- I neuroni a specchio (1)
- Il sistema motorio (2)
- Osservazione (3)
- Immaginazione (4)
- Empatia (5)

Neuroni a specchio (1)

"NEURONI MIRROR"
Neuroni a specchio

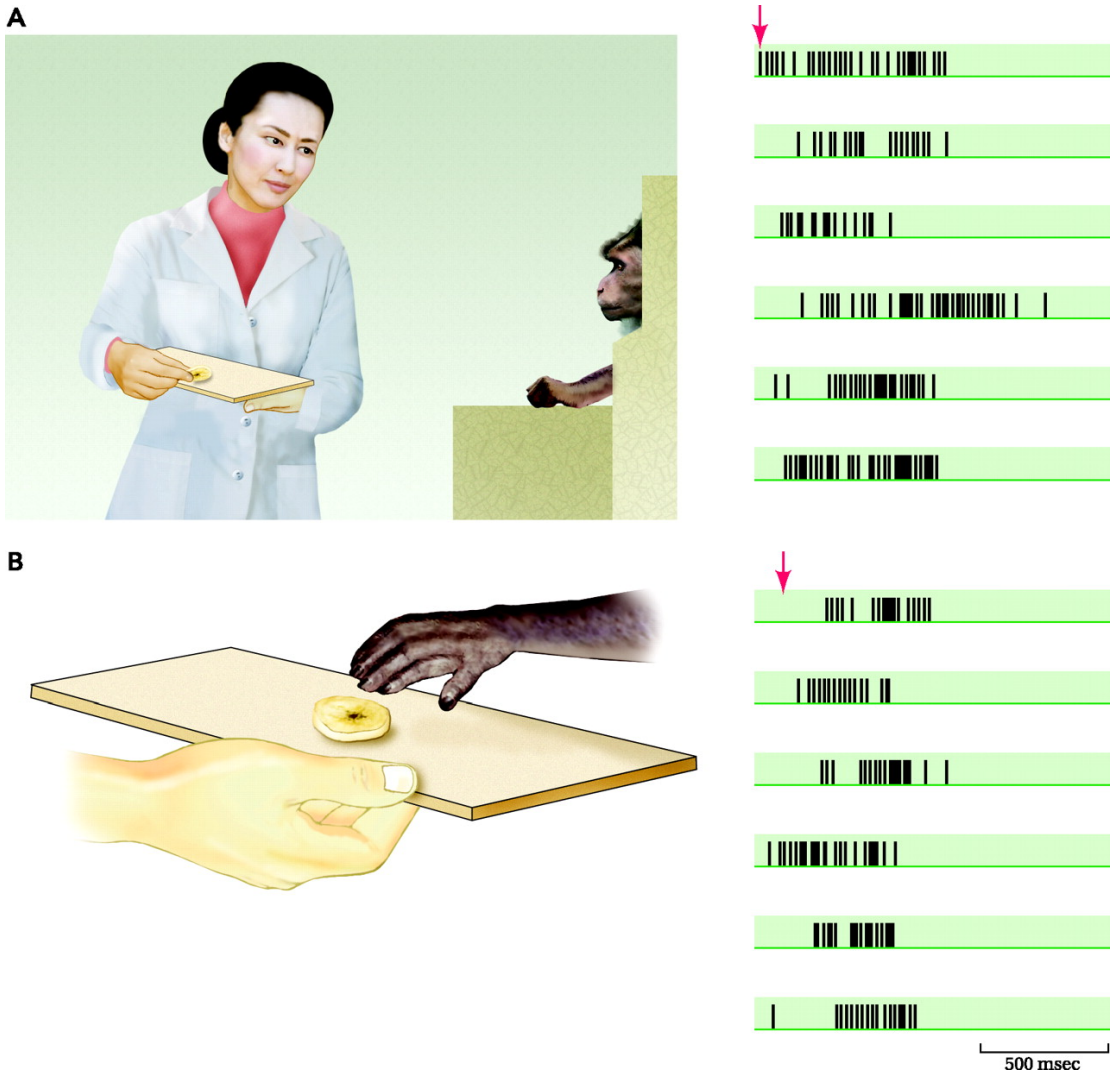
Sono neuroni che si trovano nell'area F5 delle scimmie che scaricano sia quando le scimmie eseguono una azione sia quando osservano la stessa eseguita da altri

Di Pellegrino et al., 1992

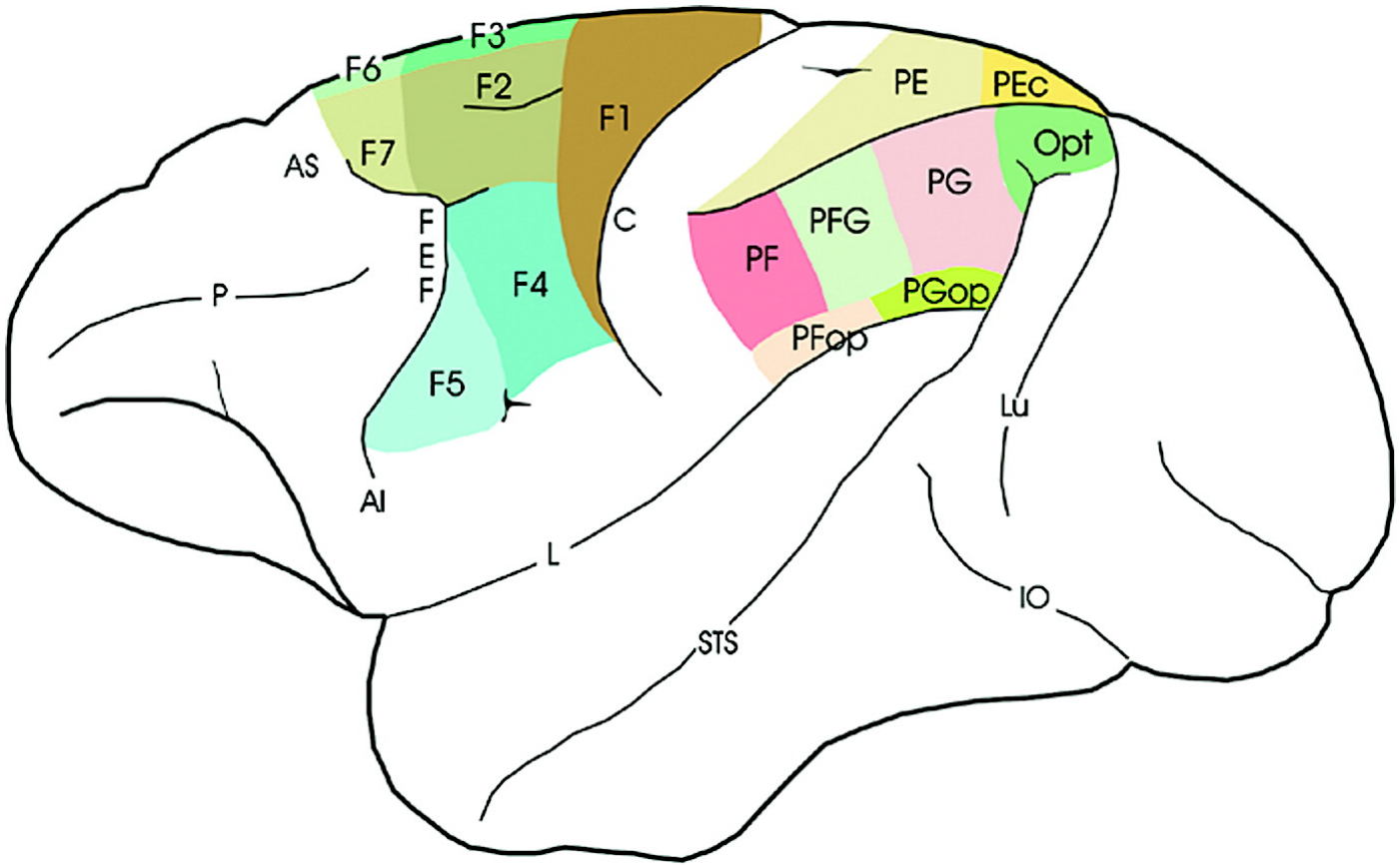
Gallese et al., 1996

Rizzolatti et al. 1996

Correlati neuro-fisiologici

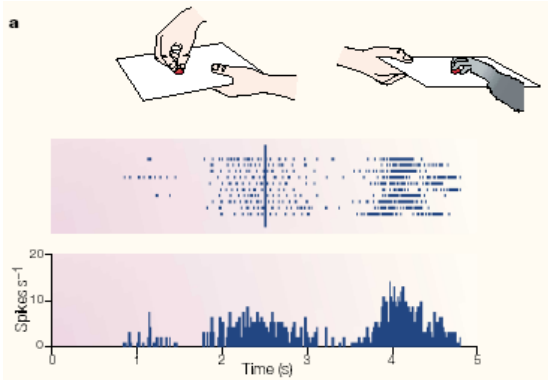


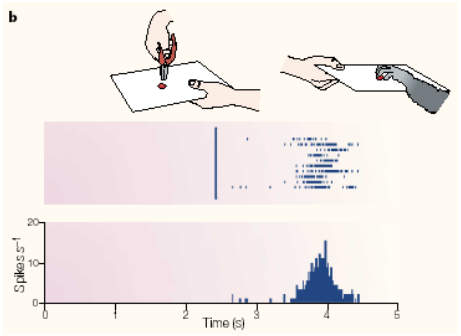
Le mappe cerebrali nella scimmia (area F5)



