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NEW ZEALAND

*

Novel Computer-Aided Therapy in Medicine: How Augmented Reflection Technology (ART) Can Assist Stroke Rehabilitation

Holger Regenbrecht
Information Science
University of Otago

*Artificial hand, from Ambroise Paré's *Instrumenta chyrurgiae et icones anathomicae* (Surgical Instruments and Anatomical Illustrations), Paris, 1564. http://www.cabinetmagazine.org/issues/22/wood.php

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University of Otago

University of Otago, Dunedin

- New Zealand's oldest university (1869)
- approx. 20.000 students
- 3.700 staff

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Department of Information Science

- 18 faculty (academic staff)
- 4 research and teaching fellows, 7 technical and admin staff
- about 50 postgraduate students (30 PhD, 10 Masters, 10 Hons/PGDip)

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Department of Information Science

- Our academic staff are involved in a wide variety of research areas (http://www.infosci.otago.ac.nz/research/):
  - Business Intelligence / Decision Support
  - Software Agents and Modelling
  - Health Informatics
  - Mobile Computing & Wireless Networking
  - Human-Computer Interaction (HCI)
  - Computer Vision & Image Analysis
  - Information Assurance & Security
  - Data Management
- We offer a wide ranging PhD Programme. PhD Scholarships and topics available.

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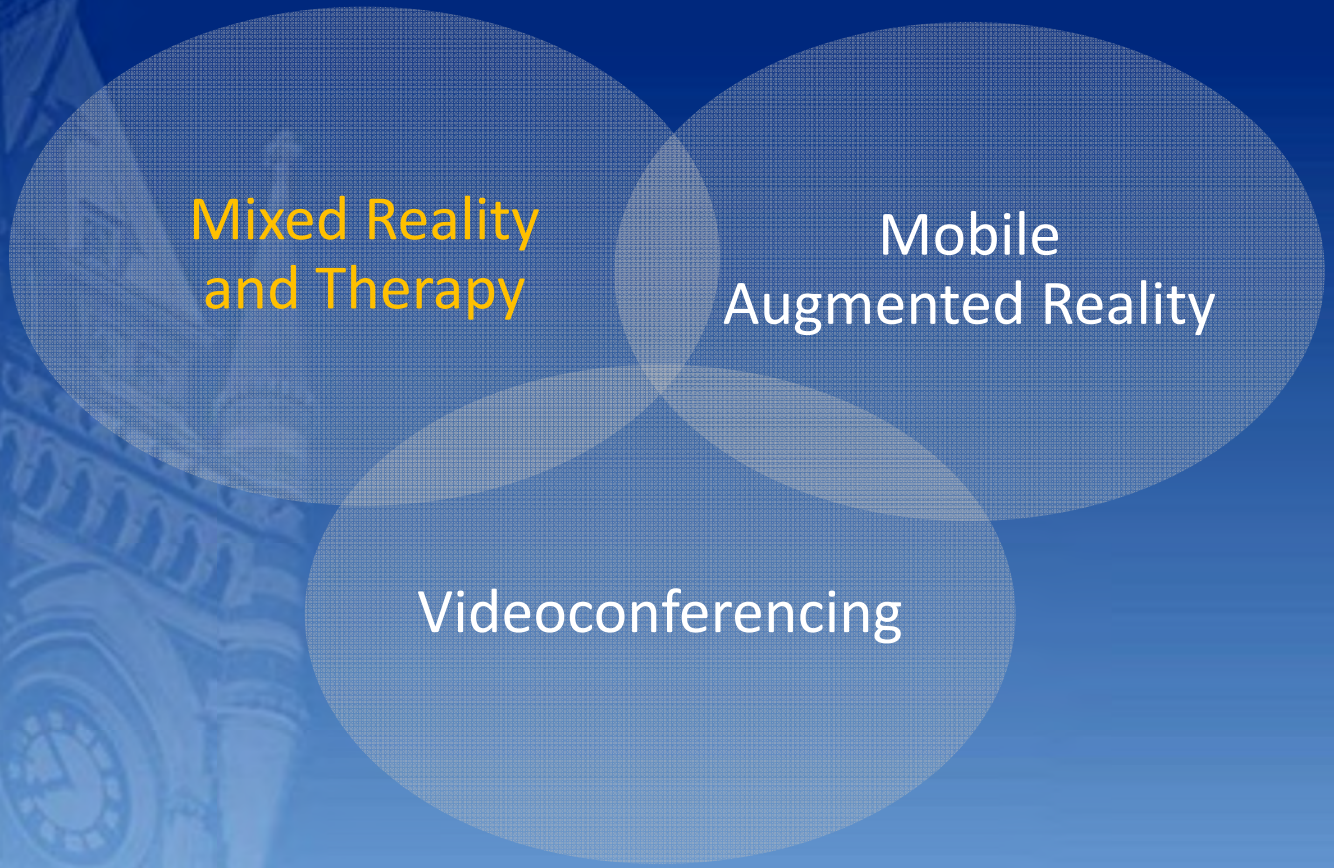
HCI::Three Main Research Themes



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Brain-related Research at Otago's Computer-Mediated Realities Lab

Research questions regarding

- sensory (in particular visual) illusions and neuroplasticity; Augmented Reflection Technology (ART)
- sense of presence and virtual rehabilitation, Mixed Reality experiences
- translational research utilising ART, in particular post-stroke rehabilitation and pain management
- CMR-based psycho- and physiotherapy, e.g. Virtual Reality Exposure Therapy
- novel technologies to measure brain-related activities and to provide new stimuli

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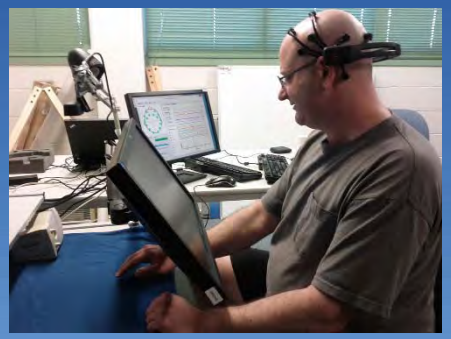
Brain-related Research at Otago's Computer-Mediated Realities Lab

collaborative Mixed Reality Exposure Therapy (here arachnophobia)

Virtual Reality Exposure Therapy (here claustrophobia)

Virtualised Nine Hole Peg Test for motor rehabilitation

ART-based TheraMem game for post-stroke rehabilitation



Evaluating affordable EEG measurements with ART system

"Fooling the brain" with Augmented Reflection Technology

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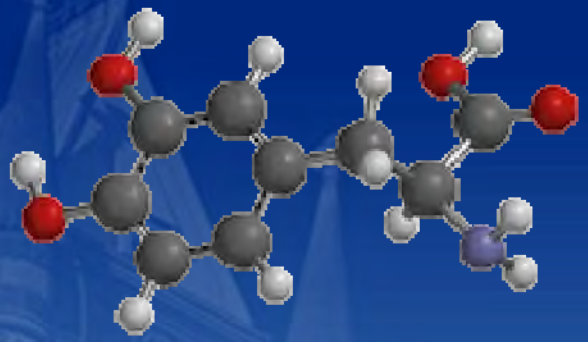
Stroke Facts (New Zealand)

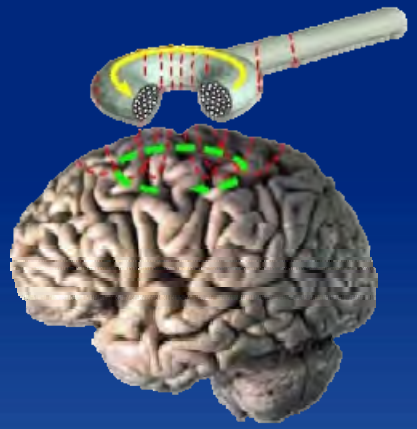
- About 9500 New Zealanders every year have a stroke
- Stroke is the third largest cause of death in New Zealand
- Stroke is the major cause of serious adult disability
- In 2010 the costs of stroke were estimated to be close to $1 billion only in New Zealand
  - of which about $590 million was attributed to the cost of primary health care
- There are an estimated 60,000 stroke survivors
- Many are disabled and need significant daily support
- About 2/3 of survivors have upper limb deficits
- Stroke recovery can continue throughout life

www.stroke.org.nz/node/16
www.gw.govt.nz/physical-inactivity-costs-almost-one-percent-of-gdp/

