L. M. Braakman-Jansen PhD,† Maarten J. IJzerman PhD‡ and Miriam M. R. Vollenbroek-Hutten PhD*§

Telerehab Patients' point of view



many patients feared a loss of treatment motivation and expressed concerns about both reduced fellow sufferer contact and reduced face-to-face therapist contact

A Home-Based Telerehabilitation Program for Patients With Stroke

Neurorehabilitation and
Neural Repair
2017, Vol. 31(10-11) 923–933
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sagepub.com/journalsPermissions.nav
DOI: 10.1177/1545968317733818
journals.sagepub.com/home/nnr



Lucy Dodakian, MA¹, Alison L. McKenzie, PhD^{1,2}, Vu Le, MS¹,
Jill See, MPT¹, Kristin Pearson-Fuhrhop, PhD¹, Erin Burke Quinlan, PhD¹,
Robert J. Zhou¹, Renee Augsberger, MHA¹, Xuan A. Tran¹, Nizan Friedman, PhD¹,
David J. Reinkensmeyer, PhD¹, and Steven C. Cramer, MD^{1*}

- **Patients were 3 to 24 months poststroke with stable arm motor deficits.**
- **Each received 28 days of telerehabilitation using a system delivered to their home.**
- **Each day consisted of 1 structured hour focused on individualized exercises and games, stroke education, and an hour of free play.**

Results. Enrollees ($n = 12$) had baseline Fugl-Meyer (FM) scores of 39 ± 12 (mean \pm SD).

Compliance was excellent: participants engaged in therapy on 329/336 (97.9%) assigned days. Arm repetitions across the 28 days averaged $24,607 \pm 9934$ per participant.

Arm motor status showed significant gains (FM change 4.8 ± 3.8 points, $P = .0015$), with half of the participants exceeding the minimal clinically important difference.

Although scores on tests of computer literacy declined with age ($r = -0.92$; $P < .0001$), neither the motor gains nor the amount of system use varied with computer literacy. Daily stroke education via the telerehabilitation system was associated with a 39% increase in stroke prevention knowledge ($P = .0007$).

Depression scores obtained in person correlated with scores obtained via the telerehabilitation system 16 days later ($r = 0.88$; $P = .0001$).

In-person blood pressure values closely matched those obtained via this system ($r = 0.99$; $P < .0001$).

Conclusions. **THIS HOME-BASED SYSTEM WAS EFFECTIVE IN PROVIDING TELEREHABILITATION, EDUCATION, AND SECONDARY STROKE PREVENTION TO PARTICIPANTS.** Use of a computer-based interface offers many opportunities to monitor and improve the health of patients after stroke.