NEURONI A SPECCHIO

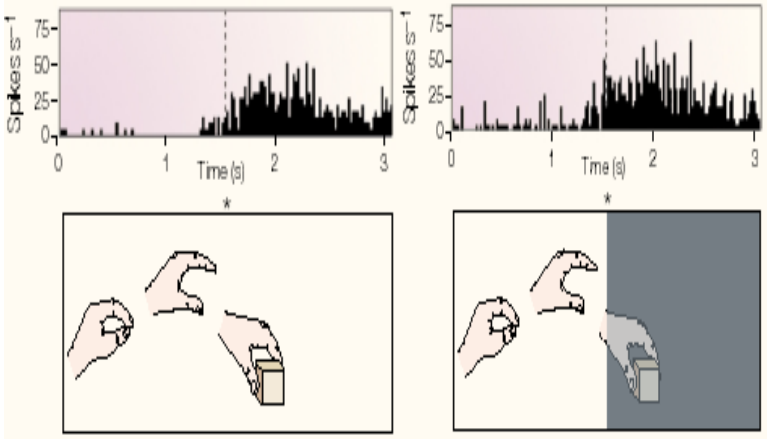
Nell'area pre-motoria della scimmia sono state identificate *cellule nervose* che mostrano la stessa attivazione sia durante l'esecuzione che l'osservazione di un' azione di prensione (di Pellegrino, et al. 1992; Gallese, et al. 1996; Rizzolatti, Fadiga et al 1996)





Questi neuroni risultano attivi solo per l'osservazione di azioni che le scimmie conoscono (afferrare un oggetto con una tenaglia anzichè con le mani non attiva il sistema di neuroni in esame)

Però questi neuroni sono attivi anche quando il movimento osservato è implicito (viene mostrata alla scimmia solo una parte dell'azione) (Umilta', et al. 2001).

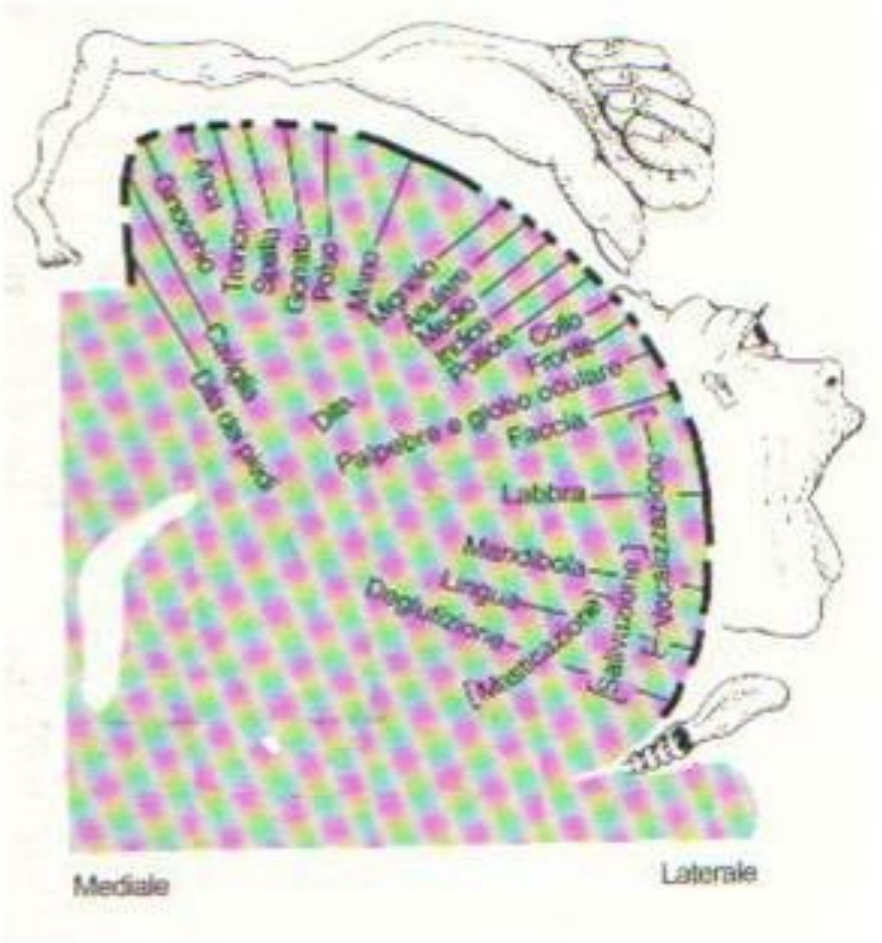


Cosa succede nella specie umana?

- Inducendo stimoli di SMT (Stimolazione Magnetica Transcranica) durante l'osservazione di un'azione di presa, si è registrato un aumento dei potenziali motori evocati proprio da quei muscoli che sarebbero stati coinvolti se l'azione fosse stata eseguita realmente, mostrando l'esistenza di un sistema a specchio anche negli esseri umani. (Fadiga, et al. 1995)

- Una simile facilitazione motoria si trova anche durante l'immaginazione di un movimento: infatti un training immaginativo comporta un aumento di eccitabilità corticale e una migliore performance. (Decety et al.,1989).