Stroke Rehabilitation Possibilities

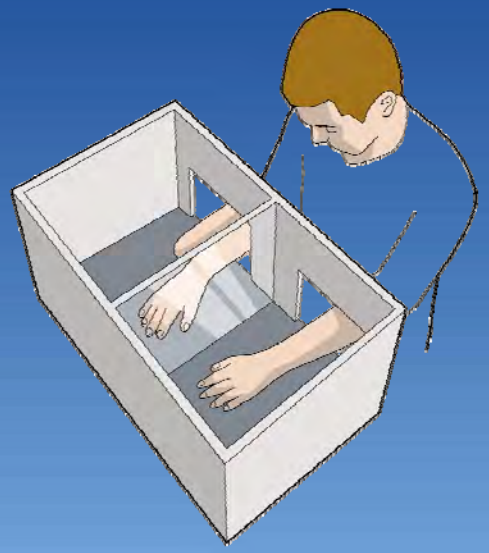


Drugs



Transcranial Stimulation

Physical Therapies



Central Sensory Stimulation

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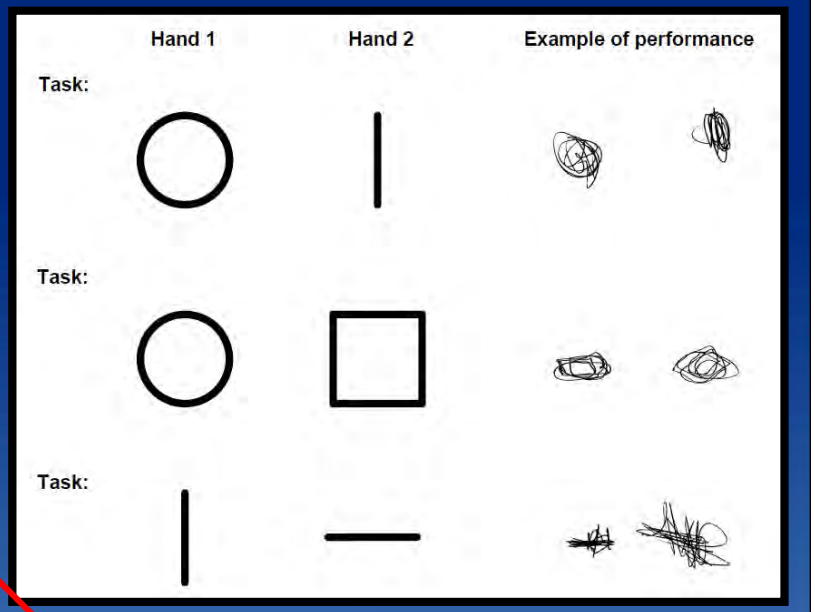
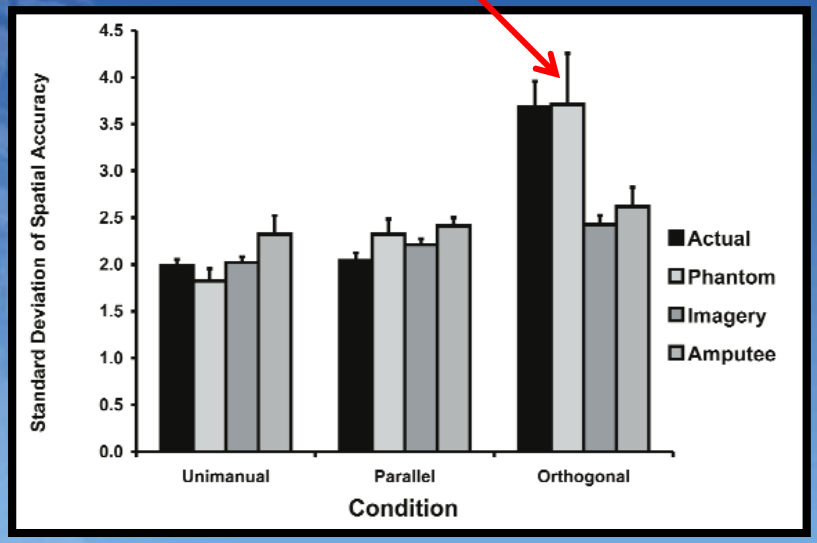
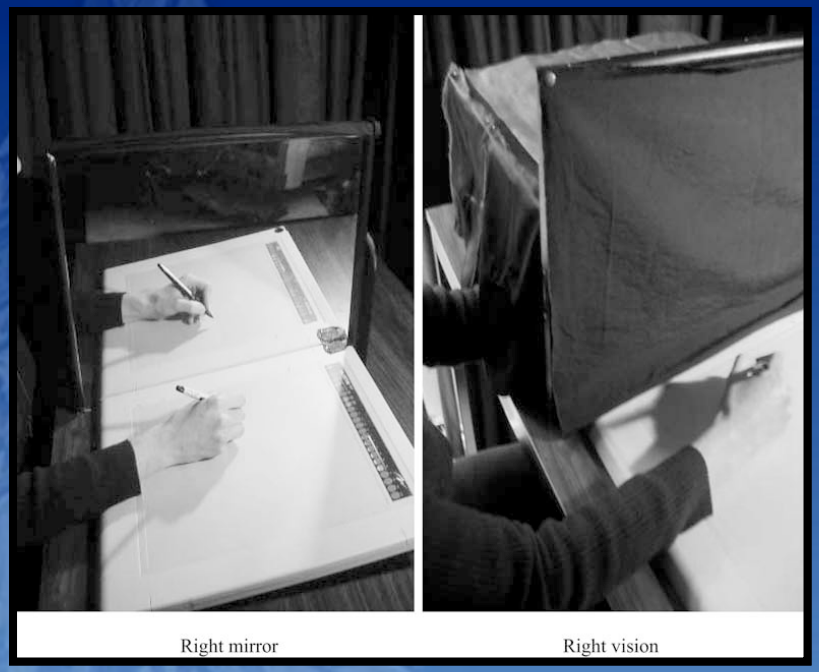
Bimanual Coupling

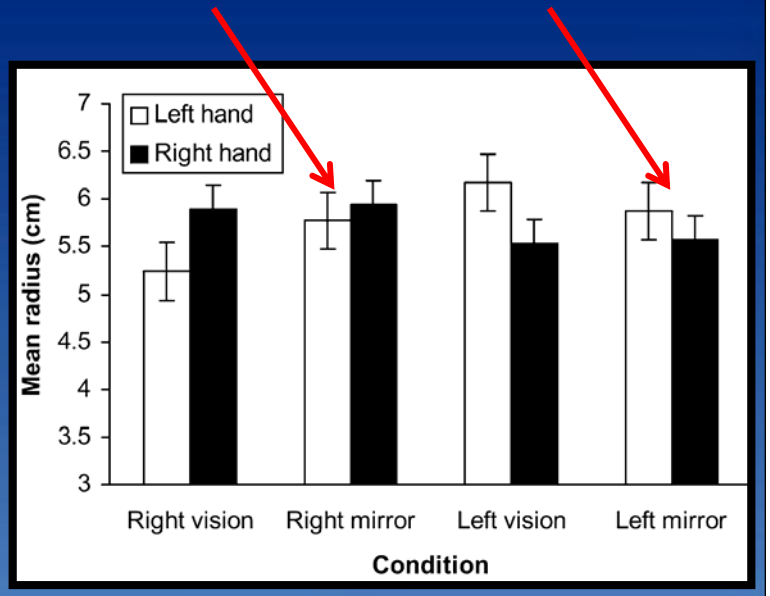




(Franz & Ramachandran, 1998)

Fooling the Brain with a Mirror





When using a mirror, the circle drawings of both hands became more alike

(Franz & Packman, 2004)

