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Mental Practice with Augmented Reality for Post-Stroke Rehabilitation: the I-learning Project

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Andrea Gaggioli

Applied Technology for
Neuro-Psychology Lab
Istituto Auxologico Italiano
Milan - Italy

Contents

Objectives of this presentation:

- To review the sports and motor learning literature regarding the effects of mental imagery and mental practice on physical skills
- To explore the feasibility of using them as adjunctive techiques in physical therapy
- To explore how mental practice may be supported by means of interactive technology: the I-Learning approach

What is motor learning?

Motor learning:

Acquisition of skilled movements as the result of physical practice;
Acquisition of temporal and spatial characteristics of movements.

How?
Modifying and consolidating the motor program for the execution of movements.

When?
After the acquisition phase

Motor imagery:

Is a sub-process that may exert a contribution to motor learning;
Process of “practising in the mind” or “mental reharsal”.

Mental Imagery and Mental Practice

- Mental imagery (MI) is cognitively reproducing or visualizing an object, scene, or sensation as though it were occurring in overt, physical reality
- Mental practice (MP) is “the symbolic rehersal of a physical activity in the absence of any gross muscolar movements”
- Using MI to practice a golf swing or tennis stroke is an example of MP. Mental practice, therefore, is the repetitious use of MI to achieve a desired result.