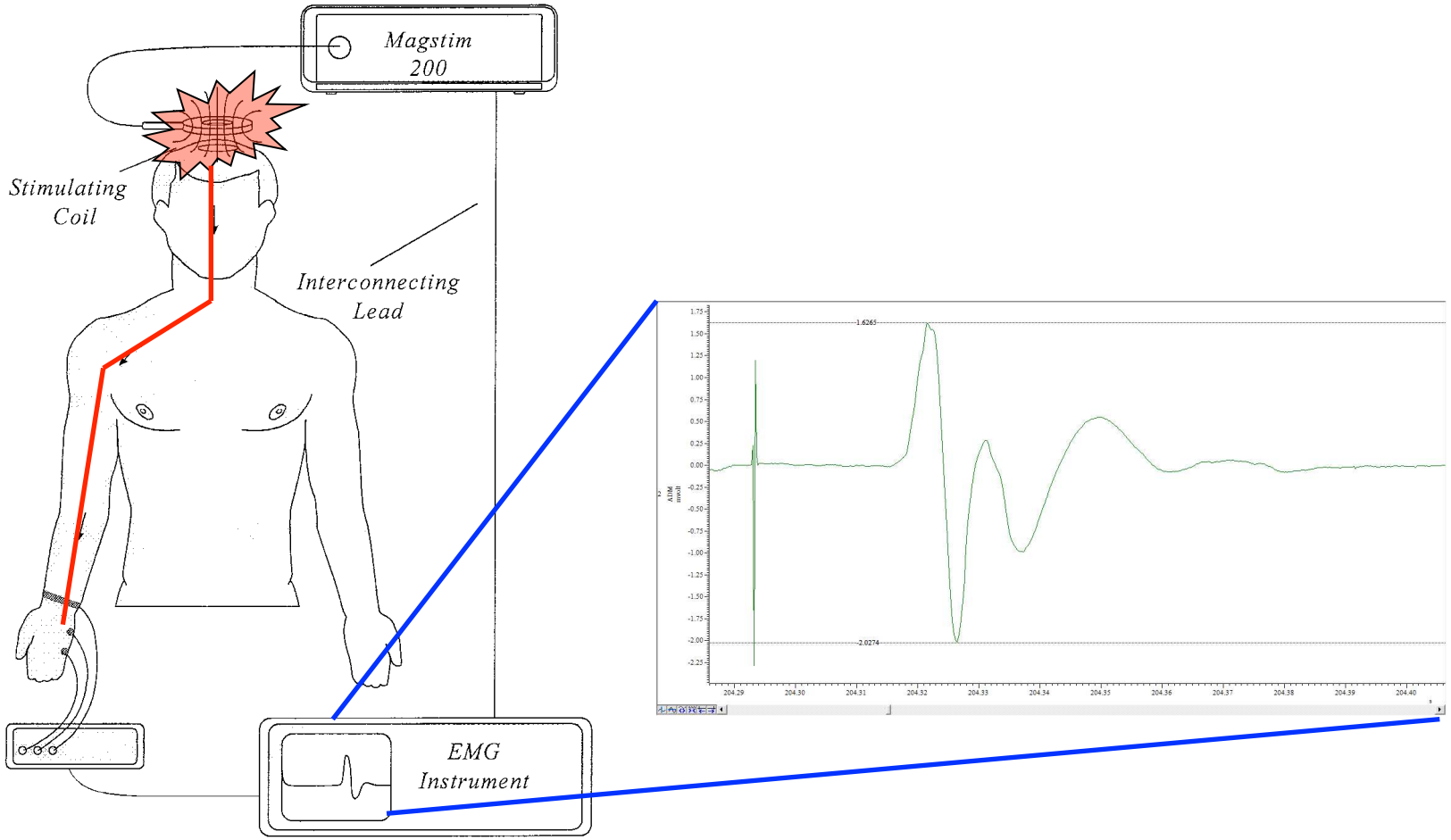
Homunculus corteccia motoria



Sistema motorio (2)

- Il sistema motorio include:
  - Attivazione a livello della corteccia (M1)
  - Via spinale
  - Ativazione alpha motoneuroni
  - Contrazione del muscolo distale

La stimolazione magnetica transcranica



Procedura TMS

Punto ottimale di stimolazione per la corteccia motoria: è stato localizzato 5 cm lateralmente e 2 cm anteriormente rispetto a Cz.

Da questa posizione il coil veniva mosso a piccoli spostamenti di mm fino a rilevare un' ampiezza del potenziale del muscolo di almeno 50 microvolt

Soglia di stimolazione: intensità della Tms necessaria per evocare almeno 5 potenziali su 10 nei muscoli di interesse.

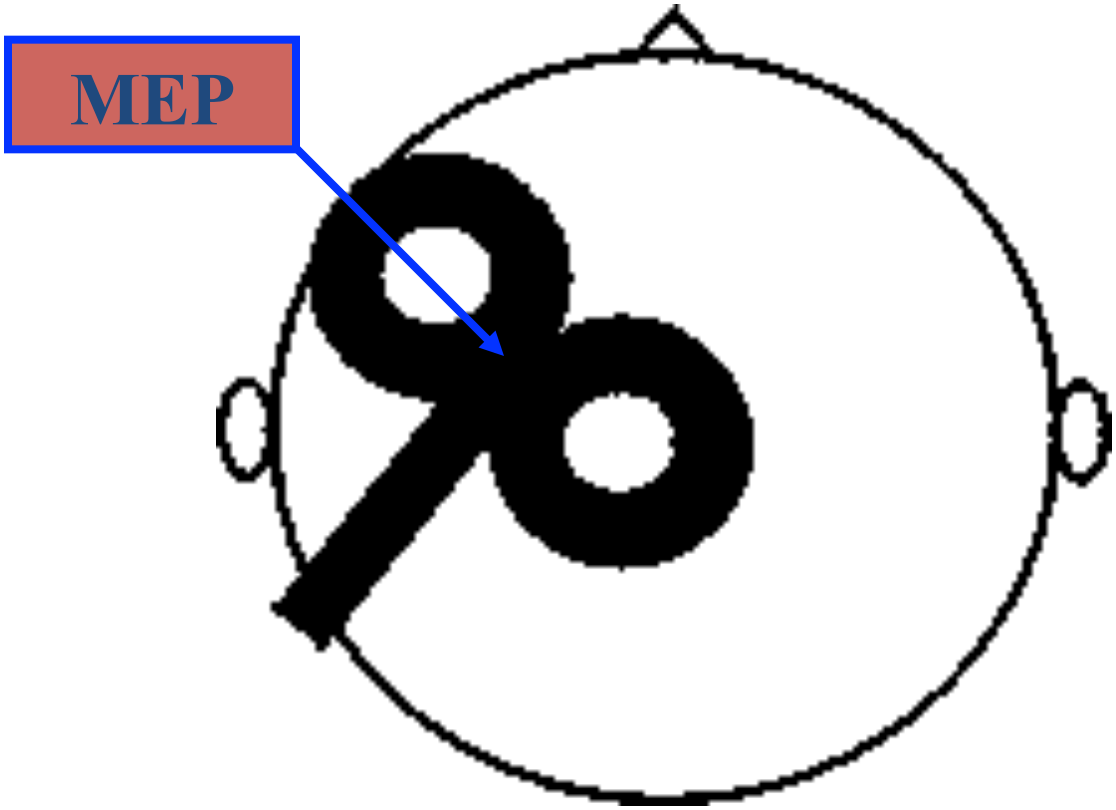
Durante il compito di osservazione abbiamo stimolato al 120% della soglia motoria.

Dati di acquisizione

- Elettrodi 1 cm diametro
- Segnale amplificato e filtro passa-banda da 30 Hz a 2.5kHz
- Frequenza di campionamento 10kHz
- Soglia almeno 3 rip a 50 μV (OSP)
- Segnale + 130% OSP
- Coil focale a farfalla
- F & M wave indici di attività spinale e nervo ulnare
- Registrazione EMG finestra temporale

Tecnica

Stimolazione magnetica transcranica dell'area motoria primaria dell'emisfero sinistro



