The Virtual Reality Mirror: Mental Practice with Augmented Reality for Post-Stroke Rehabilitation

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Summary and goals

- to apply augmented-reality technology to train upper limb movements in hemiplegic patients following stroke
- "stimulation-through-simulation" approach based on motor imagery
- EU-funded project (I-Learning, IST-FET)

Hemiplegia

- hemiplegia is total paralysis of the arm, leg, and trunk on one side of the body
- stroke (reduced blood flow to a specific brain area) is one of the most common causes
- traditional rehabilitation focuses on passive movement or on compensatory training of the non-paretic arm
- 5–52% of patients regain functional recovery of the upper extremity (Whitall et al. 2000)

Recovery and neuroplasticity

- practice of active functional tasks shows more positive outcomes for upper limb rehabilitation (Langhorne et al, 1996)
- these changes occur by modifying neural reorganization of the cerebral cortex (Traversa et al, 1997)
- reorganization may be stimulated by mental practice of the task without any accompanying movement (Jackson et al. 2001)

What is motor imagery?

- MI is the simulation of a movement in working memory without motor output (Decety and Jeannerod 1995)
- sport psychology studies have shown a positive effect of MI on motor performance
- best results are obtained when the exercise is performed by an internal perspective (*kinesthetic imagery*)

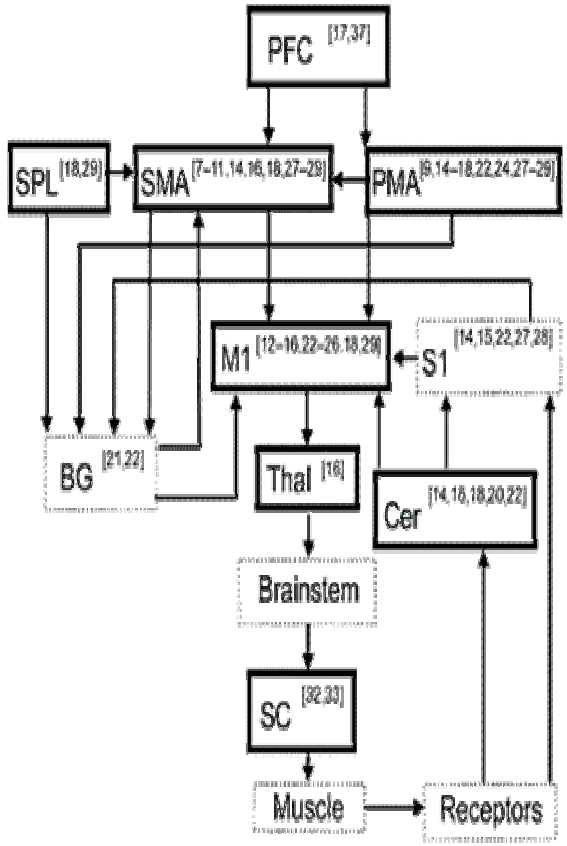
"I am visualizing the shot that I want to hit.

I am working out of a very positive frame of mind."

Phil Mickelson, professional golfer

Evidence of functional similarity between imagined and executed actions

1. temporal correspondence between real and imagined actions (isochronic principle)
2. vegetative responses vary in the same manner during both imagery and motor performance
3. fMRI shows similar cortical activity during real and imagined actions
4. corticospinal excitability is similar during imagery and actual movement (Lacourse et al., 2004).