Rehabilitation after stroke with a Mirror

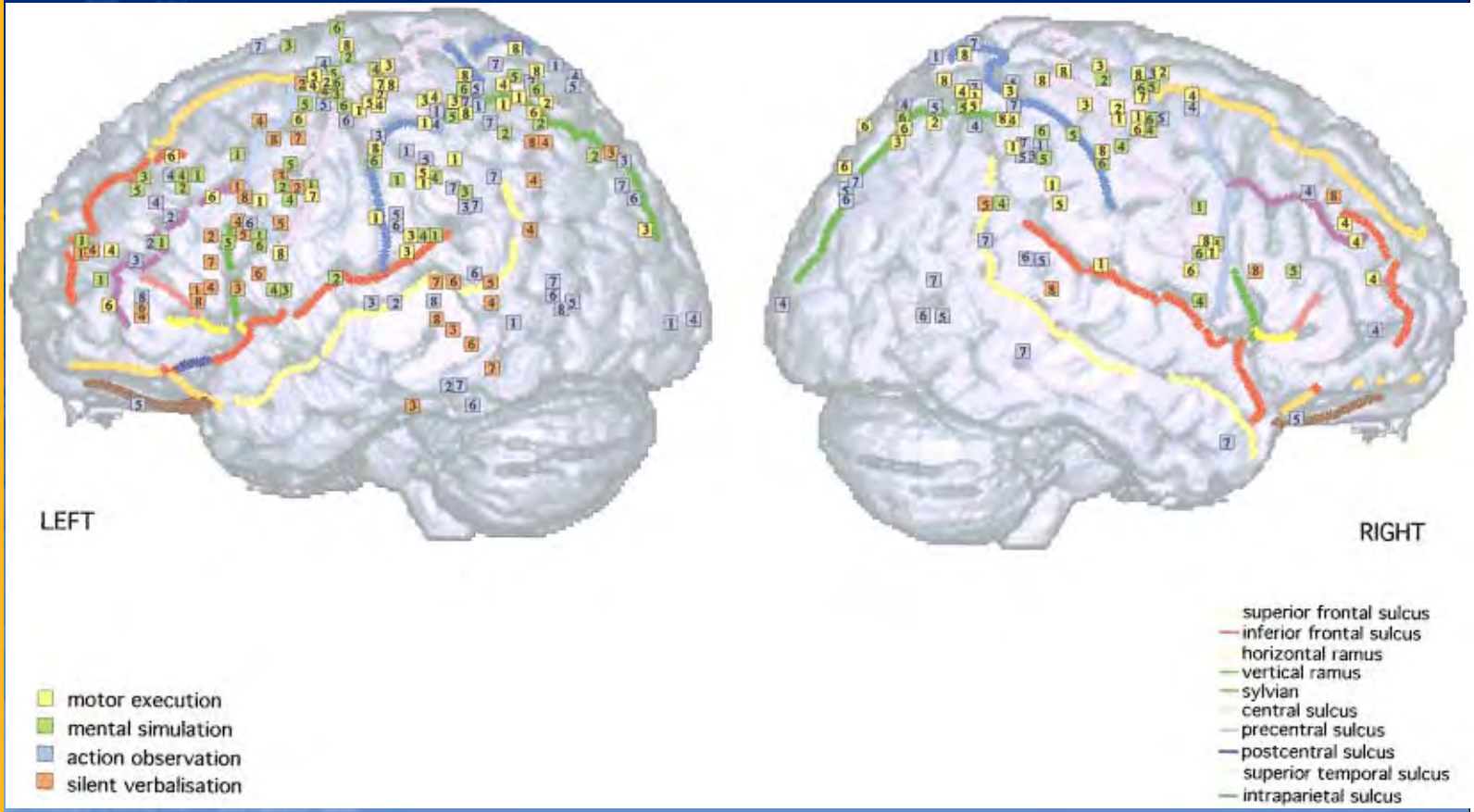
Patient number	Age, sex, handedness	Side of CVA, severity, time since CVA	Rehabilitation focus	First four weeks			Second four weeks		
				Treatment	G1	G2	Treatment	G1	G2
1	59, M, R	RCVA, mild, 2·1 years	Hand, wrist, elbow	C	+1	+0·5	M	+1	+1
2	55, M, R	RCVA, severe, 1 year	Shoulder, elbow	C	0	0	M	+1	+0·5
3	53, F, R	RCVA, extremely severe, 1·5 years	Shoulder	M	+0·5	0	C	0	0
4	55, M, R	RCVA, extremely severe, 6 months	Shoulder	M	+1	0	C	0	0
5	54, F, L	RAVM, severe, 26·25 years (AVM resection and CVA during pregnancy)	Shoulder, elbow	C	0	0	M	+1	0
6	60, F, R	RAVM, severe, 4·75 years	Shoulder, elbow	C	0	0	M	+1	0
7	53, F, R	RCVA, moderate-severe, 2·25 years	Shoulder, elbow	M	+0·5	0	C	0	0
8	73, M, R	RCVA, severe, 4·5 years	Shoulder, wrist	C	0	0	M	+1	+0·5
9	62, M, R	LCVA, moderate, 8 months	Shoulder, elbow, wrist	M	+1	+0·5	C	+1	+0·5

All patients had severely decreased to absent proprioceprion in the affected limb.
CVA=cerebrovascular accident (R=right; L=left); AVM=arteriovenous malformation; G=grader; M=mirror; C=control (transparent plastic).

Patient characteristics

(Altschuler et al., 1999)

Action execution, mental simulation and observation activate similar areas



(Grèzes & Decety, 2001)

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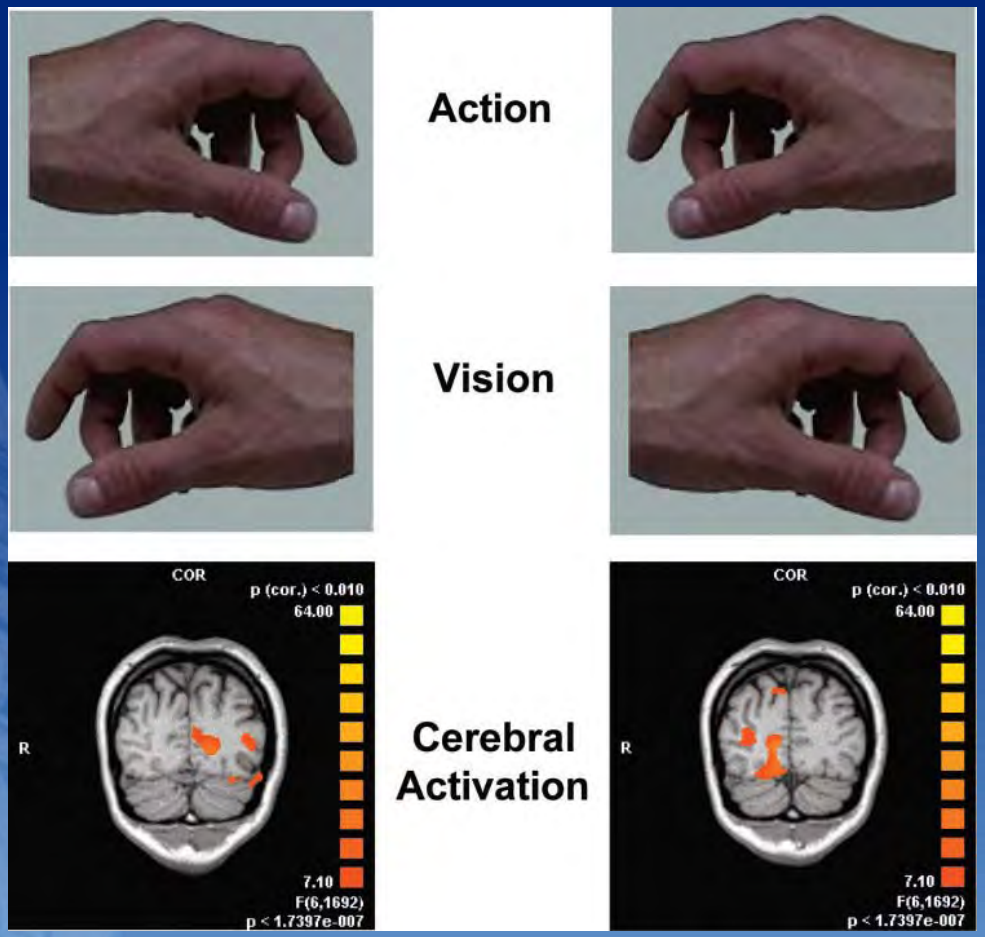
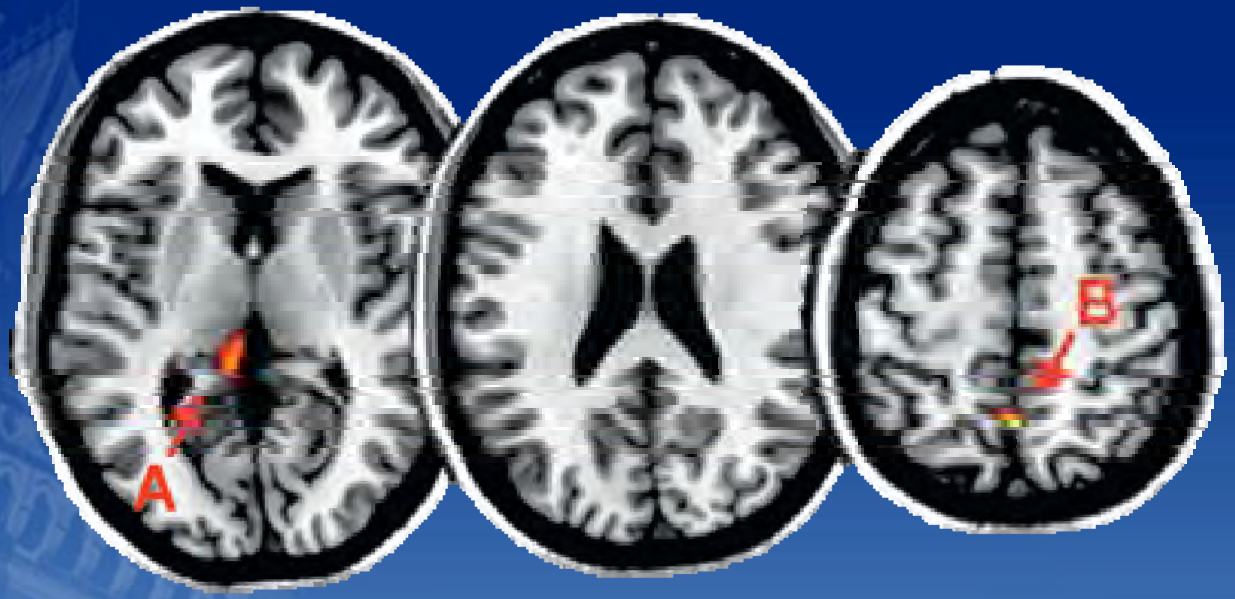
Neurophysiological Correlates



