Therapeutic Reflection: 
The Augmented Mirror Box Project

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Outline

- Introduction: Pain, movement, mirrors and brains
  - Theory and practice – The Mirror box
  - Potential for neuroplastic change
- Augmented Reflection Technology
  - The Augmented mirror box
  - AMB studies (non-clinical and cases)
  - TheraMem “game“ for physical rehabilitation
  - TheraMem studies
- Future directions
Pain, movement, mirrors & brains
Background, theory and practice

- Some amputees experience phantom pain (and other sensations) in the missing limb.

- Phenomenon of phantom limb movement (Carlen et al., 1978).

- Franz et al “spatial coupling” between limbs (Franz, 1997).

- Franz and Ramachandran (1998) found bimanual coupling still occurs in amputees (ie central, not peripheral or physical process)

- Development of therapeutic devices to ameliorate unilateral (one sided) sensory and motor impairments.
Applications

“virtual” movement (ie by reflection in a mirror) to:

- reduce pain for amputees (Ramachandran & Rogers-Ramachandran, 1996)
- relieve chronic pain (Tichelaar, 2007; Rudd et al., 2008)
- increase movement affected by wrist fractures (Altschuler & Jeong, 2008);
- and enhance motor output in unilateral stroke (Gaggioli et al., 2005; Jang et al., 2005; Dohle et al., 2008).
VR/AR therapy: Illusory ownership of limb

Moseley, Olthof, Venema, Don, Wijers, Gallace, & Spence (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. PNAS  September 2, 2008 vol. 105  no. 35  13169–13173
Mirror-Box Therapy
Mirror Box Therapy: Phantom Limb

**Fig. 6** The mirror box. A mirror is placed vertically in the centre of a wooden or cardboard box whose top and front surfaces have been removed. The patient places his normal hand on one side and looks into the mirror. This creates the illusion that the amputated hand has returned.

Ramachandran & Hirstein (1998)
Mirror Box Therapy: CRPS Type 1 (no nerve damage)

Mirror Box Therapy: CRPS Type 2 (nerve damage)

Mirror Box Therapy: Stroke Rehabilitation

Neuroplasticity: The flexible brain

NZ Listener, 4 May 2012
Pros and cons of optical mirrors

Standard OMB:
- Is low cost, portable, readily available and has a long history of use

BUT limitations include:
- Rigidity of use, only presents actual reflected images in real time
- Asymmetrical body postures may be counterproductive
- Limited scope for augmentation in therapy
- Proliferation of applications (no protocols, poorly researched, claims untested)
- Few ways of manipulating a physical mirror (predetermined expectations)
- This resulted in recently developed prototypes of virtual reality mirror approaches, but with still some use of optical mirrors, eg Giraux & Sirigu, 2003; Sveistrup, 2004.
Augmented Reflection Technology
Augmented Mirror Box
Augmented Mirror Box::from optical to electronic


Early ART/AMB experimentation
Augmented Mirror Box::Working Prototype MkII.1.0
Augmented Mirror Box: Non-clinical studies

Various experimental studies have been carried out to explore the AMB

- Student volunteers N=22
  Temperature/sensation/movement

- “Normals” (students and staff) N= 30 Perceptions and ownership

- Subjects perceived reflections as their own hands (directly reflected)

- Most were unable to discern manipulation of reflected image (eg left reflected as right; images reversed etc)
Augmented Mirror Box: Pilot case study “F1“

- First case study on CRPS using AMB
- Mirror effect seemed to work as well as mirror therapy (F1: subjective report)
- F1 did not believe in/accept ownership of mirrored limb but pain levels decreased.
- Development issues: the equipment setup was more suitable for hands; display placement warranted more consideration
Subject F1: Pain ratings in foot (blue) and in CRPS area (red)
Augmented Mirror Box: Case studies

Examples of range of patient/subjects’ presenting problems

- F1: CRPS in foot
- F2: Right sided hemiplegia since TBI in m.v.a. 3 years ago
- F3: Pain left shoulder and arm post surgery 1996
- M1: left hand injury, affecting driving work (gear changes)
- M2: 6 yr history of stroke, no pain but debilitating sensations in right arm, hand, fingers; problems manipulating objects and fine motor tasks (eg use of cutlery)
- M3: 30 yrs old; 10 yr hx of pain and limited movement after injuring right wrist; impedes writing and flexing / rotation are limited and painful

We administer a wide range of psychometric instruments relating to pain, movement and wellbeing and conduct detailed assessment interviews with each patient before baseline assessment with the AMB.
Augmented Mirror Box::Potential Application Areas

Current focus on primary application fields (unilateral impairments)
- Stroke and brain injury rehabilitation
- Complex Regional Pain Syndrome
- Phantom Limb Pain Management