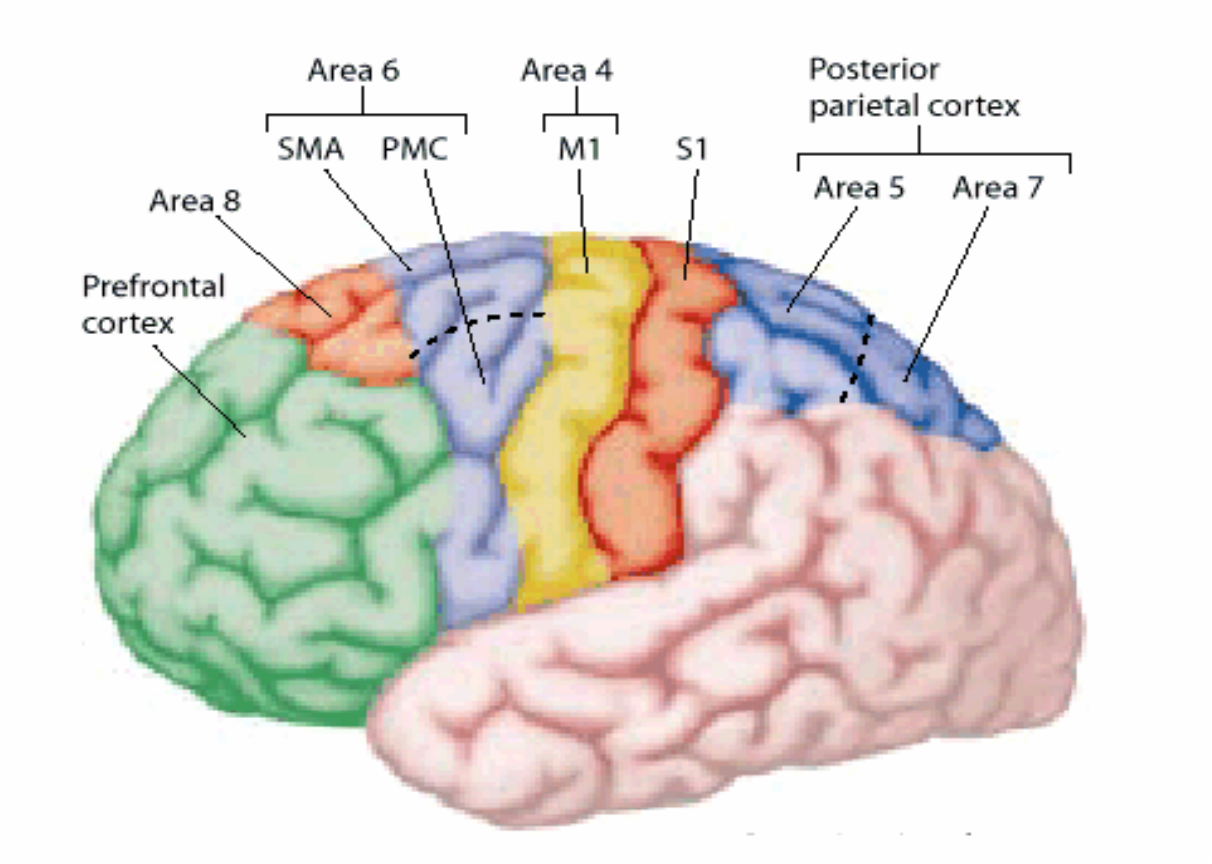
Mental Imagery and Mental Practice

- There is compelling scientific evidence that motor imagery is correlated to a subliminal activation of the motor system.
- This observation has lead to the hypothesis that cortical activation produced during motor imagery may affect the acquisition of specific motor skills and help the recovery of motor functions (mental practice with motor imagery).
- We propose an innovative technique to help rehabilitation of motor skills based on the integration of motor imagery and low-cost VR technology.

Brain imaging studies about motor imagery

Technique Used	Task	pF	pM	SMA	Cg	SM	M1	S1	Ps	Pi	Ce	BG
SPECT												
Ingvar and Philipson[24]	Clenching of hand	I	√				E		E	√		
Roland et al[25]	Finger-to-thumb	E	E	√		E	E	E				
Gelmers[26]	Finger-to-thumb	I		√		E			√			
Decety et al[92]	Writing	√	√	√		E					√	
PET												
Stephan et al[31]	Joystick mvts		√	√	√	E			√	√	E	
Jueptner et al[36]	Joystick mvts										√	
Seitz et al[37]	Writing		E	E	I		E	E	√	√	E	
Deiber et al[28]	Cued finger mvts	I	E	√	√					√	E	
	Free finger mvts	I	√	√	√		E			√	E	
fMRI												
Rao et al[93]	Finger mvts		√	√			E	E				
Sanes[94]	Outlining a square		√	√	√		E	E	√			
Tyszka et al[29]	Finger-to-thumb		√	√								
Leonardo et al[9]	Finger-to-thumb		√			√			√			
Sabbah et al[42]	Finger mvts			E		√						
Roth et al[35]	Finger-to-thumb		√	√			√	E				
Porro et al[41]	Finger-to-thumb		E				√	E				
Luft et al[32]	Finger-to-thumb		√				√	√			√	E
Lotze et al[43]	Clenching of hand		√	√	√		√	E			√	
EEG												
Naito and Matsumara[95]	Finger mvts			√								
Beisteiner et al[38]	Joystick mvts					√						
Cunnington et al[96]	Tapping board			√								
Green et al[97]	Finger mvts		I	I			E					
MEG												
Lang et al[39]	Finger mvts						√					
Schnitzler et al[40]	Finger mvts						√					

Cortical areas activated during motor imagery



Mental practice (I)

- The literature on mental practice is extensive and generally leads to the conclusion that vary forms of imagery practice can have measurable effects on performance
- Mental training affects not only global motor performance (e.g. muscolar strenght) but also aspects of the performance normally thought to be more specific outcomes of training, such as reduction of variability and increase in temporal consistency

Mental practice (II)

- The use of imagery is commonly reported by elite athletes and is reccomended by sport psychologists as part of an athlete's program of mental preparation;
- According to Garfield, a well-known professional sport trainer, "recent major breakthroughs in Olympic sports are due to mental training"
- There is considerable variety in the purposes and the techniques employed.
- A major part of the experimental literature concerns mental practice which Richardson defined as "the symbolic rehersal of physical activity in the absence of any gross muscolar movement"

Mental practice (III)

- There is little agreement as to the mechanisms by which these effects are obtained.
- Paivio (1985) suggests that the role of imagery in simply motivating the athlete may have been underestimated.
- A meta-analytic study of 35 selected published reports reached the conclusion that mental practice has a significant effect on subsequent physical performance, although the effect is usually less powerful than that achieved by overt physical practice (Driskell, 1994)
- The Psychoneuromuscolar theory and the Symbolic theory

MI/MP In sport training

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Approaches already tempted in athletes training

Performance preparation
Procedures for fully automated tasks enhancement

Imagery focused on **global task** execution
Arousal techniques to intensify attentional focus
Positive self-efficacy