In the mirrored condition, activation in the visual cortex was lateralized contralateral to the seen hand

(Dohle, Kleiser, Seitz, & Freund, 2004)

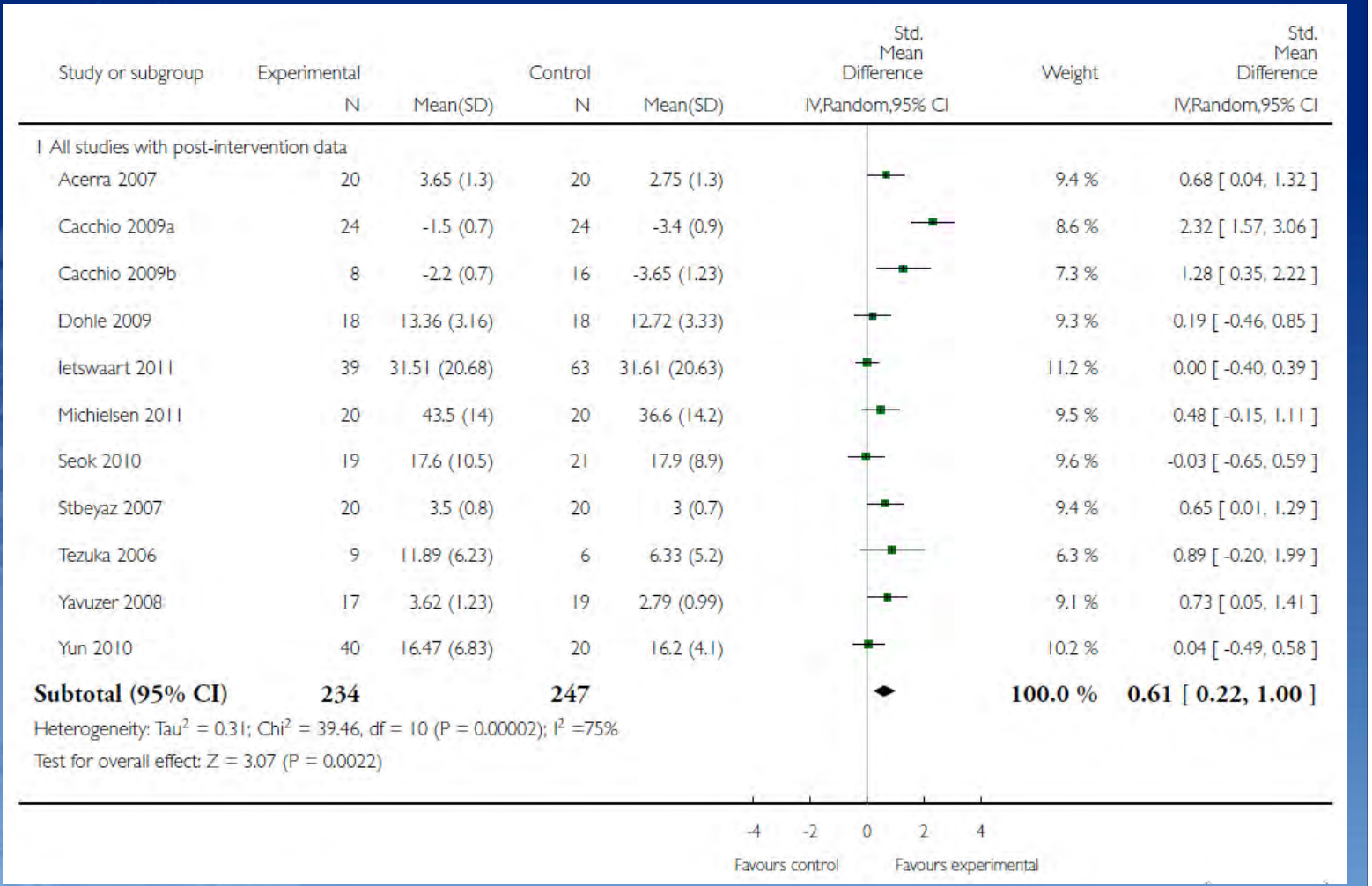
Also with patients who suffered a stroke



Increased activity as a result of the mirror illusion during bimanual movement in two areas: the precuneus (B) and the posterior cingulate cortex (A)

(Michielsen et al., 2011)

Mirror therapy improves motor function after stroke – Cochrane Review



Study or subgroup	Experimental N	Mean(SD)	Control N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 All studies with post-intervention data							
Acerra 2007	20	3.65 (1.3)	20	2.75 (1.3)		9.4 %	0.68 [0.04, 1.32]
Cacchio 2009a	24	-1.5 (0.7)	24	-3.4 (0.9)		8.6 %	2.32 [1.57, 3.06]
Cacchio 2009b	8	-2.2 (0.7)	16	-3.65 (1.23)		7.3 %	1.28 [0.35, 2.22]
Dohle 2009	18	13.36 (3.16)	18	12.72 (3.33)		9.3 %	0.19 [-0.46, 0.85]
Ietswaart 2011	39	31.51 (20.68)	63	31.61 (20.63)		11.2 %	0.00 [-0.40, 0.39]
Michielsen 2011	20	43.5 (14)	20	36.6 (14.2)		9.5 %	0.48 [-0.15, 1.11]
Seok 2010	19	17.6 (10.5)	21	17.9 (8.9)		9.6 %	-0.03 [-0.65, 0.59]
Stbeyaz 2007	20	3.5 (0.8)	20	3 (0.7)		9.4 %	0.65 [0.01, 1.29]
Tezuka 2006	9	11.89 (6.23)	6	6.33 (5.2)		6.3 %	0.89 [-0.20, 1.99]
Yavuzer 2008	17	3.62 (1.23)	19	2.79 (0.99)		9.1 %	0.73 [0.05, 1.41]
Yun 2010	40	16.47 (6.83)	20	16.2 (4.1)		10.2 %	0.04 [-0.49, 0.58]
Subtotal (95% CI)	**234**		**247**			**100.0 %**	**0.61 [0.22, 1.00]**

Heterogeneity: $Tau^2 = 0.31$; $Chi^2 = 39.46$, df = 10 (P = 0.00002); $I^2 = 75\%$

Test for overall effect: Z = 3.07 (P = 0.0022)

-4 -2 0 2 4

Favours control Favours experimental

(Thieme et al. 2012)

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Optimal Rehabilitation / Neuroplasticity

1. Treatment **frequency** and **intensity** correlate with recovery (Kwakkel et al., 2004; Sonoda, Saitoh, Nagai, Kawakita, & Kanada, 2004).

2. Movement **practice** and **repetition** play a fundamental role in recovery (Karni et al., 1995).

3. **Specificity** of rehabilitation training with respect to the deficits and required functional outcomes has an impact on recovery (Krakauer 2006).

(Bermudez i Badia, 2013), (Takeuchi & Izumi, 2013)

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Rehabilitation

Rehabilitation has been defined by the World health organization (WHO) as a coordinated process that **enhances activity** and participation.

Rehabilitation is a process of education the disabled person in order to support him/her coping with family, friends, work and leisure as independently as possible.

Broeren, 2007

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ART was created to

Exploit the current technological capabilities, both experimentally and therapeutically, to foster the brain's ability to heal itself and give patients after a stroke an opportunity to regain their quality of life.