Misura di eccitabilità del sistema motorio

Ampiezza dei potenziali evocati motori

Primo interosseo dorsale

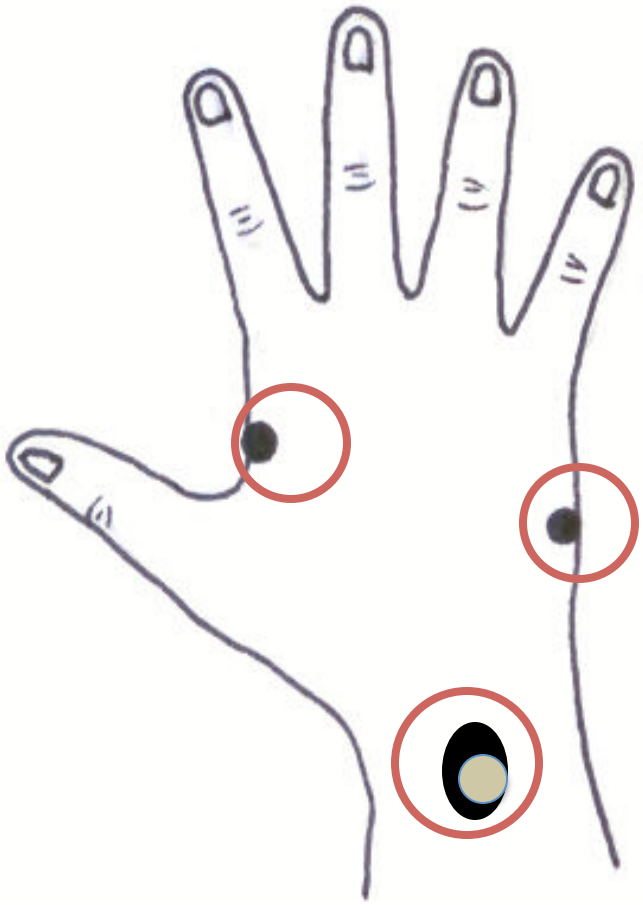
FDI

Abduttore del quinto dito

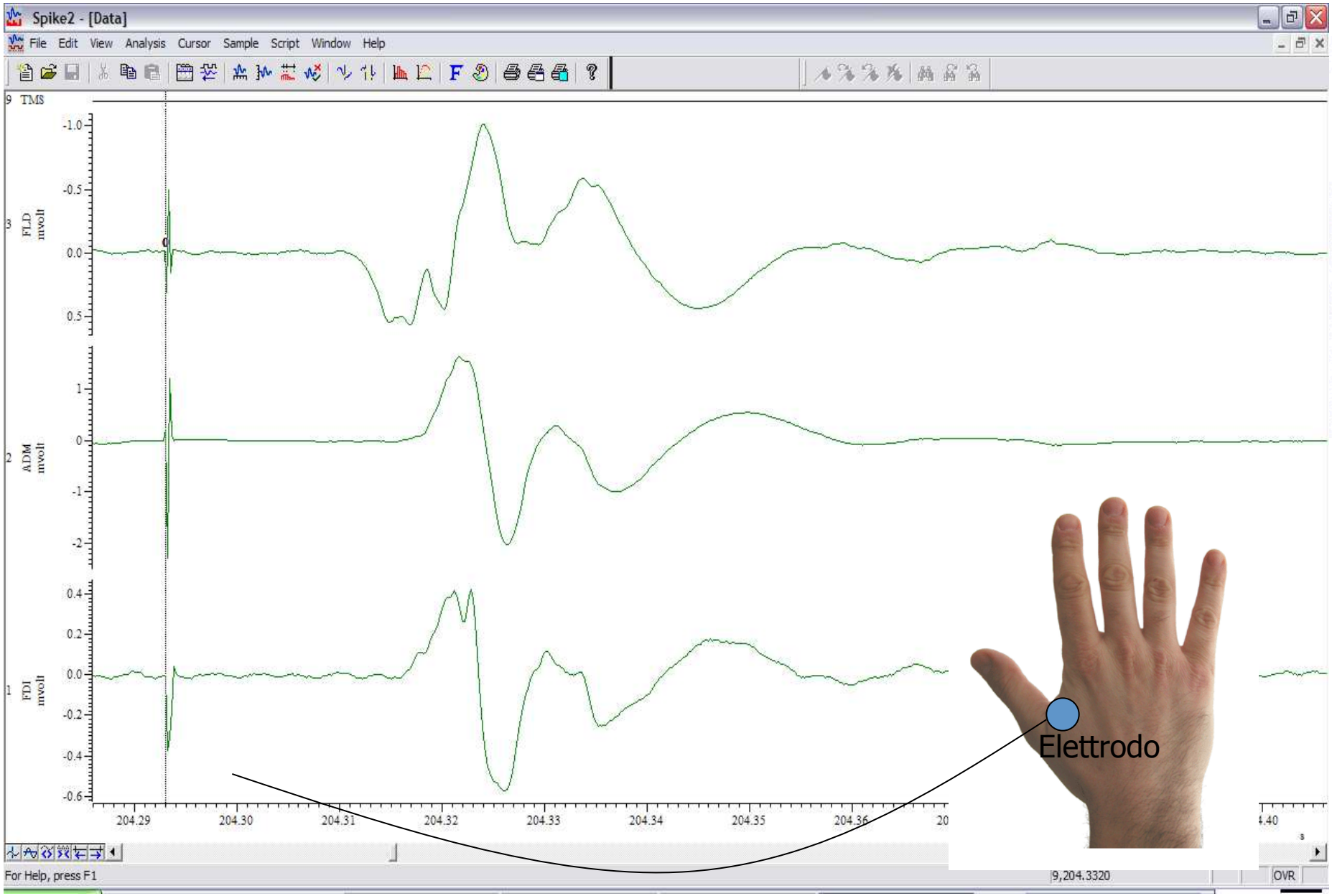
ADM

Estensore Indice

EIP

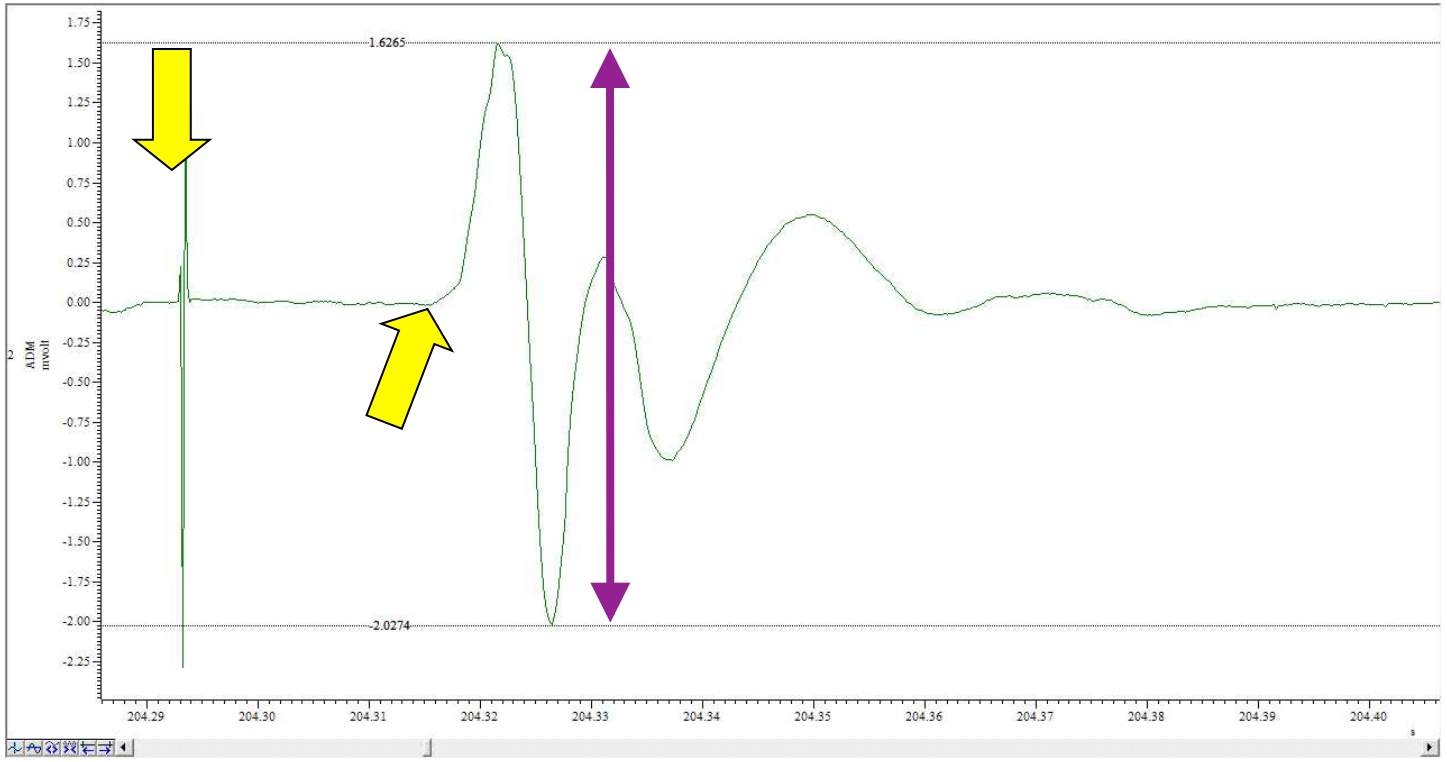


TMS (Stimolazione magnetica Transcranica)



TMS

- Viene rilevata l’ampiezza dei potenziali elettrici



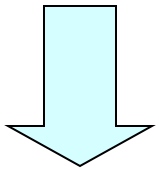
Correlati fisiologici dell'osservazione di azioni

- Durante l'osservazione di movimenti l'attività muscolare è solo parzialmente inibita nel senso che esiste sempre una, seppur debole, attivazione
    - Wehner, T., S. Vogt, et al. (1984) Psychological research
- L'attivazione delle vie discendenti durante l'osservazione sono indagabili mediante la TMS
    - Pascual-Leone, A., D. Nguyet, et al. (1995) Journal of neurophysiology

Osservazione (3)

le aree motorie degli esseri umani si attivano durante l'osservazione di azioni compiute da altri

studi di
stimolazione magnetica transcranica



aumento dell'eccitabilità del sistema motorio durante l'osservazione di azioni

Grafton et al. 1996
Rizzolatti et al., 1996
Grezes et al. 1999
Cochin et al., 1999
Hari et al.1998