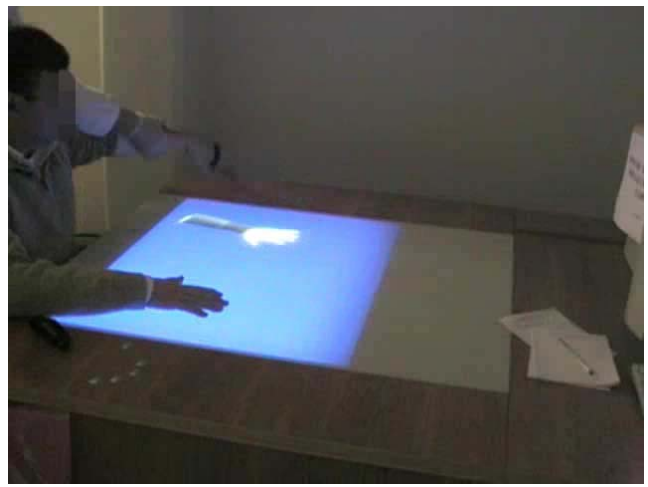
adapted from Lacourse, 2004

Motor imagery in rehabilitation

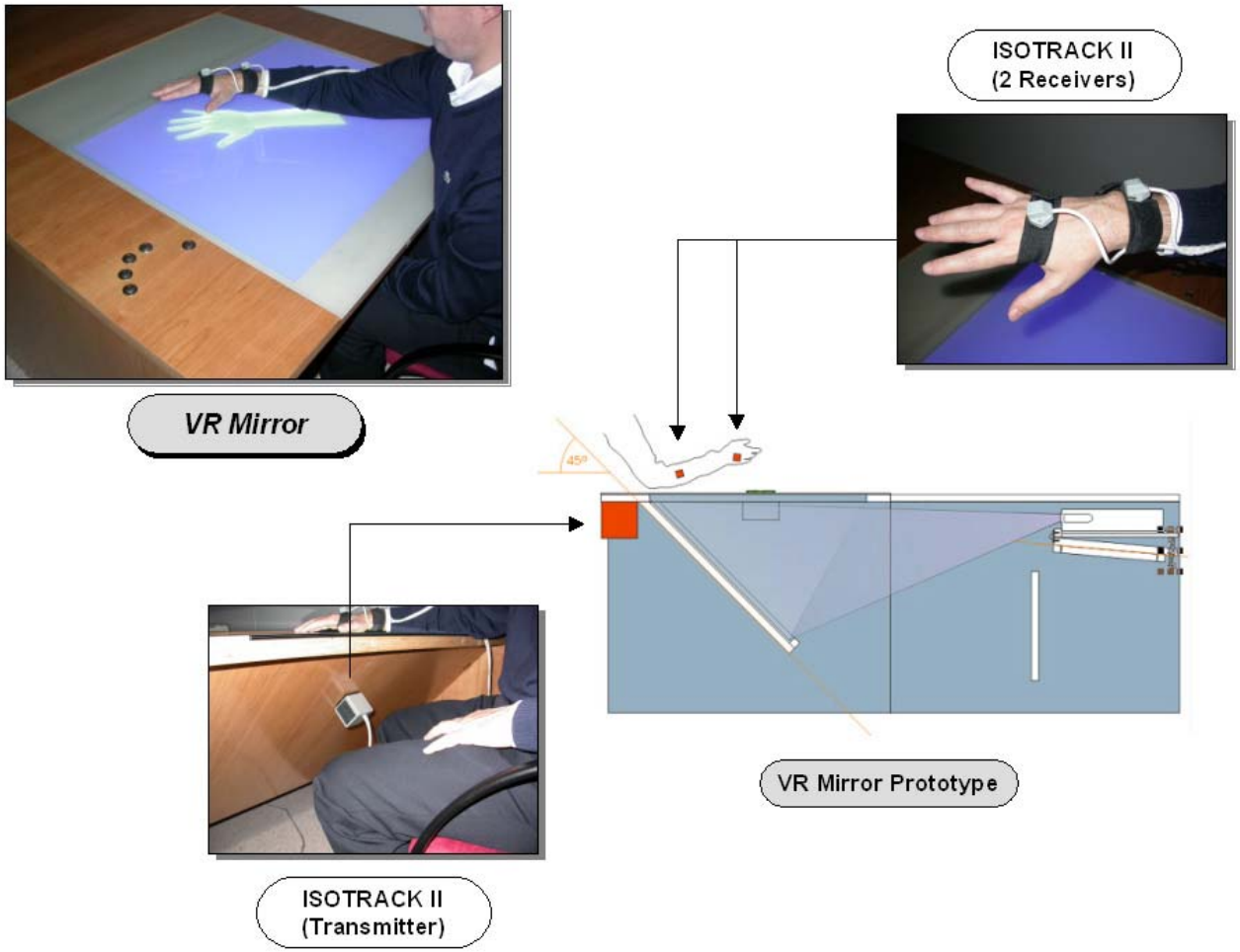
- pioneering clinical studies have described the contribution of motor imagery for improving upper limb motor function after stroke
- one approach is to use a mirror to simulate the impaired limb moving about succesfully (Altschuleret al, 1999; Stevens et al, 2003)
- studies report that passive movement observation facilitates primary motor cortex excitability for muscles engaged in the observed action