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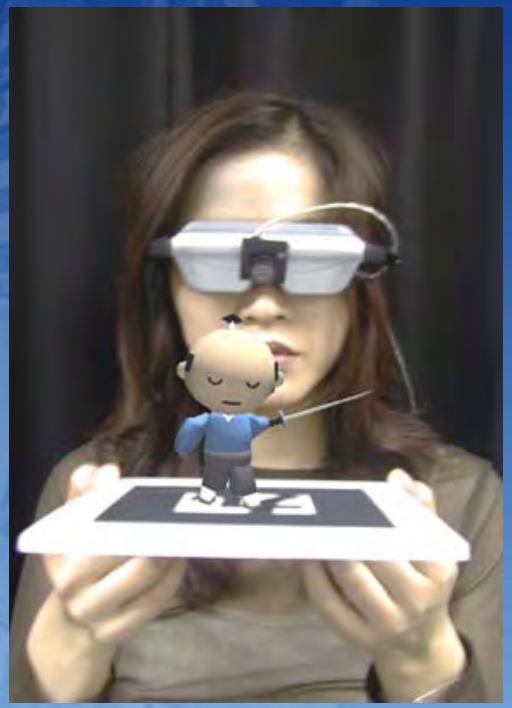
Augmented Reality (AR)

- Real-world view augmented by 3D virtual information, which is computer-generated in real-time.
- The goal is to create the impression that the virtual objects are part of the real environment.



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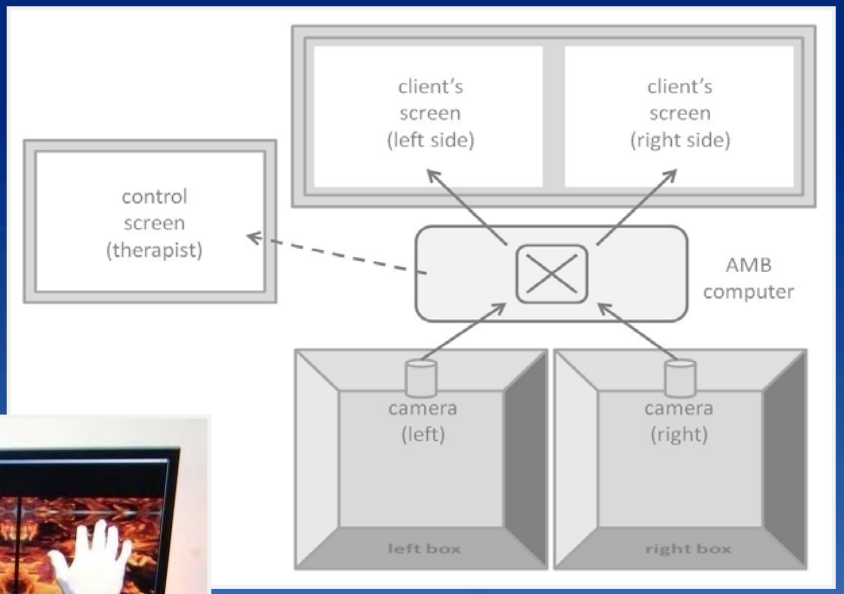
Augmented Reflection Technology

Presence: Teleoperators and Virtual Environments (2011)



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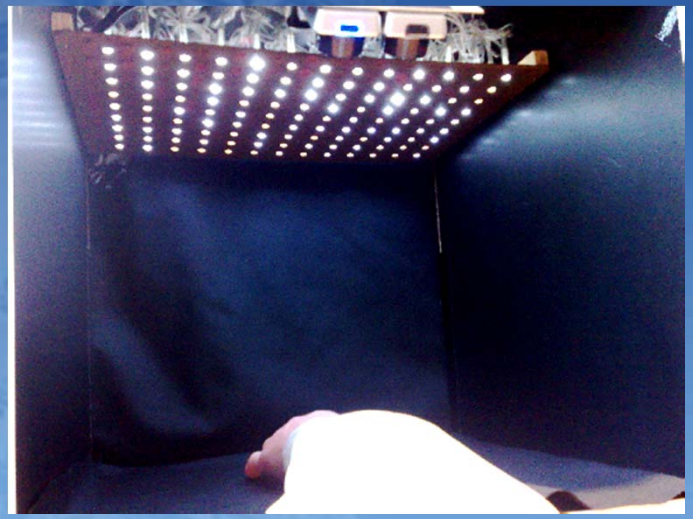
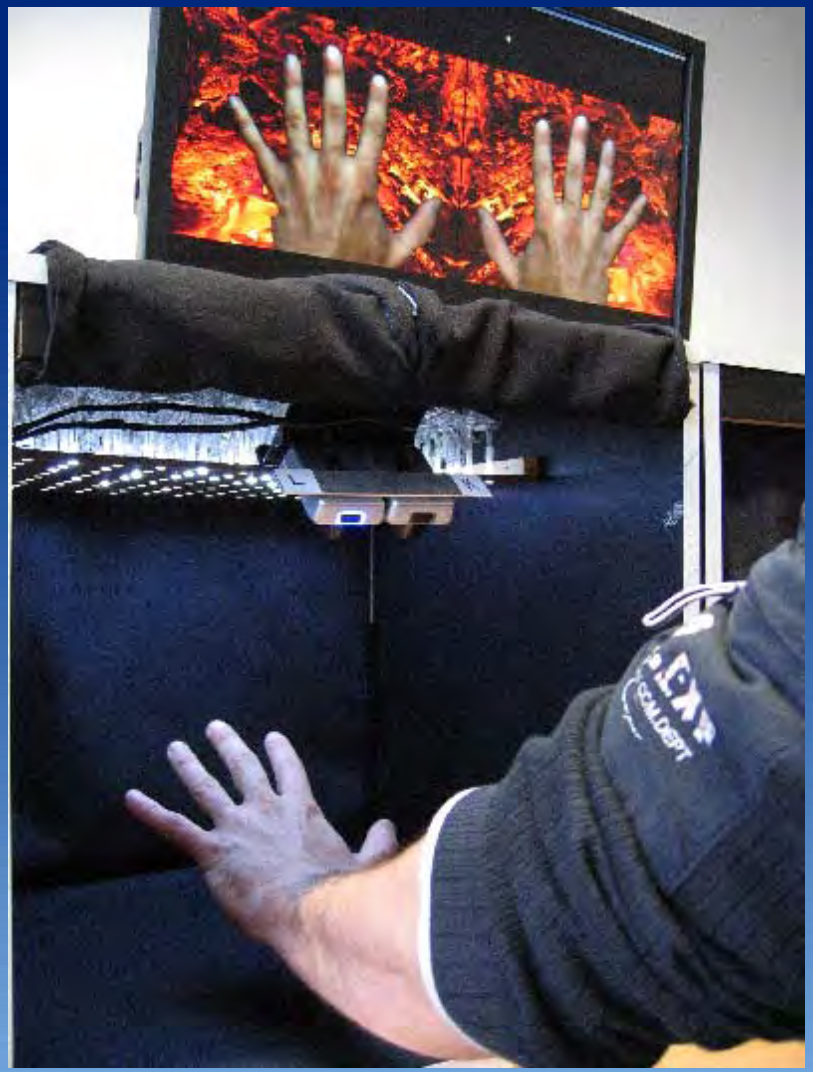
Augmented Reflection Technology





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Augmented Reflection Technology