Skill learning
Procedures for acquisition of new skills

Imagery focused on **detailed** sequences of movements
Arousal techniques are to be used cautiously
Relaxation techniques

apositiva 11

Differenze di impostazione della mental imagery nello sport training a seconda che si voglia preparare l'atleta per una performance (ovvero sk già acquisito) oppure insegnargli un nuovo skill (in questo secondo caso l'imagery dovrà essere molto più focalizzata sulla scomposizione del task in movimenti elementari e sulle tecniche di rilassamento). Nel caso di preparazione alla performance, la tecnica è diversa in quanto mirat a focalizzare l'attenzione sull'insieme della performance e non a distrarre l'atleta con i dettagli del task.

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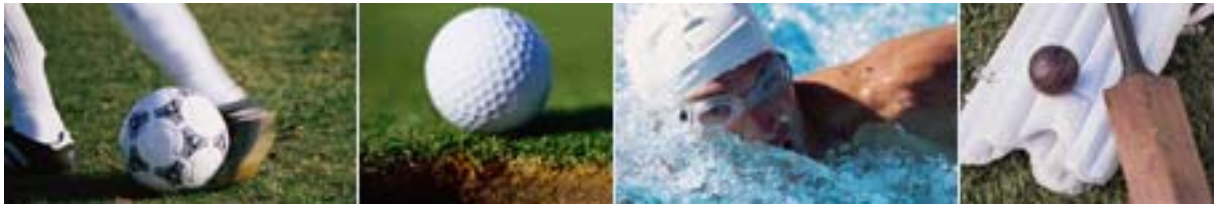
Application examples (I)

• Vandell (1943) reported that groups of subjects who mentally practiced basketball free throws or dart throwing demonstrated improved skills similar to those who physically practiced the task;

•Significant results were found in studies involving the ring toss (a gymnastic skill) and basketball free throws (Twining, 1949; Start, 1962);

•More recent studies have replicated these results. (Mendoza, 1978; Ryan, 1982; Nigro, 1984; Jones, 1965);

•One interesting study consisted of subjects categorized according to “strong” or “weak” kinesthetic ability, with those with strong skills exhibiting greater performance success than those with weak skills in this area (Ryan, 1982).



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Application examples (II)

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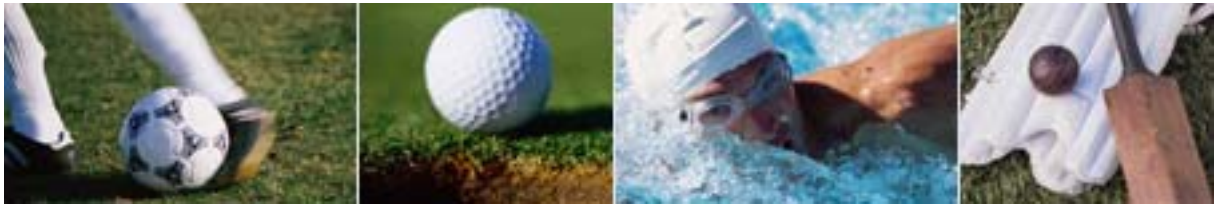
- Imagery in *soccer players:* Elite athletes reported more imagery use than non-elite athletes (Salmon, 1994)
- Imagery in *basketball* (Kendall et al., 1990)
- Imagery in *figure skaters:* Senior skaters were superior on kinesthetic imagery (Mumford, 1985)
- Imagery use in *rowing:* Internal imagery was used more than external imagery (Barr, 1992)