Fadiga et al. 1995
Strafella et al. 2000
Maeda et al. 2001,2002

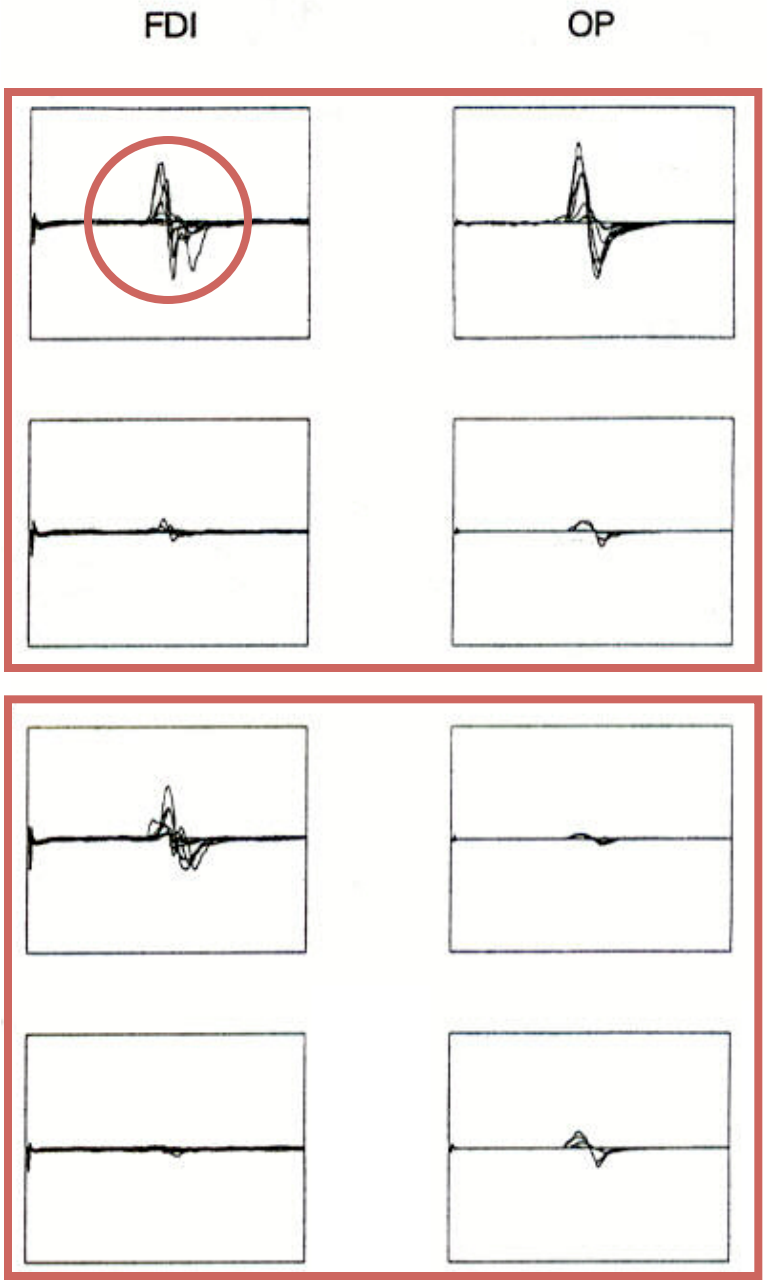
Fadiga et al. 1995

Osservazione di una azione di presa di un oggetto

Osservazione dell’ oggetto

Osservazione del movimento di un braccio

Cambio della luce ambientale



SAPPIAMO

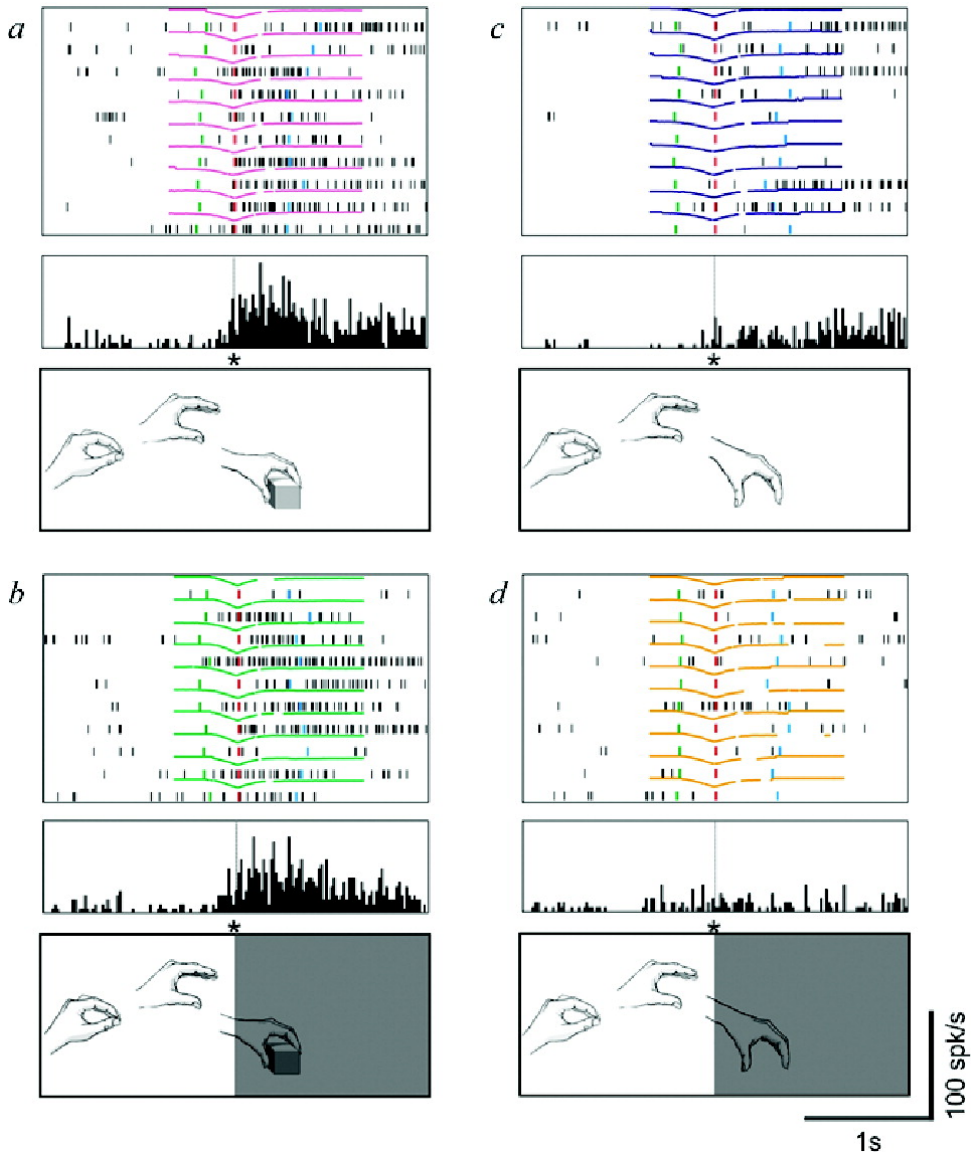
che l'eccitabilità del sistema motorio aumenta non solo durante l'**esecuzione** dell'azione, ma anche durante la sua semplice **osservazione e immaginazione**

…come si comportano i neuroni a specchio in diverse condizioni?

Mimare un gesto

Mostrare solo una parte di azione (conoscenza implicita)