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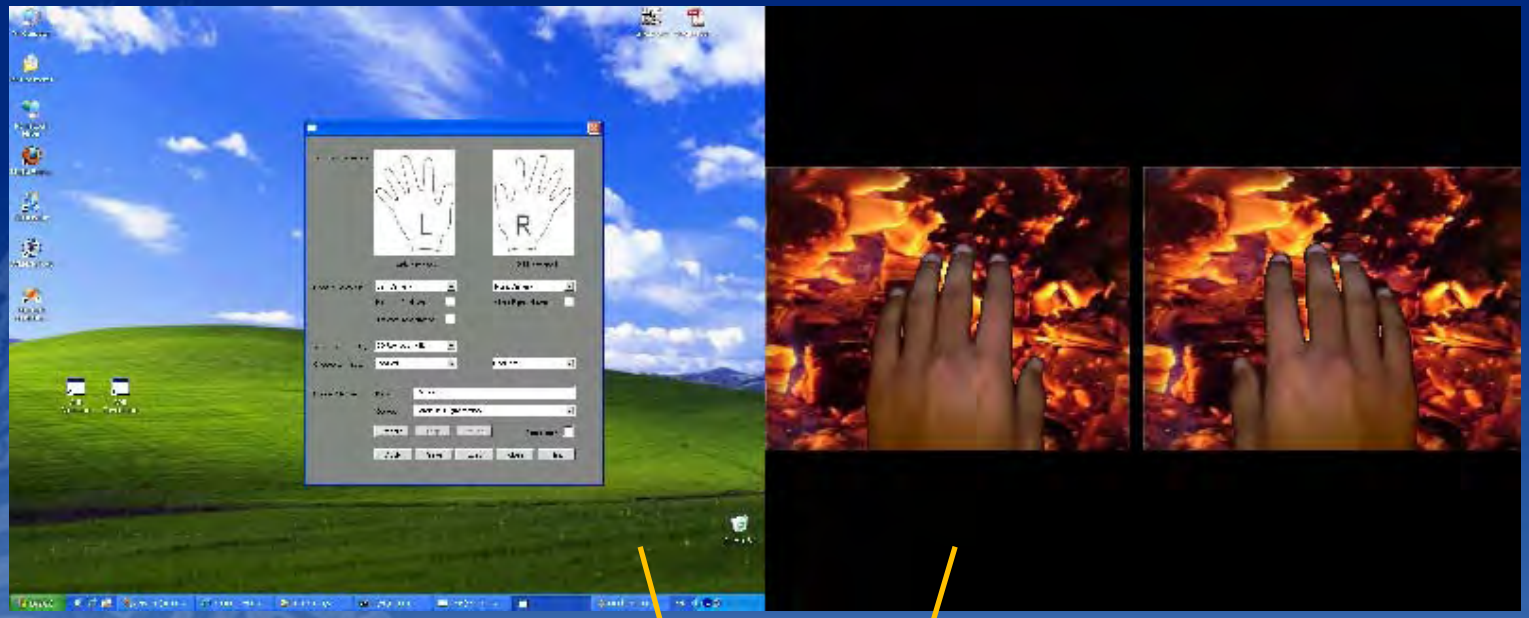
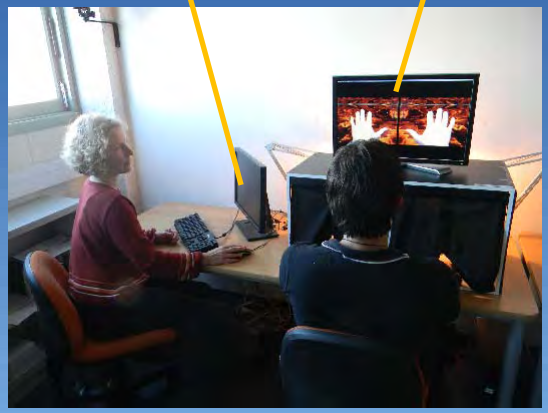
Augmented Reflection Technology



Operator (experimenter, therapist)

User (participant, client, patient)



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Augmented Reflection Technology

Colour etc.

Mirroring

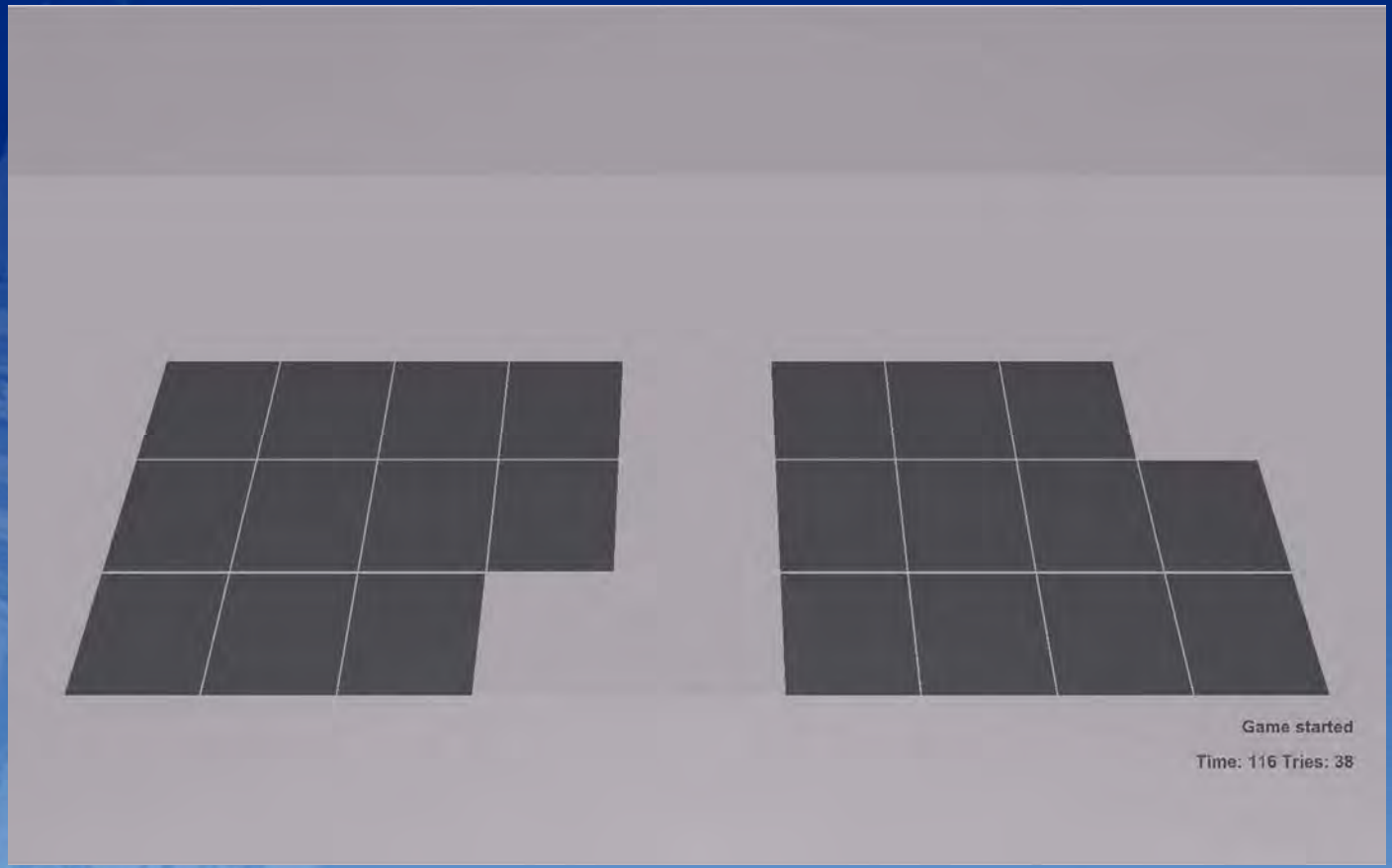
Position

Size

3D Models

2D Backgrounds

TheraMem Game



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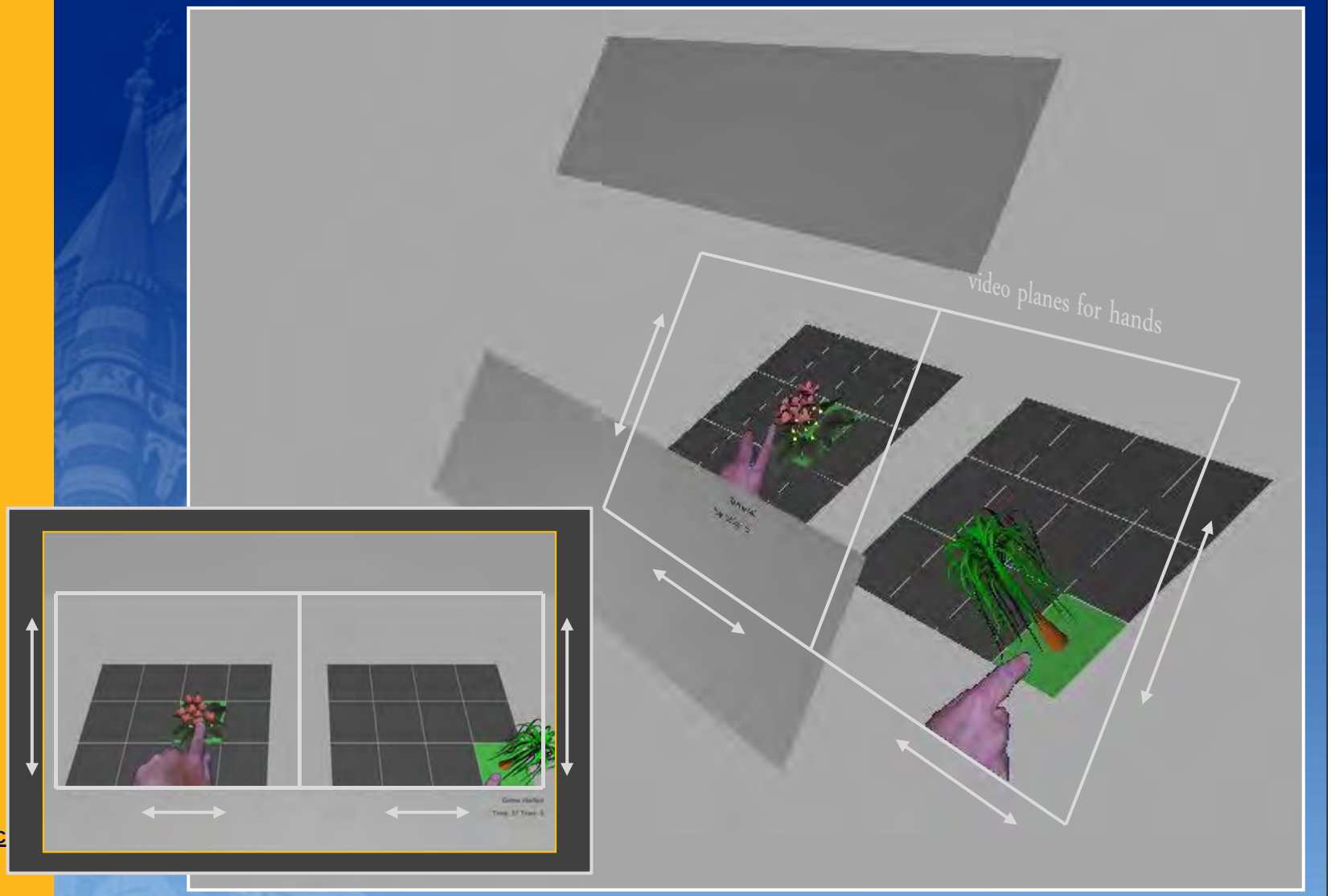
3D Scene Construction