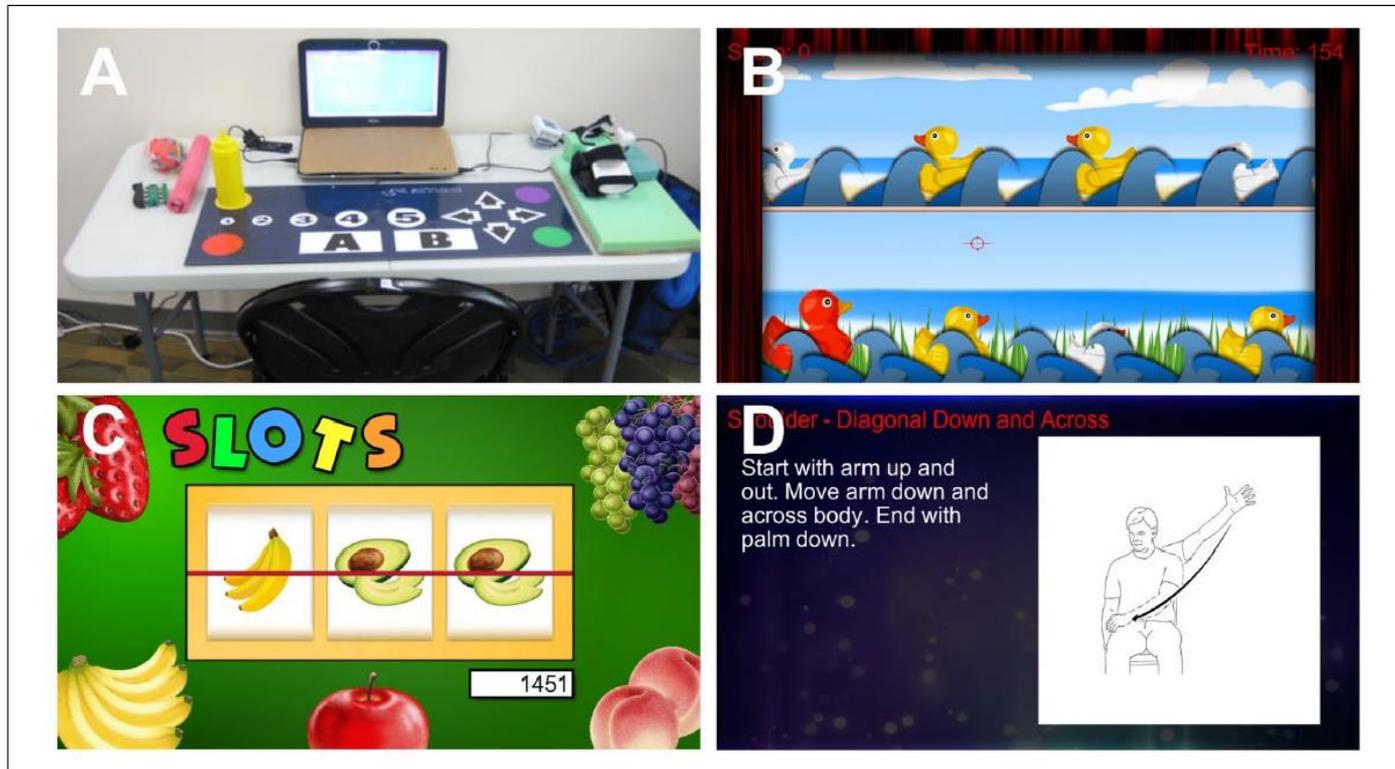


Figure 1. A. Hardware for the telerehabilitation system included a standard table, chair, laptop with keyboard covered, Verizon wireless modem, mat used for game play and moving through the day's itinerary (via the buttons and arrows), standard rehabilitation equipment, and multiple USB-based input devices to drive game play. B. Carnival shooting, a game in which the patient performed supination/pronation movements to move the red cursor then squeezed a trigger using a lateral pinch movement to shoot at the yellow, but not red, ducks. C. Slot machine, a game in which the patient had to perform shoulder extension movements to stop each of the 3 reels from spinning at the correct time to match all 3 symbols. D. Shoulder abduction/adduction, 1 of the 67 available exercises.