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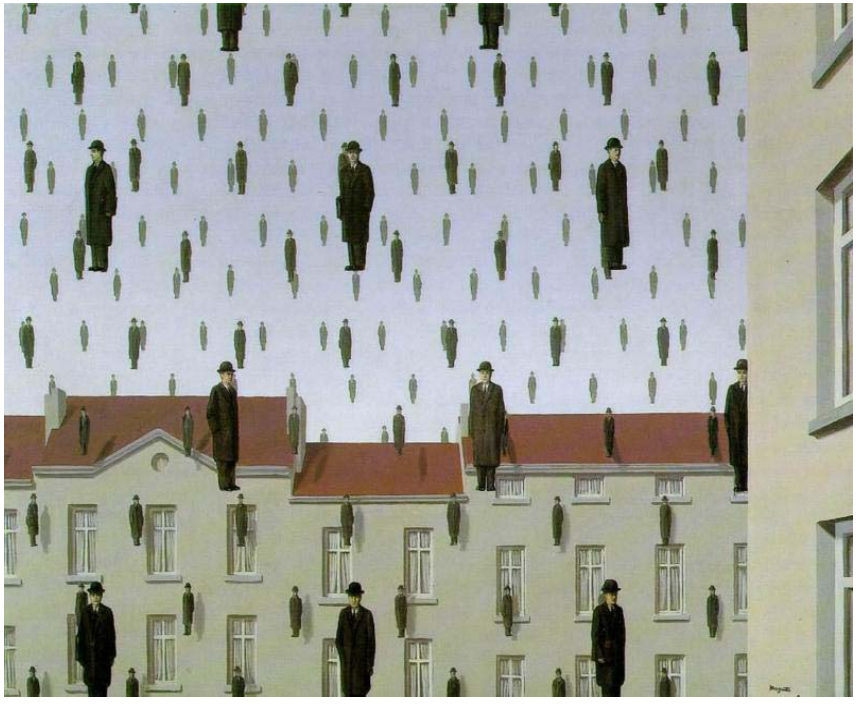
Mental practice in rehabilitation

- "A viable tool for rehabilitative performance improvement" (Carr et al, 1998; Warner et al., 1988)
- It should be combined with physical practice to accelerate motor learning (Fansler et al, 1985; Page et al., 2001)
- Objectives targeted by therapeutic approaches based on MP are:
- ✓ Reducing enhanced muscle tone;
- ✓ Facilitating muscolar activity;
- ✓ Improving motor execution in a "real world" environment.



Mental practice in rehabilitation: clinical studies (I)

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1. **L.B. Green** (1992)

   developed a paradigm for rehabilitation of injured athletes from psychophysiological and psychomotor perspectives that is based on the use of mental imagery of specific physical exercises

2. **Tremblay F, Tremblay LE, Colcer DE.** (2001)

   demonstrated that corticospinal excitability can be enhanced during motor imagery to facilitate responses in specific lower limb muscles.

3. **Page SJ, Levine P, Sisto SA, Johnston MV.** (2001)

   developed a program combining physical therapy for the affected side with mental practice

4. **Hummelsheim H.** (1999)

   developed a rationale for improving motor function by means of mental imagery

5 **Porretta DL, Surburg PR.** (1995)

   examined the effect of imagery practice in conjunction with physical practice on the performance of anticipating a coincidence (striking) by adolescents with mild mental retardation

Mental practice in rehabilitation: clinical studies (II)

- **Page et al. (2001)**: “A randomized efficacy and feasibility study of imagery in acute stroke”.
- DESIGN: Randomized, controlled case series of acute stroke;
- INTERVENTION: 1 hour of therapy 3 times a week for six weeks + 10 min. guided imagery sessions after each therapy session + 2 times a week imagery at home;
- RESULTS: therapy + imagery group showed significant improvement on the Fugl-Meyer and ARA.
- **Page et al. (2001)**: “Mental practice combined with phys. practice for upper-limb motor deficit in subacute stroke”
- DESIGN: Case study (upper-limb hemiparesys) ;
- INTERVENTION: Physical therapy for 1 hour/3 times a week for 6 weeks + guided imagery sessions 2 times a week (audiotape instructions) + 2 times a week audiotaped instructions for mental imagery exercises at home;
- RESULTS: reduction of mimpairment (Fugl-Meyer Scale) and improvement in arm function (ARA and STREAM scales).

Mental practice in rehabilitation: clinical studies (III)

- Other interesting clinical studies (randomized controlled methods + indipendent evaluators + significant effects):
- **Fansler et al. (1985)**

  demonstrated greater improvements on balance tasks among elderly women who combined mental practice with physical practice than those who participated only in physical practice
- **Fairweather and Sidaway (1993)**

  reported that a 3-week mental practice program, when combined with physical practice, improved posture of individuals with abnormal curvature of the spine.