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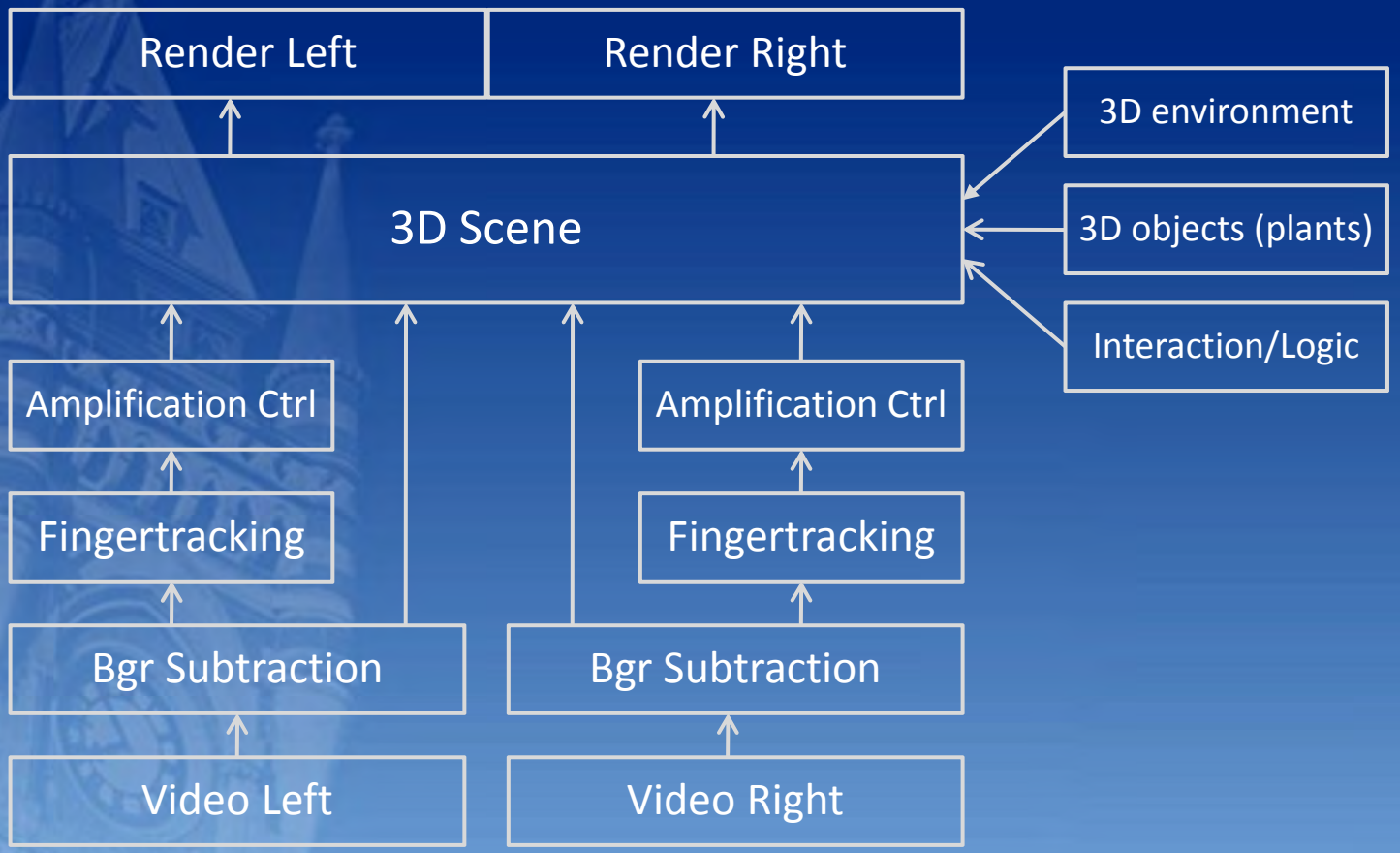
ART::TheraMem Software Architecture (simplified)



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Studies

Fooling effectiveness of ART (compared with Optical Mirror Box)

(Regenbrecht, Franz, McGregor, Dixon, & Hoermann, 2011)

Limb Ownership and Referred Tactile Sensations in OMB and ART

(Hoermann, Franz, & Regenbrecht, 2012)
(Regenbrecht, Hoermann, Ott, Muller, & Franz, 2014)

Limb ownership & presence in virtual environments in ART

(Regenbrecht , Hoermann et al., 2012)

ART-TheraMem's usability and utility

(Regenbrecht et al., 2011)

Evaluation of advanced User Interfaces

(Allen, Hoermann, Piumsomboon, & Regenbrecht, 2013)
(Regenbrecht, Collins, & Hoermann, 2013)
(Collins, Hoermann, & Regenbrecht, 2014)

Clinical feasibility of ART for rehabilitation of patients with chronic motor impairments after stroke

(Hoermann, Hale, Winser, & Regenbrecht, 2012)

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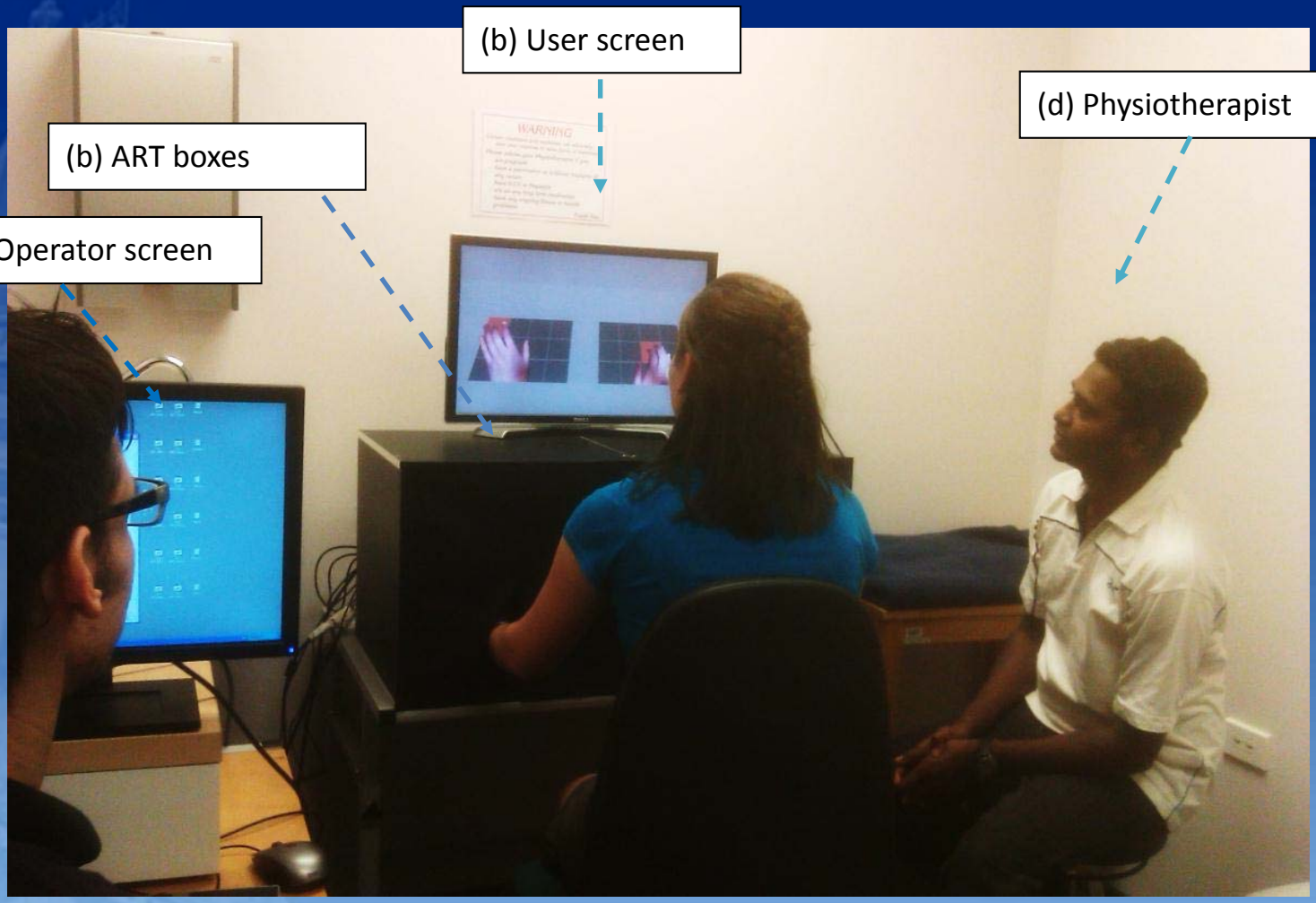
Clinical Feasibility - Setting