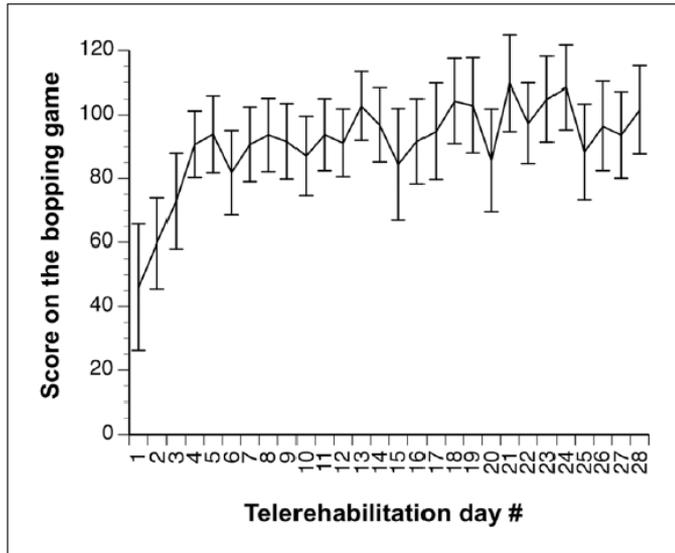
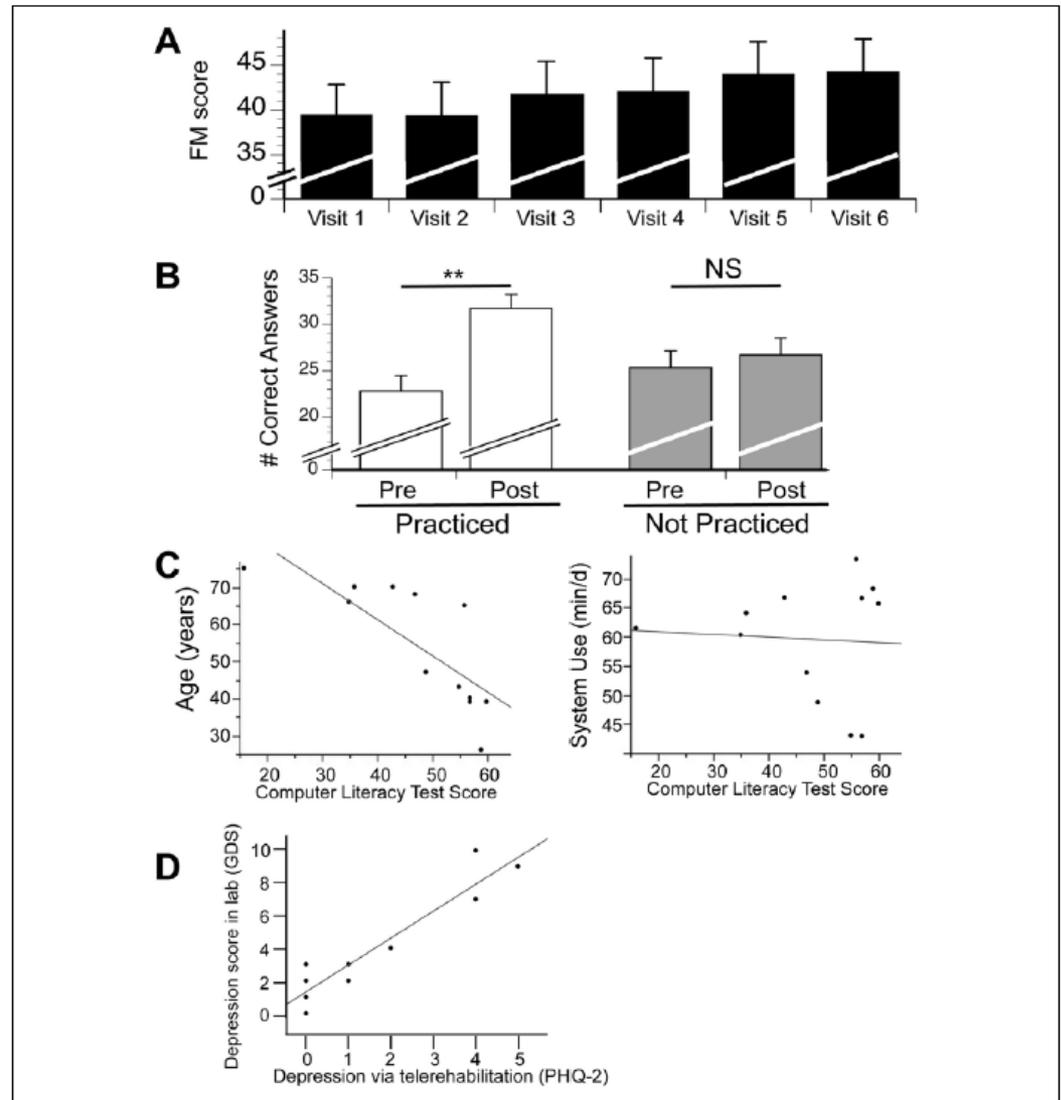


Figure 2. Mean \pm standard error of the mean scores on the bopping game, during which participants had to use a cylinder held in the stroke-affected hand to bop the tabletop mat target that was indicated on the computer screen. Scores increased significantly across the 28 days of therapy ($r = 0.65$; $P = .0002$); note that this increase in scores over time remained significant if values from the first 3 days were removed.

