ERehabilitation: Using virtual reality technologies in rehabilitation for children and adolescents with cerebral palsy

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Virtual reality

- Emerging therapeutic modality
- Potential to increase therapy dose
- Diverse simulation systems
- Allow user to interact in ‘realistic’ manner using computer hardware and software
- Interactive Computer Play: “any kind of computer game or virtual reality technique where the child can interact and play with virtual objects in a computer-generated environment” [Sandford, 2009]

Classification

- Immersive
  - First person view of 3D virtual world
  - User wears head mounted display & force feedback
  - Very expensive, limited to research
- Non Immersive
  - Controlled through 2D flat screen
  - Interact through motion detecting interfaces
  - Vary in cost
- Whole body movement
- Upper limb movement
- Train upper extremity skills

Current therapy for CP

- Evidence suggests 60 hours of direct rehabilitation
- High repetition therapy
  - Motor adaptations in humans → 300 repetitions
  - Skill learning post stroke → 500 repetitions
- Barriers prevent adequate dose:
  - Limited access and health resources/expertise
  - Inequity of access for children in rural/remote areas
  - Rehabilitation inaccessible even in metropolitan areas
- Amount of therapy may be insufficient to drive neuroplasticity and lead to functional changes

Dance Dance Revolution

- Availability: Commercially available
- Equipment: Game, console and mat with weight bearing sensors: ~US$400
- User: independent standing, stepping & dynamic balance
- Setting: Centre or home based
- Flexibility: Pre-defined games, adjust difficulty
- Measures: Game score and length

Playstation Eye / EyeToy

- Availability: Commercially available
- Equipment: Game, console and EyeToy camera: US$260
- Interface: User represented in screen environment
- User: From sitting with limited UL movement → independent standing, stepping, balance, full UL
- Setting: Centre or home based
- Flexibility: Pre-defined games, adjust difficulty
- Measures: Game score

References:

**Paediatric Interactive Therapy System (PITS)**

- **Availability:** Rehabilitation specific system upper limb reaching and grasp training.
- **Equipment:** Custom table, pressure sensor gloves or squeeze bottle, computer, TV, PITS software; 7Cost
- **Interface:** Virtual arms on screen in environment
- **User:** All U.L functional levels
- **Setting:** Centre based
- **Flexibility:** Can adjust parameters of games
- **Measures:** Detailed data

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**Playstation 3 Based Sensor Glove**

- **Availability:** Professional tele-rehabilitation system - trains upper-limb and HAND movements
- **Equipment:** PlayStation3, computer, TV, HDMI cables; SDT Ultra glove – fibre optic sensor per finger; 7Cost
- **Interface:** Hand represented on screen
- **User:** All functional levels
- **Setting:** Centre based
- **Flexibility:** Adjust parameters of games
- **Measures:** Receive detailed measurement

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**Cogmed**

Cogmed Working Memory Training is an evidence-based program for helping children, adolescents, and adults sustainably improve attention by training their working memory.

- **Availability:** Available through Cogmed qualified coaches throughout Australia
- **Equipment:** Computer and purchase of the program through coach
- **Interface:** User in computer game
- **User:** children and adults with working memory issues
- **Setting:** home based in conjunction with coach
- **Flexibility:** automatically adjusted parameters (exercise time and difficulty) to maximise success.
- **Measures:** various for studies ranging from working memory, attention, learning and executive functioning measures

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**Classification framework**

**VRD**

1. **MRI**
2. **PET**
3. **EEG**
4. **TMS**
5. **fMRI**

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**Wii**

- **Availability:** Commercially available
- **Equipment:** Game, console, WiiTM uses remote which detects acceleration, Wii FitTM uses remote and balance board; ~US$330
- **Interface:** User represented as avatar on screen
- **User:** Wii: Requires grasp but can be done sitting
  Wii Fit requires standing & dynamic balance
- **Setting:** Centre or home based
- **Flexibility:** Predefined games, adjust difficulty
- **Measures:** Output in score, time and balance displacement

