
(are you coming to bed?)

I can't. This is important.

What?

Someone is wrong on the internet.
Therapeutic Reflection: the Augmented Mirror Box project.

A novel augmented reflection interface for pain relief and motor rehabilitation

Brian Dixon, Holger Regenbrecht, Elizabeth Franz, Graham McGregor & Simon Hoermann (University of Otago, Dunedin, New Zealand)
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: Pain - 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

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 (light blue) and in CRPS area (dark blue)
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 (e.g. 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
Desired manipulation options:

- Mirroring: none, left, right, both
- Size: environment or limb
- Position: x, y, z
- Movement: amplitude, pace (also shake/jitter)
- Timing: slow down, speed up, delayed
- Appearance: colour, visibility
- Touch: virtual or tactile (being touched or touch)
- Temperature (real, perceived)
- Grasp: virtual or real (being grasped or grasp)
- Immersion: resolution, fps, latency
- Foreign limb vs. own limb
- ...

Augmented Reflection Technology – image manipulation
Augmented Reflection Technology – augmentation menu

- Colour etc.
- Mirroring
- Size and Position
- 3D models
- 2D Backgrounds
Augmented Reflection Technology – screen views

Client’s View

3D Scene View
TheraMem: Background. Motor Rehabilitation with VR/AR

TheraMem System
3D Scene Construction – memory and movement “game”

3D Scene View

Client’s View
“Fooling the brain” – amplifying movements
Amplification Factor 2.0 \[s_{\text{new}} = s_{\text{ori}} \cdot (f+1)\]

Camera Video Stream (original movement)

User’s View (left hand with amplified movement)
TheraMem

- Usability Study (N=45)
- Utility Evaluations
  - 100 Physiotherapy Students
  - SoP Seminar & Neuro SIG meeting
  - Interviews with experts
- Clinical Case Studies with 6 patients
Where to from here?

• Clinical Case Studies (ongoing)
• Further developments
• Clinical Feasibility Studies
• RCT
• Deployment
Augmented Mirror: Potential Application Areas

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.
Research principals

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http://www.otago.ac.nz/psychology/staff/otago028734.html
http://www.hci.otago.ac.nz

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Links and publications


Links and publications (contd.)

[http://otago.ourarchive.ac.nz/handle/10523/1811](http://otago.ourarchive.ac.nz/handle/10523/1811)


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