THIS HOME-BASED SYSTEM WAS EFFECTIVE IN PROVIDING TELEREHABILITATION, EDUCATION, AND SECONDARY STROKE PREVENTION TO PARTICIPANTS



TELE-RIABILITAZIONE & ACTION OBSERVATION THERAPY

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Action-Observation

Progetto di ricerca finanziato dal Ministero Salute GR-2011-02349761 Young Researcher (under 40 years).

Titolo: Action observation therapy: a chance for Parkinson Disease patients of improving mobility through a home-based training

Principal In...

Online available rehabilitation based on action observation

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Challenging points:

- **Remote clinical monitoring** a patient's engagement and motivation

09:03
18/03/2017



Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com



An instrumental approach for monitoring physical exercises in a visual markerless scenario: A proof of concept

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Accepted Manuscript

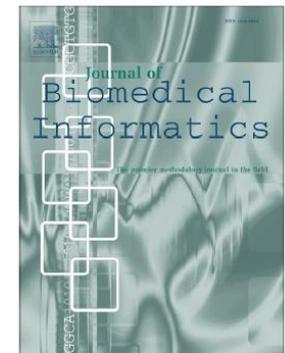
A Hidden Semi-Markov Model based Approach for Rehabilitation Exercise Assessment

Marianna Capecci, Maria Gabriella Ceravolo, Francesco Ferracuti, Sabrina Iarlori, Ville Kyrki, Andrea Monteriù, Luca Romeo, Federica Verdini

PII: S1532-0464(17)30282-4
DOI: <https://doi.org/10.1016/j.jbi.2017.12.012>
Reference: YJBIN 2907

To appear in: *Journal of Biomedical Informatics*

Received Date: 29 July 2017



Collaborative design of a telerehabilitation system enabling virtual second opinion based on fuzzy logic

ISSN 1751-9632
Received on 14th February 2017
Revised 13th December 2017
Accepted on 31st December 2017
E-First on 15th February 2018
doi: 10.1049/iet-cvi.2017.0114
www.ietdl.org

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A low cost telerehabilitation system made up of a commercial red–green–blue depth (RGBD) camera and a web-based platform. The authors goal is to monitor and assess subject movement providing acceptable and usable at-home remote rehabilitation services without the presence of a clinician. Clinical goals, defined by physiotherapists, are firstly translated into motion analysis features.

A Takagi Sugeno fuzzy inference system (FIS) is then proposed to evaluate and combine these features into scores. In this stage, the ‘collaborative design’ paradigm is used in depth and complete manner: the contribution of the clinician is not limited only to the rules definition but enters in the core of the evaluation algorithm through the definition of the fuzzy rules.

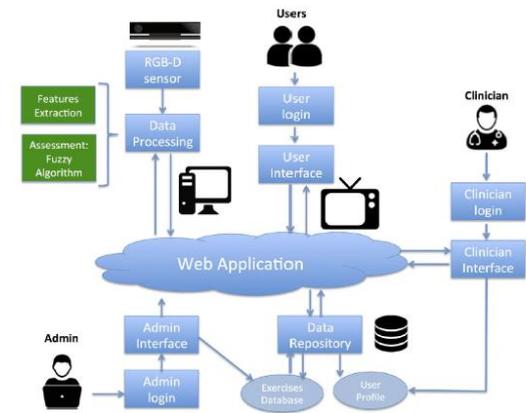
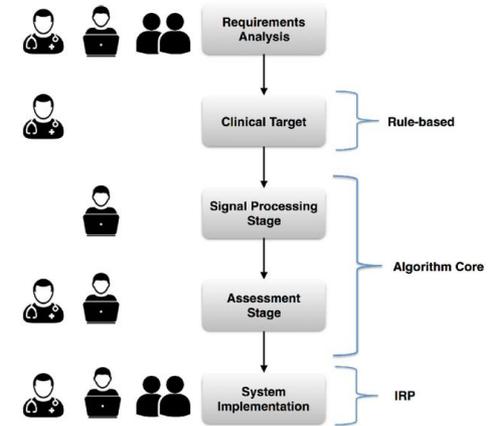