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**IREX**

- **Gestreurek’s Interactive Rehabilitation and Exercise System**
- **Availability:** “Rehabilitation specific” professional system
- **Equipment:** IREX system - TV, green background, Camera, Computer, Red Glove → Camera detects movement; ~US$13,000
- **Interface:** User on screen in environment
- **User:** All functional levels
- **Setting:** Centre based
- **Flexibility:** Can adjust parameters of games
- **Measures:** Detailed measurements & therapeutic outcomes

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Evidence of low quality

Upper limb function

Commercially available systems

- PlayStation EyeToy
  - No change in impaired UL capacity (RCT, n=10) (Chen, 2007)
  - Increase in manual dexterity (n=14) (Sandlund et al., 2006)
  - Improved reaching kinematics, visual performance and fine motor performance (n=4) (Reid, 2002)
  - No change in MACS* (n=16) (Ritterband et al., 2005)

Web-based systems

- Move it to improve it (MII™)
  - Increase in ADL motor skills, no change in bimanual performance (Yin, 2008)
  - Improved sense of agency (Koster et al., 2012)

- Wii
  - No change in MACS* (n=16) (Bryanton et al., 2011)

- Nintendo Wii
  - No change in impaired UL capacity (RCT, n=10)
  - Small changes in 3/4 participants (n=4) (Sandlund et al., 2006)
  - Changes in neuropsychology on FIMR; ↑ motor performance (n=1) (You, 2005)
  - PITS
    - 4/5 Improved hand function (n=5) (Deutsch, 2008)
    - PlayStation 3 based 5D Ultra glove
    - Improved ADL and UL speed and dexterity (n=3) (Leslie et al., 2008; Sandlund et al., 2011)

Inconclusive evidence regarding upper limb function

- VRT: ↑ free movement, ↑ range of motion, ↑ improved task performance (n=1)

- EyeToy: ↑ time, hold and range of ankle dorsiflexion (Bryanton et al., 2011)
- Wii: (n=13) Improvements in visual perception (TVPS), reduced postural sway, ↑ ambulance distance (Sandlund et al., 2006)
- Home-based VR cycling: (n=28) Increased isometric torque in knee E and F muscles
- VR system with treadmill training: (n=5) ↑ speed for one condition of walking obstacle course, Dimension E (Sandlund et al., 2006)
- MITii: (n=9) Increased strength and endurance on Bruce treadmill endurance test (Sandlund et al., 2006)

- Marig et al. (2012) Virtual reality in pediatric neurorehabilitation: attention deficit hyperactivity disorder, autism and cerebral palsy
- Neurorehabilitation 31:398
- Marig et al. (2012) Interactive Computer Play as “Motor Therapy” for Individuals with Cerebral Palsy, Seminars in Pediatric Neurology, 20:127-139

Lower limb strength

- IREX: (n=10) ↑ time, hold and range of ankle dorsiflexion (Chen, 2007)
- Case-Control (n=3:3) Improved posture during reach & rest (Reid, 2002)
- Wii: (n=13) Improvements in visual perception (TVPS), reduced postural sway, ↑ ambulance distance (Sandlund et al., 2006)
- Home-based VR cycling: (n=28) Increased isometric torque in knee E and F muscles
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Physical activity

- Wii: (n=8) Energy expenditure equivalent to moderate intensity exercise (Koster et al., 2012)
- IREX: (n=4) ↑ walk distance, community balance & mobility. No difference on GMFM-E or up/down stairs (Bryanton et al., 2011)
- EyeToy: (n=14) ↑ steps, physical activity & energy expenditure; ↑ Movement ABC. No difference motor proficiency or 1-min walk test (Sandlund et al., 2011)
- MITii: (n=9) functional strength and walking endurance (Bryanton et al., 2011)


Developing area of research

Pubmed search: number of publications 2000-2014 ‘cerebral palsy’ and ‘virtual reality’

Inconclusive evidence regarding upper limb function

- VRT: ↑ free movement, ↑ range of motion, ↑ improved task performance (n=1)
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Visual Perception

Commercial Systems
- Wii
  - Improvements in visual perception (TVPS-3 non-motor) (n=1) (Deutsch, 2008)

Web-based Systems
Mitii™
- Improvements in overall visual perception and figure ground discrimination (TVPS-3 non-motor) (n=9) (Deutsch, 2012)