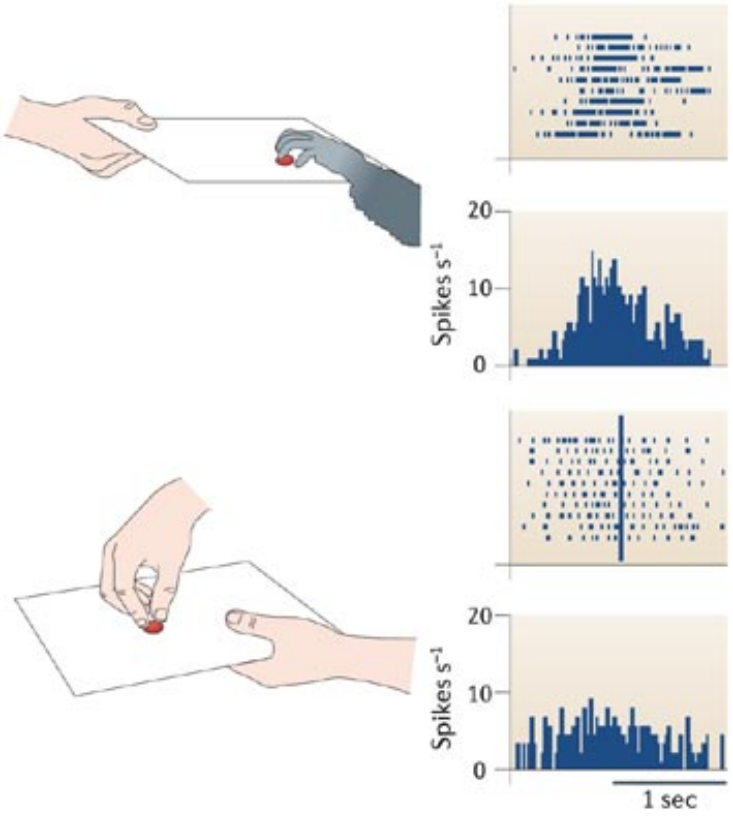
Correlati neuro-fisiologici

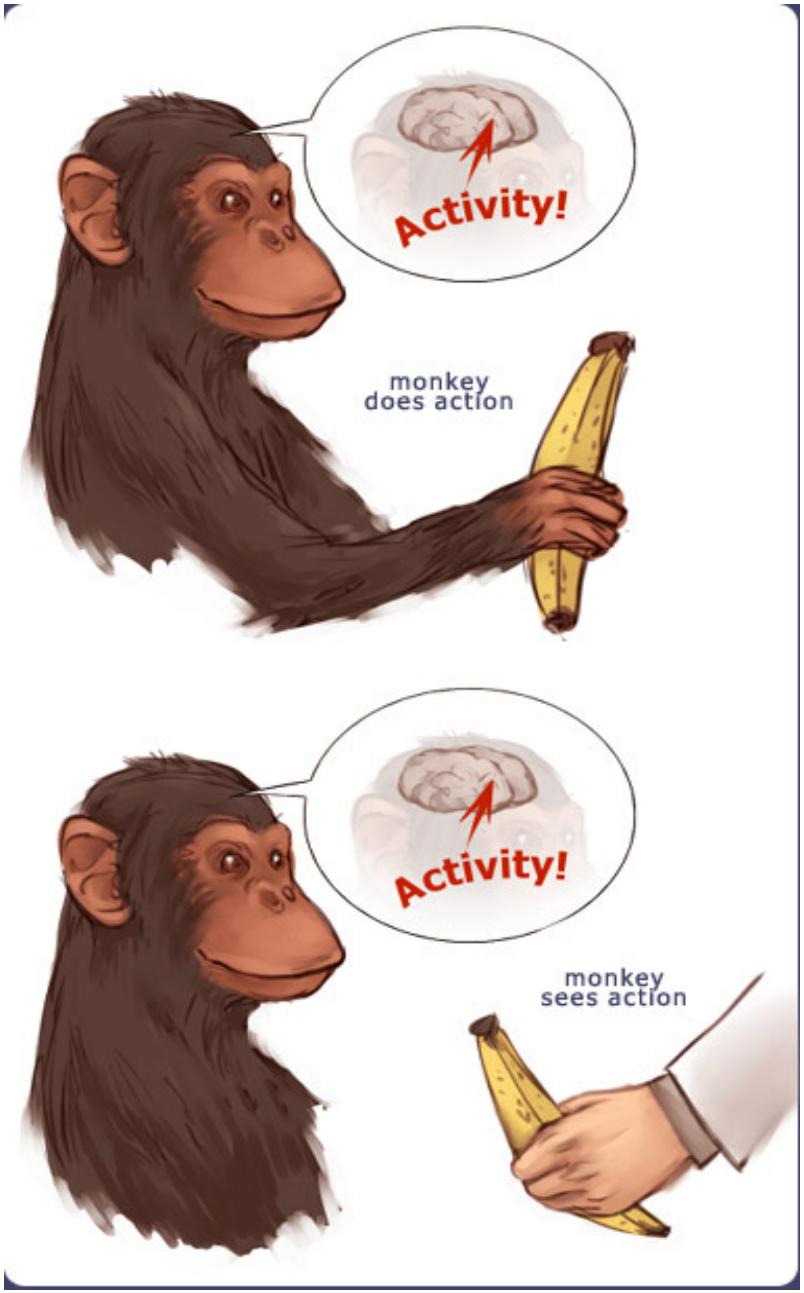


Imitation

Meltzoff & Moore, Science 1977

Rizzolatti and the Parma's group: The mirror system





Open problems for Mirror neurons

- Normally is not possible to study single neurons in the human brain, so most evidence for mirror neurons in humans is indirect.
- The function of the mirror system is a subject of much speculation:
  - Are the neurons active when the observed action is goal-directed? Or is a pantomime of a goal-directed action?
  - How do they "know" that the definite action is goal-directed or is a pantomime of the goal-directed action?
-

The primary motor cortex (M1)

- M1 may have a role in action recognition and skill acquisition
- Imagery (a cognitive process that involves multiple areas) may lead to potentiation of output from M1 (which is involved directly in execution)
- We may expand the knowledge about the role for forward models