Also
- AMB technique as a diagnostic tool
- AMB to help understanding the underlying (perceptual / neuropsychological) processes
Augmented Mirror Box::Objectives

- Providing more therapeutic control in mirror-box applications using Augmented Reality technology
- Possible use of similar technology in different therapy/rehab areas, e.g. preventive (occupational) healthcare
- Research into the experienced sense of presence / motor control of real and imagined scenes: embodied interaction, affordances, possible actions
- Provision of a system (mature prototype) actually usable in clinical settings
- Extension of clinical and experimental work including that by the research partners (eg Liz’s mirror-box work and embodied interaction research, Brian’s and Holger’s VR exposure therapy work, Holger’s presence research and technical VR/AR work of work ) utilising the features of the AMB.
- Exploring the possibility of neuroplastic changes – combining the AMB and f-MRI techniques.
Augmented Reflection Technology System
Augmented Mirror Box::Setup
Augmented Mirror Box::Schematic
Augmented Mirror Box::Working Prototype MkII.2
Augmented Mirror Box::Working Prototype MkII.2
Augmented Reflection Technology

- Colour etc.
- Mirroring
- Size and Position
- 3D models
- 2D Backgrounds
Augmented Reflection Technology
TheraMem
TheraMem::Background

Motor Rehabilitation with VR/AR

Cameirão, Bermúdez i Badia, Oller & Verschure (2008)
(A) VR exercise setup, (B) birdball exercise game, (C) conveyor exercise game, and (D) soccer exercise game

TheraMem::Background

Exercise

Neuroplasticity
TheraMem

Goals and Assumptions

a) The system will be used for physical (functional and motor) rehabilitation, in particular for after-stroke therapy.
b) Using a casual computer game approach increases the motivation and engagement of the clients (patients) and might distract them from pain or discomfort while moving their impaired upper limb (arm/hand)
c) A controlled amplification of the movement of the impaired limb will lead to a systematic and gradual improvement of motor movement (in particular range of reaching and selection movements)
TheraMem System
TheraMem Game
Amplification Value 2.0 \[ s_{\text{new}} = s_{\text{ori}} \times (f+1) \]

Camera Video Stream
(original movement)

User’s View
(left hand with amplified movement)
3D Scene Construction

3D Scene View

Client’s View
3D Scene Construction
TheraMem::Project Progress

- System Development and Test
- Usability Study
- Utility Evaluations
  - Physio Students Lab week
  - SoP Seminar & Neuro SIG meeting
  - Interviews with experts
- Clinical Case Studies (6 chronic stroke patients)
TheraMem::Case Studies
TheraMem::Case Studies
Case Study::Patients and Sessions

5 chronic stroke patients:
- stable motor deficits (> 5 years since stroke)
- different impairment severity (2 dependent, 3 independent)
- different range of impairments
- all having motor-deficits in their upper limb

4 sessions of 1h

First session:
- Assessment of patient’s motor capabilities
- Orientation of patient to the ART

Second & Third Session:
- 3- 5 patient tailored exercises based on the outcomes of assessment

Fourth Session
- Exercises
- Reassessment of patient’s motor capabilities
TheraMem::Case Study
TheraMem::Case Study
Case Study::Conclusions

- The ART system is feasible for the use in clinical physiotherapeutic settings
- Patients are able to successful complete TheraMem
- Assistive devices might be required for patients with severe motor-impairments
- Patients were highly engaged in the exercises
- Patients liked the system and suggested it for further use

For details see:
TheraMem::State of progress

- Usability Studies
- Utility Evaluations
  - Physio Students Lab week
  - SoP Seminar & Neuro SIG meeting
  - Interviews with experts
- Systems Paper (ISMAR 2011)
- Clinical Case Studies (6 chronic stroke patients)
- Clinical Case Studies w/ sub-acute stroke patients (funding application submitted)
- Collaboration partners?, further developments
- Application for funding for RCT (Health Research Council)
Disorders/conditions with paralysis or disturbances of sensation that may be responsive to augmented virtual mirror approaches:

- Hemiplegia/hemiparesis (full or partial paralysis) due to traumatic brain injury, stroke, TIA’s or spinal injury/neoplasm

- Alternating Hemiplegias

- Missing or damaged limb/appendage sensory abnormalities (eg “Phantom limb” pain).

- Bell's palsy (Facial palsy; Idiopathic peripheral facial palsy).

- Conditions involving weakness or altered sensory awareness (eg of pain, temperature, pressure etc) affecting a limb or appendages - such as Complex regional pain syndrome (CRPS) and Brown-Sèquard syndrome.
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