The VR Mirror

1. The movement is acquired by the system from the healthy arm
2. The movement is being mirrored and displayed so that the patient can observe and see as if the impaired arm is performing the movement (kinestetic imagery)
3. The patient is instructed to rehearse in his imagination the movement he has just observed
4. Last, the patient has to perform the movement with the affected arm



The VR Mirror: hardware architecture



Home rehabilitation

- In the home-rehabilitation phase the patient is given a portable display with multimedia capabilities that displays a sequence of pre-recorded movies, picturing the movement to be trained.
- After viewing the movies, the patient is instructed to take a first person perspective and to imagine performing the task with the impaired arm
- Exercises are performed on a daily basis

Case report: clinical protocol

- 46-year-old man with stable motor deficit (> 12 mth) of the upper right limb caused by ischemic stroke
- single-case design, with four weeks intervention
- 3 practice sessions per week at the hospital using the VR-Mirror, in addition to usual therapy (Bobath method)
- hospital intervention was followed by 1-month home-rehabilitation program using the portable display

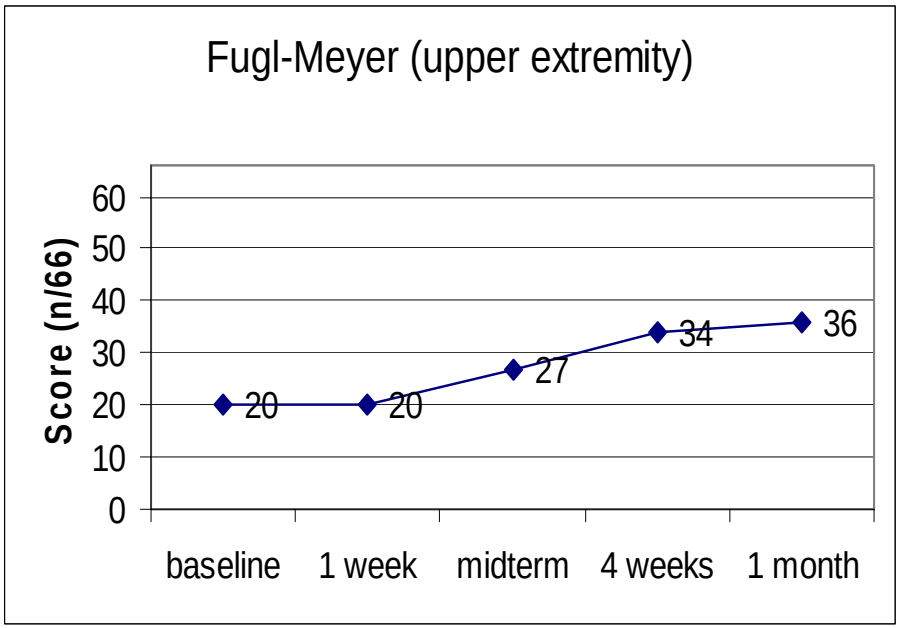
Neuropsychological assessment

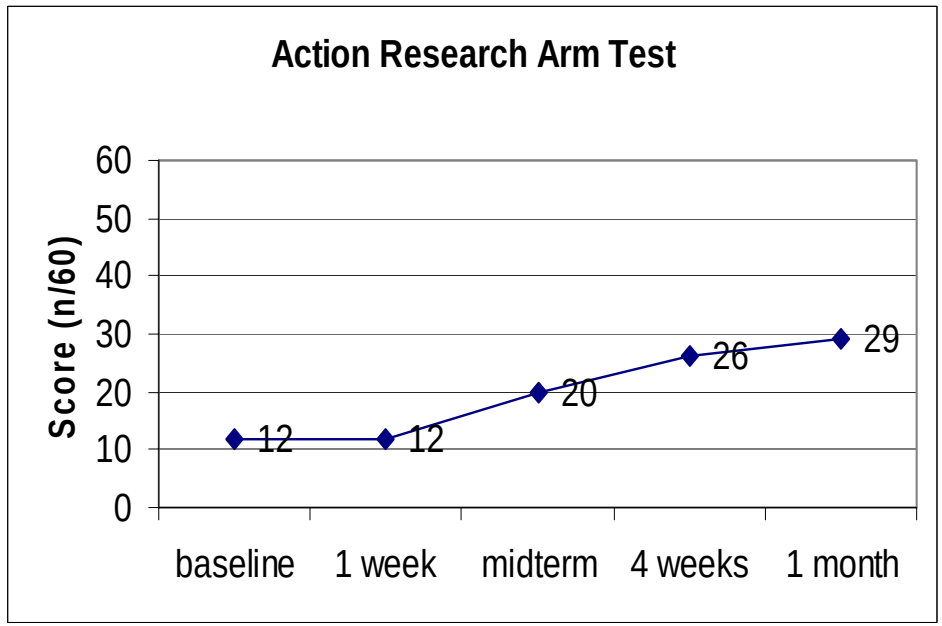
Type of Test	Measure	Outcome	Notes
Mini-Mental State Examination (Folstein et al. 1975)	Communication and cognitive skills	**28/30**	Normal communication and cognitive skills
Vividness of Visual Imagery (Marks 1973)	Visual imagery	**75/80**	Good visual imagery
Vividness of Movement Imagery (Isaac et al. 1986)	Kinesthetic imagery	**120/120**	Good movement imagery
Mental Rotation test (Metzler and Shepard 1971)	Mental rotation of 3D objects	**Normal**	Normal ability to mentally rotate 3D objects

Testing of motor abilities

- Upper-extremity subsection of Fugl-Meyer Assessment of Sensorimotor Impairment (Fugl-Meyer et al. 1975),
- Action Research Arm Test (Lyle, 1981)
- Kinematic data derived from arm-tracking sensors