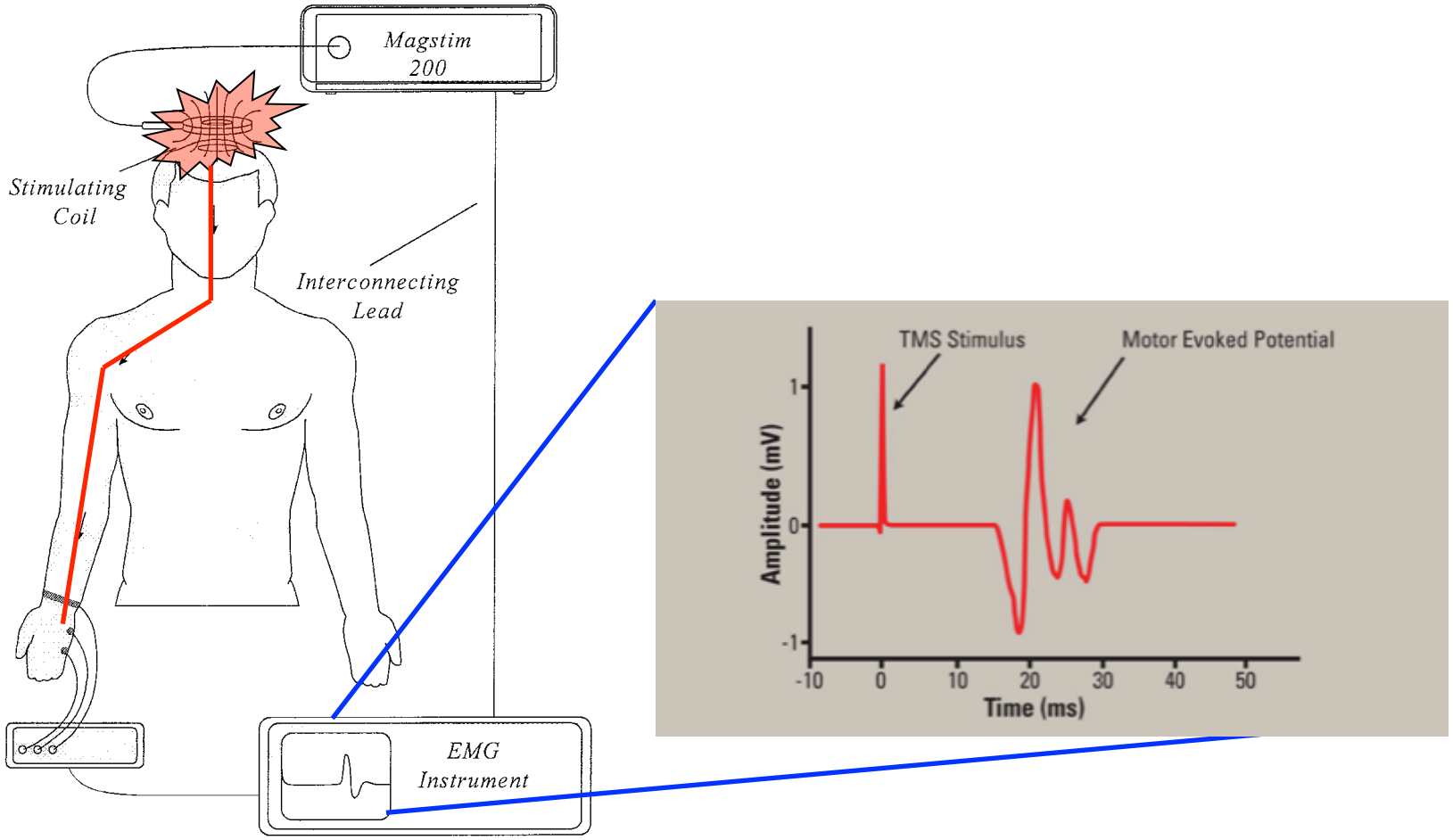
Action observation and imagination

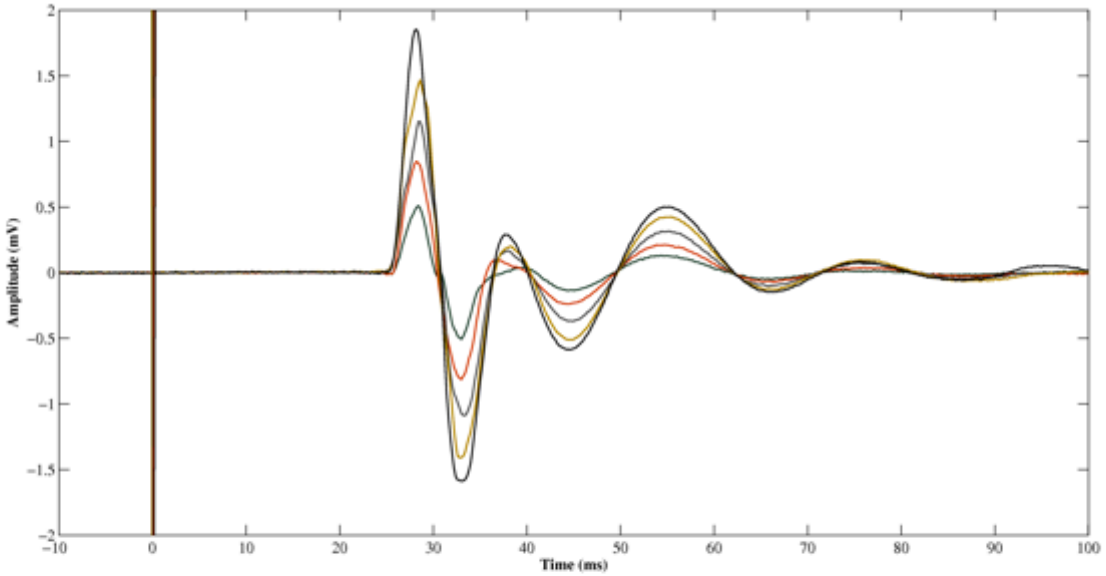
- The motor cortex “resonates” for
- Muscle specific activation
  - Body’s parts
  - Task parameters
    - direction-amplitude, object’s dimensions
- Internal action simulation
  - Action prediction
    - correct vs erroneous
    - fake movements

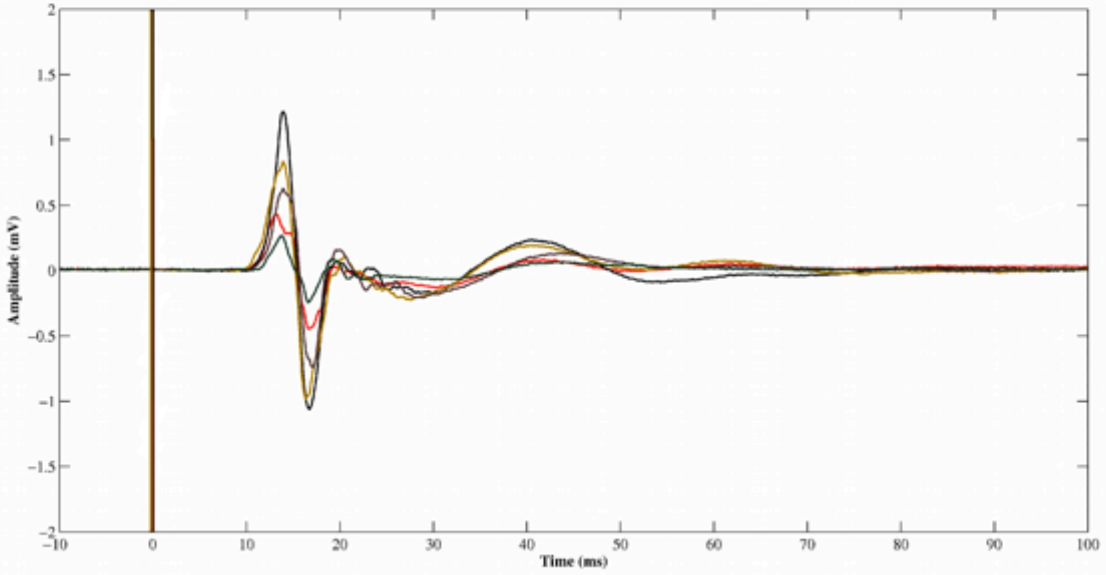
Motor Cortex

To obtain evidence of motor cortex activity during observation and imagination of different movements

TMS-EMG


Magstim
200
Stimulating
Coil
Interconnecting
Lead
EMG
Instrument
TMS Stimulus
Motor Evoked Potential
Amplitude (mV)
1
0
-1
-10
0
10
20
30
40
50
Time (ms)


Amplitude (mV)
Time (ms)


Amplitude (mV)
Time (ms)