Factors affecting effectiveness of motor imagery for motor skills learning

Most articles reviewing motor imagery or motor practice contain evidence of the effectiveness of mental practice but suggest the need for attention to factors such as:

- type of imagery
- type of practice
- type of instructions

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Sport psychology studies

+

Clinical studies of brain-injured and hemiplegic patients

+

Evidences indicating that motor imagery and motor planning share common neural mechanisms

Imagery may be an effective intervention in the rehabilitation of brain-injured patients.

Can MI be supported by means of technology?

- Johannson (1973) has demostrated that meaningful features of human movement are detectable from minimal cues.
- Whiting and his associates (1987) have shown that subjects learning a simulated ski task by observing a model appear to be able to pick up certain qualitative features of the model's performance and incorporate these into their own responses.

The I-learning approach

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✓ Being inspired from these studies, the I-learning approach aims at stimulating the end-users to create meaningful representations of the movement to be trained (or re-trained)

✓ The general goal is EVOKING, not SIMULATING, the image of the motor ability that must be learnt

✓ I-learning is an innovative technique which makes no attempt to simulate the real-world motor behaviour, but which draws patient's attention to its underlying dynamic structure

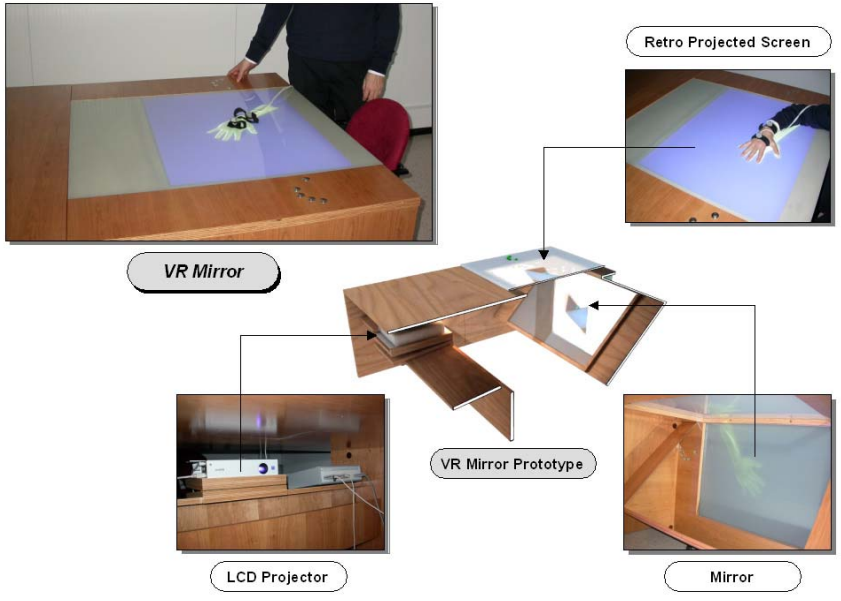
4 attenzione al concetto di low-cost introdotto da Beppe, ma sul quale ho forti dubbi!
user; 23/01/2003

The I-Learning approach

- The strategy: to gradually increase feedback & use of nondirectional instructions
- This strategy assumes that optimal learning will be achieved when the patient is allowed to elaborate his own schema and sequences of movements, thereby *constructing his own personal image of the motor behavior to be trained.*
- Therefore the patient will be given an impoverished feedback of the task he has to perform in the first sessions, while at a later stage the feedback will increase gradually.
- Distributed practice

I-learning approach

- no invasive equipment
- reduced costs
- simplified interface
- data recording
- ne need of pre-programmed content



Hardware architecture

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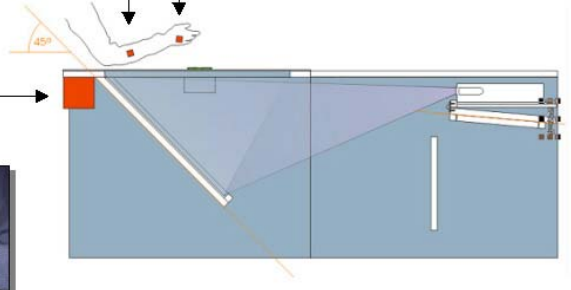
VR Mirror

ISOTRACK II
(2 Receivers)



VR Mirror Prototype

ISOTRACK II
(Transmitter)

Software architecture