Small sample sizes → inconclusive evidence for visual perception

Incorporated with conventional treatment?
- Evidence of VR as an adjunct to conventional therapy
- Systematic review
- 31 papers: 7 RCTs, 16 cohort studies, 8 single-case studies
- Conventional therapy: Interventions (Oral medication, Baclofen etc) and rehabilitation
- Difficult to compare treatment effects
- Non-standardized patient follow up, use of clinical scales/scores

Active ingredients
- System or game properties
  - Opportunities to practice
  - Task specificity
  - Flexibility to individualise treatment parameters
  - Feedback on task performance
  - Social play equalisation
- Effects on the user
  - Neuroplastic changes
  - Problem solving
  - Motivation
- Therapist Roles
  - Role of a support person

Subjective Reports
- No formal qualitative studies to date
- Generally positive engagement and participation
- Overall high enjoyment and satisfaction
- Motivation
- Novety of “game-like” therapy
- Contact with therapists
- Desire to improve functional abilities
- Can be difficult to maintain over long periods

"Move it to improve it"
- Multimodal web-based training program
  - Cognitive, upper limb and physical activity training
- Two versions
  - 1st generation Green Band → old version
  - 2nd generation Kinect → current version
- Aimed to drive neuroplasticity

Mitii™ Program
- Designed by Helene Elsass Centre and University of Copenhagen
- Accessed via internet (Cloud technology)
- Minimal equipment
  - Computer with webcam
  - Green tracking bands or Kinect
  - Balance foam
  - Step block
- 20 week program
- ~30 mins daily, 6 days/week


AACPDM 67th Annual Meeting: IC4 Handouts – ERRehabilitation: Using VRT in rehabilitation for individuals with cerebral palsy

**Mitii™ compared to standard video games?**

- Upper-limb training
- Cognitive training
- Physical activity
- Neuroplasticity
- Visual perception
- Uses internet
- Individualised and tailored program
- Delivered by therapists

**Examples of Modules**

- Visual discrimination: Select the image does that is different using hemiplegic upper limb
- Visual perceptual games incremented by difficulty of images, number of images, distractions and upper limb hover time.
- Physical activity games incremented by number of repetitions, use of step block and balance foam.

**Why Mitii™ compared to standard video games?**

**Upper-limb training**

**Cognitive training**

**Physical activity**

**Neuroplasticity**

- Uses internet
- Individualised and tailored program
- Delivered by therapists

**Pilot study**

- Pre-post design
- Children aged 9-13 years with unilateral CP (n=9)
- Intensive 30min/day, 20-week training period
- High compliance
- Improvements in ADL motor and processing skills, functional strength, endurance and visual perception
- No change in bimanual performance

**Mitii™ Australia CP Study**

- Waitlist randomised controlled trial
- n = 102 (51 pairs matched for age, gender and MACS)
- Unilateral CP, 8-18y, MACS I-III, GMFCS I-II
- Green band Mitii™
- Full ethics approval

**Mitii™ Australia Acquired Brain Injury Study**

- Waitlist Randomised controlled trial
- n = 60 (30 pairs matched for age, gender and MACS equivalent)
- 12 months post ABI, 8-16y, equivalent to MACS I-III, GMFCS I-II
- Kinect Mitii™
- Full ethics approval

**Multi-disciplinary studies**

**Overall aim**

- Occupational Therapy
- Physiotherapy
- Neuropsychology

**1° Hypothesis**

- ↑ Occupational performance, UL, VP, participation (n=102)
- ↑ Habitual physical activity
- ↑ Executive function

**2° Hypothesis**

- ↑ UL, VP, participation
- ↑ Strength, PA capacity, function
- ↑ Use dependant neuroplasticity

**1° Outcome**

- AMPS
- 4 day Actigraph HPA
- fMRI

**2° Outcomes**

- JTTHF, AHA, MUUL, TVPS, COPM, LIFE H
- Fx strength, 6MWT, MobQues
- Executive function, SDQ, BRIEF

**Other**

- PEM-C/C, CPQOL, Study Questionnaire, Qualitative Studies

**Stay tuned for results!**

- Mitii™ has allowed families all around the east coast of Australia to participate in therapy in the home environment
- Full details of study in Mitii™ CP study protocol