Functional improvements after training

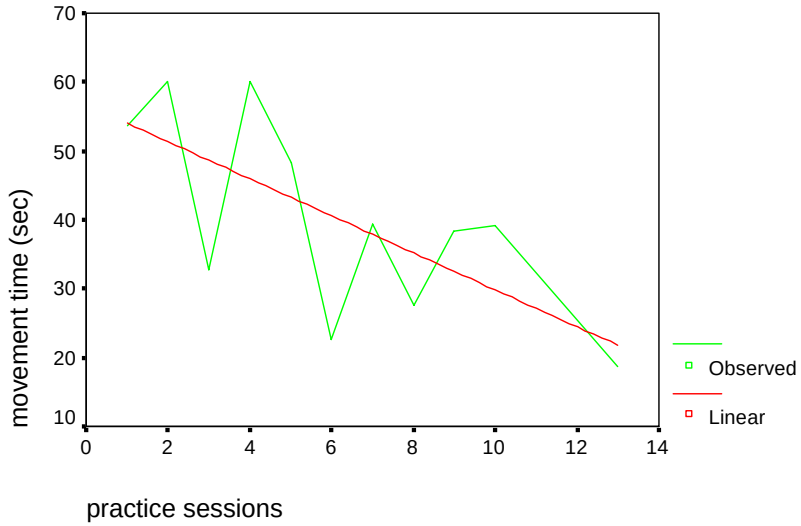




Kinematic data: wrist flexion-extension

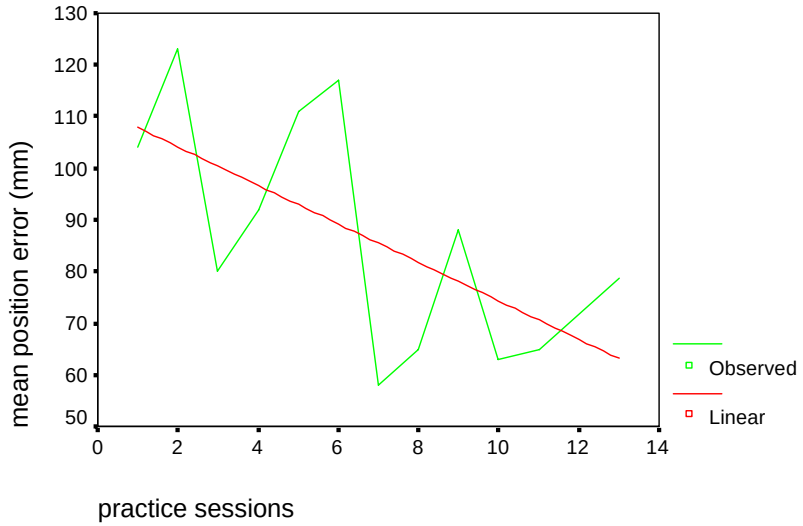
movement time

F=5.64, p<.05



mean position error

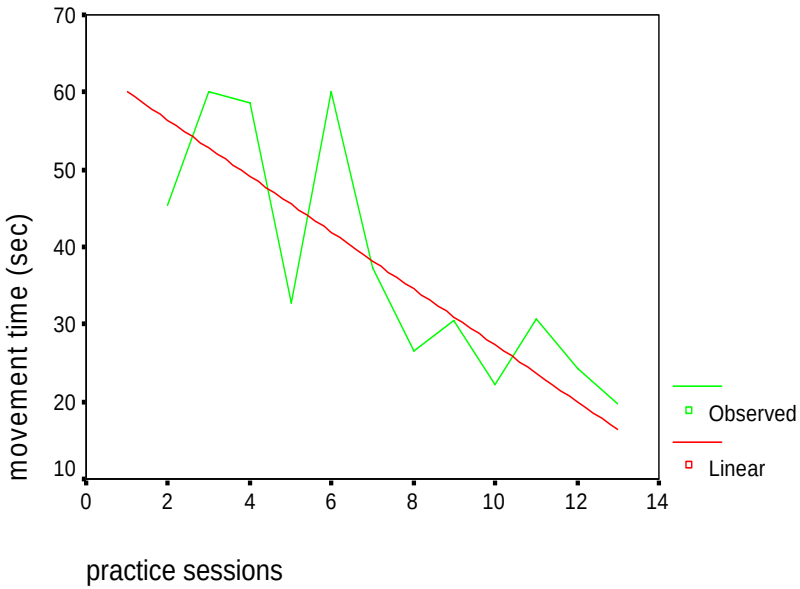
F=6.24; p<.05



Kinematic data:
intra-extra rotation of the forearm

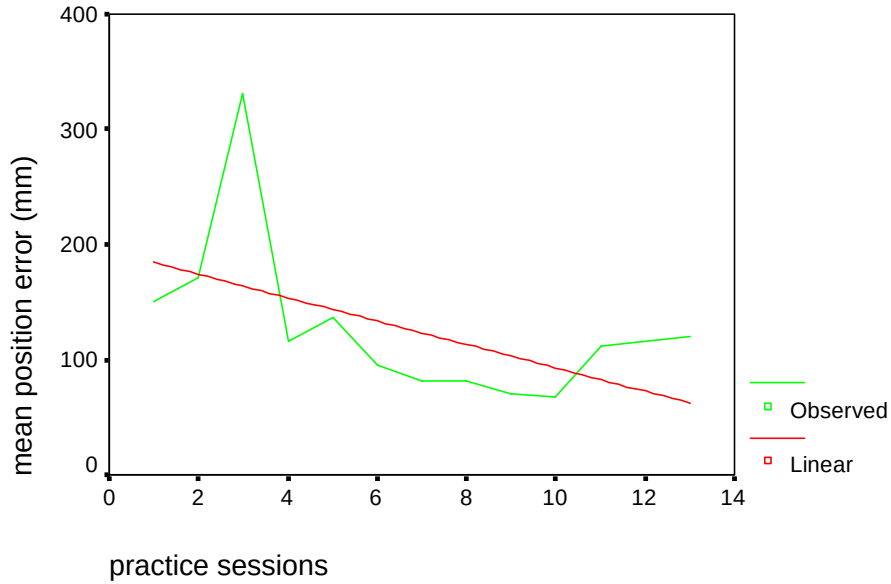
movement time

F=12,84; p<.01



mean position error

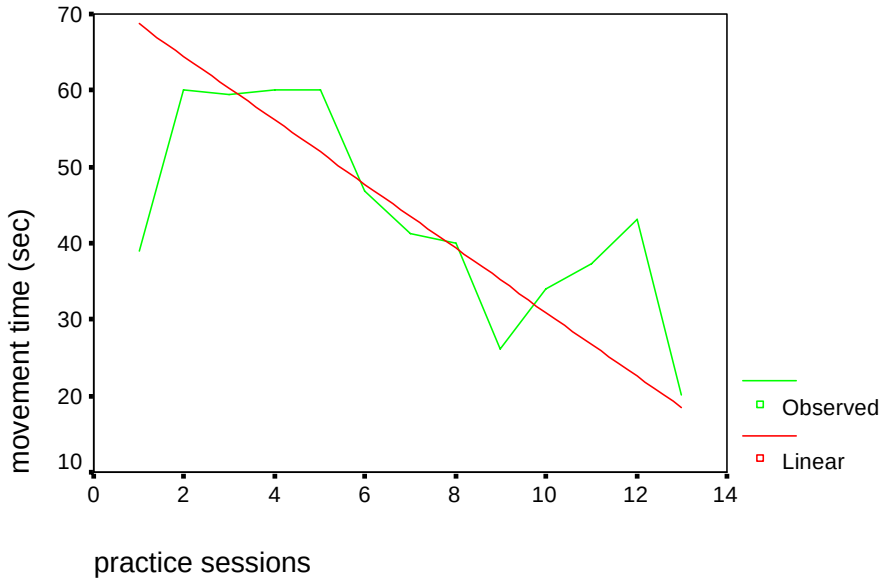
F=3.92; p<.076



Kinematic data: elbow flexion-extension

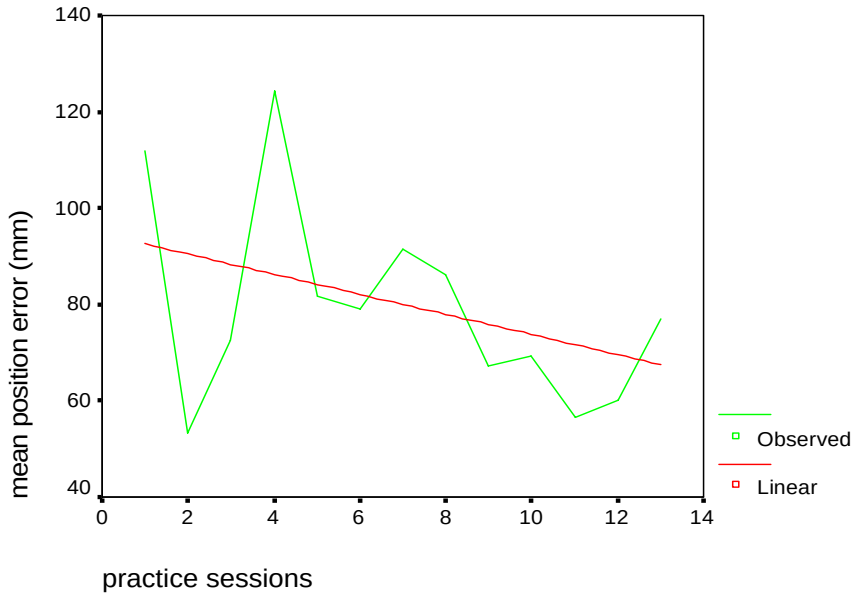
movement time

F=72.18; p<.001



mean position error

not significant



Discussion

- mental training combined with physical training improved key measures of sensorimotor impairments and functional ability
- results were maintained (and even improved) at 1 month after home rehabilitation training, suggesting that home practice was useful
- high patient’s motivation and compliance

Discussion

- hypothesis: passive movement observation, in the absence of overt movement of either limb, facilitates primary motor cortex (M1) excitability specifically for muscles engaged in the observed action (Aziz-Zadeh et al. 2002)
- mirror viewing may affect M1 excitability ipsilateral to the moving limb (Garry et. al., 2005)

Conclusion and next steps

Potential advantages:

- non-invasive equipment (no HMD!)
- objective performance recording
- no need of pre-programmed exercises
- home rehabilitation

Needs & issues:

- run controlled clinical trial
- further neuropsychological exp.
- improve usability (i.e. wireless tracking)
- reduce device size (i.e. LCD/plasma display)

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