(Hoermann, Hale, Winser, & Regenbrecht, 2012)

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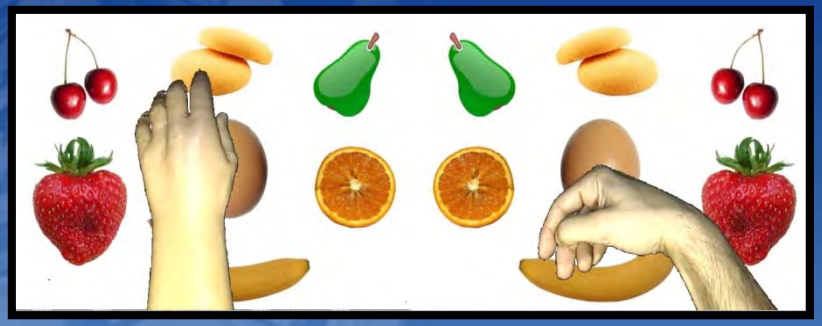
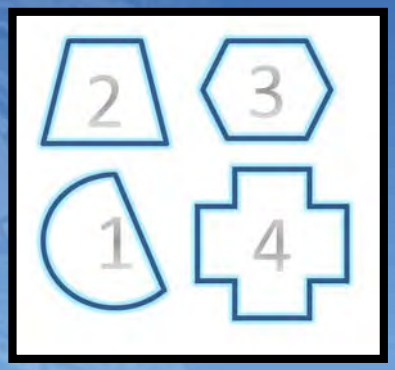
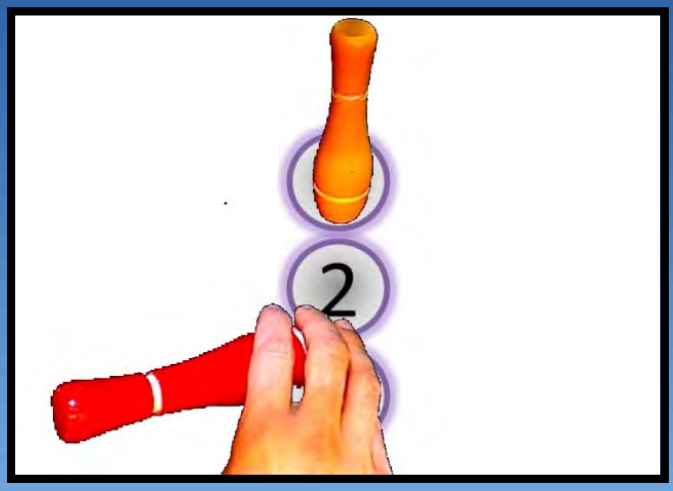
Various Exercises in ART







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ART-TheraMem

(Hoermann, Hale, Winser, & Regenbrecht, 2012)

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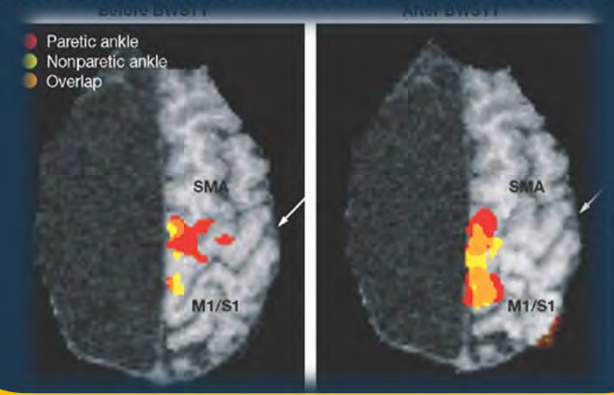
In Summary: With ART we can combine

Optimal Rehabilitation practice

Latest Neuroscientific Evidence



Cutting-Edge Technology

Engaging User Experience

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Ongoing Study - NeuroART

Controlled Pilot Intervention Study with ART for upper limb motor rehabilitation in early phase after stroke

Aim: evaluate the clinical feasibility of ART as an adjunct upper limb rehabilitation intervention for patients in their early phase after stroke

Measures: Upper limb function measured by validated instruments

Population: Adults in their early phase after (< 6 months) stroke with unilateral impairments of the upper limb

Sample: 12 participants (6 in intervention and 6 in control group)

Sessions: Up to 5 sessions a week for 4 weeks, as tolerated during inpatient rehabilitation

Duration: ~30 minutes exercise per session, 45 minutes per session including breaks

Location: ISIS Rehabilitation Ward & Dunedin Hospital

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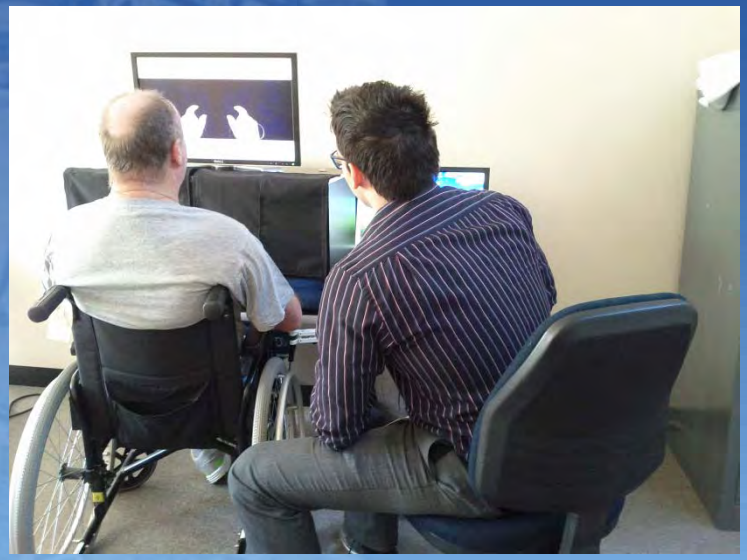
ART in Clinics (research and intervention)

- Dunedin Hospital
- Wakari Hospital
- Otago School of Physiotherapy
- Median-Kliniken/Charité, Berlin, Germany



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with

Dr **Simon Hoermann** (Medicine and Information Science)

Prof **Elizabeth Franz** (Psychology),

A/Prof **Leigh Hale** (Physiotherapy)

Dr **Nick Cutfield** (Medicine)

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Selected Publications

Regenbrecht, H., Hoermann, S., Ott, C. Mueller, L., & Franz, E. (2014). Manipulating the Experience of Reality for Rehabilitation Applications. Proceedings of the IEEE 102(2), February 2014, 170-184.

Hoermann, S., Hale, L., Winser, S., & Regenbrecht, H. (2014). Patient engagement and clinical feasibility of Augmented Reflection Technology for stroke rehabilitation. International Journal on Disability and Human Development 13(3):355-60.

Hoermann, S., Franz, E., & Regenbrecht, H. (2012). Referred Sensations Elicited by Video-mediated Mirroring of Hands. PLoS ONE, 7(11), e50942. doi:10.1371/journal.pone.0050942pdf

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