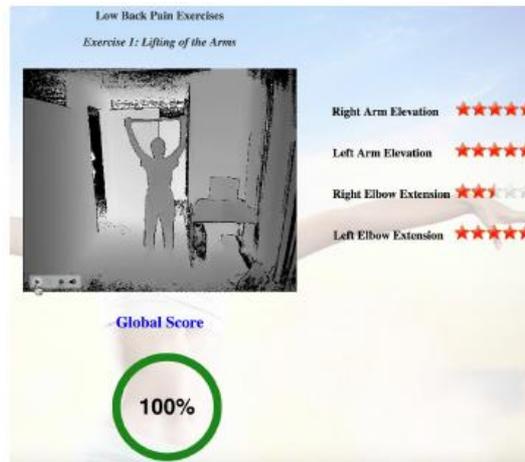
Fig. 9 System architecture using RGB-D sensor

Collaborative design of a telerehabilitation system enabling virtual second opinion based on fuzzy logic

A case study on low back pain rehabilitation involving 40 subjects, 5 exercises, and 4 physiotherapists is then presented to the effectiveness of the proposed system. Results of the validation of the system aimed at the assessment of the reliability of the proposed approach show high correlations between clinician evaluation and FIS scores. In this scenario, due to the high correlation, each FIS could represent a virtual alter-ego of the physiotherapist which enable a real time and free second opinion.

Capecci et al Computer Vision 2018

User interface with the global score related to exercise 1. The interface provides also an intuitive 'star rating' for each the extracted feature



Clinical interface for exercise 1. The interface provides the histograms related to PT, PC, and SC, together with their temporal evolution in the week

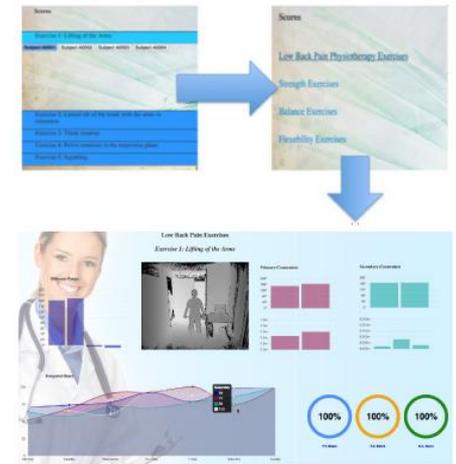


Table 5 Pearson correlation test between real and virtual physiotherapist evaluation: ρ and (p value) for all the scores

Ex.	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5
global score	0.91 ($p < 10^{-7}$)	0.86 ($p < 10^{-5}$)	0.80 ($p < 10^{-4}$)	0.79 ($p < 10^{-4}$)	0.74 ($p < 10^{-3}$)
PT score	0.88 ($p < 10^{-6}$)	0.84 ($p < 10^{-5}$)	0.76 ($p < 10^{-4}$)	0.76 ($p < 10^{-3}$)	0.73 ($p < 10^{-3}$)
PC score	0.87 ($p < 10^{-6}$)	0.86 ($p < 10^{-5}$)	0.79 ($p < 10^{-4}$)	0.81 ($p < 10^{-4}$)	0.74 ($p < 10^{-3}$)
SC score	0.80 ($p < 10^{-4}$)	0.83 ($p < 10^{-5}$)	0.82 ($p < 10^{-5}$)	0.76 ($p < 10^{-4}$)	0.64 ($p < .005$)



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