Muscle specificity

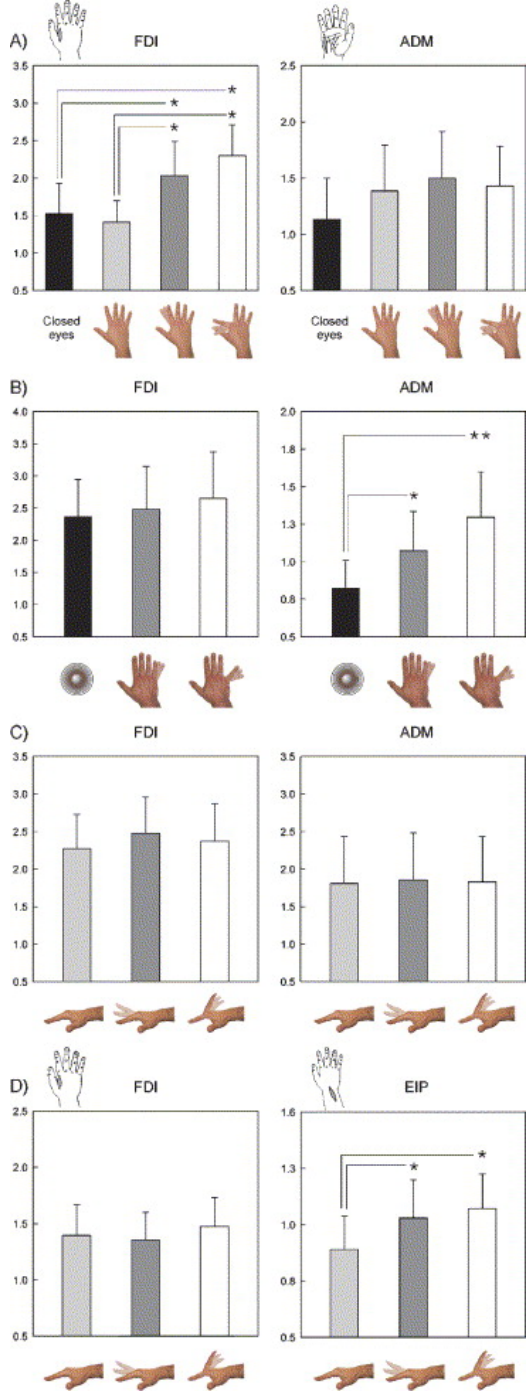
Imagine …Observe…

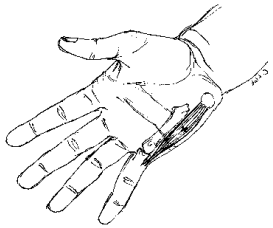
Control

FDI

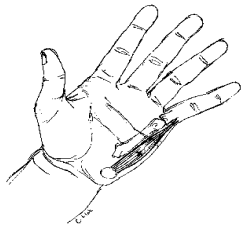
ADM

EIP

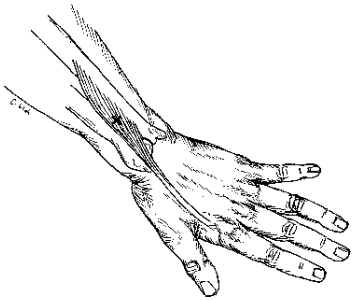




FirstDorsalInterosseus



AbducturDigitiMinimi



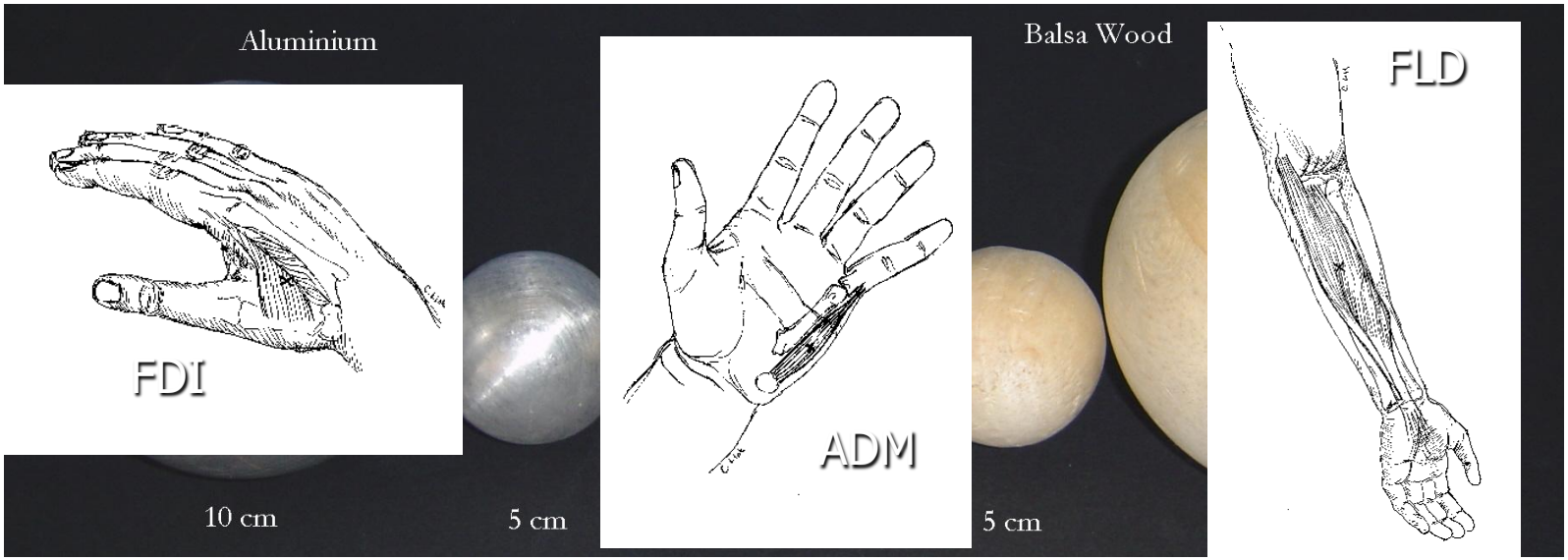
ExtensorIndicisProprius

Muscle-specific for action observation and imagination

Bufalari et al. Biol. Psych. 2010

Romani et al., Neuroimage, 2005

Task Parameters

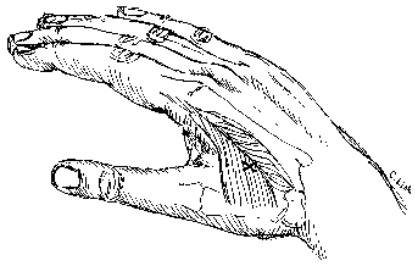


Imagine to hold a sphere

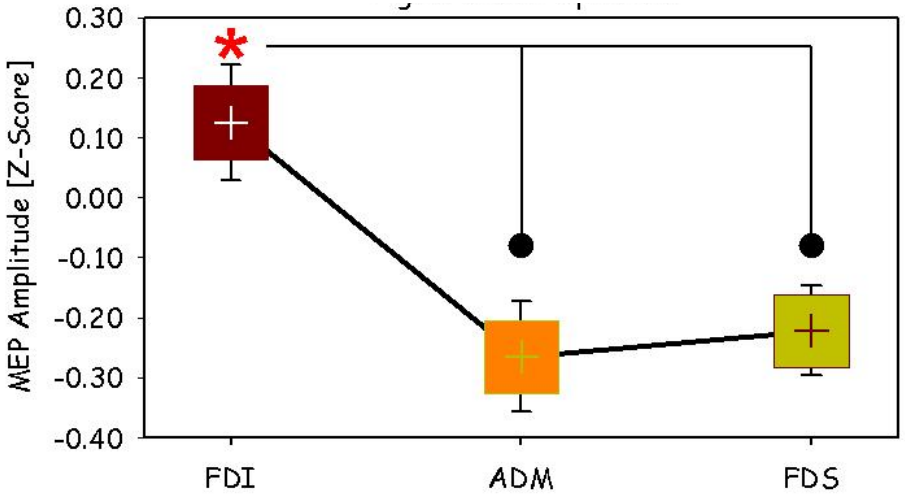
Hold a sphere

Cesari et al. Neuropsychologia 2011

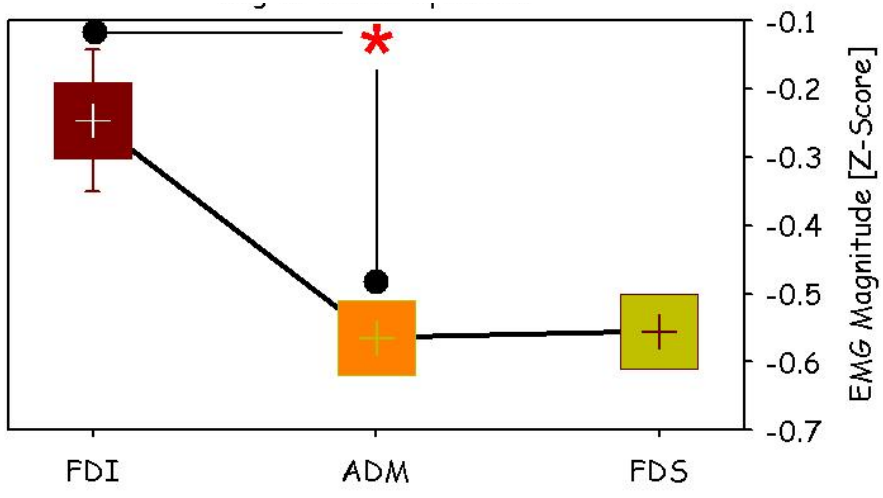
Small Spheres



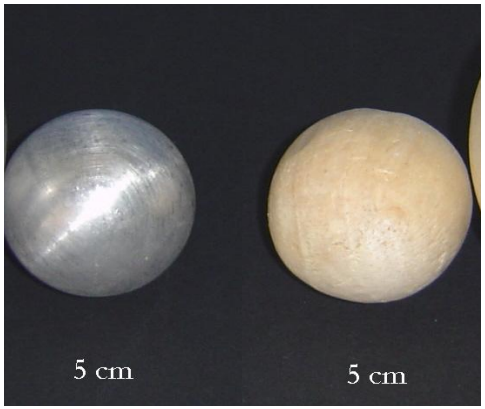
Imagination



Actual Action

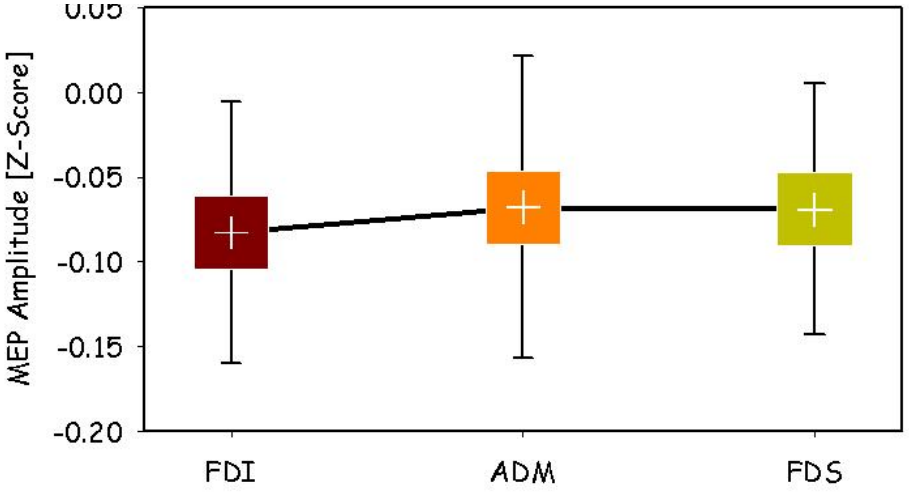


Cesari et al. Neuropsychologia 2011

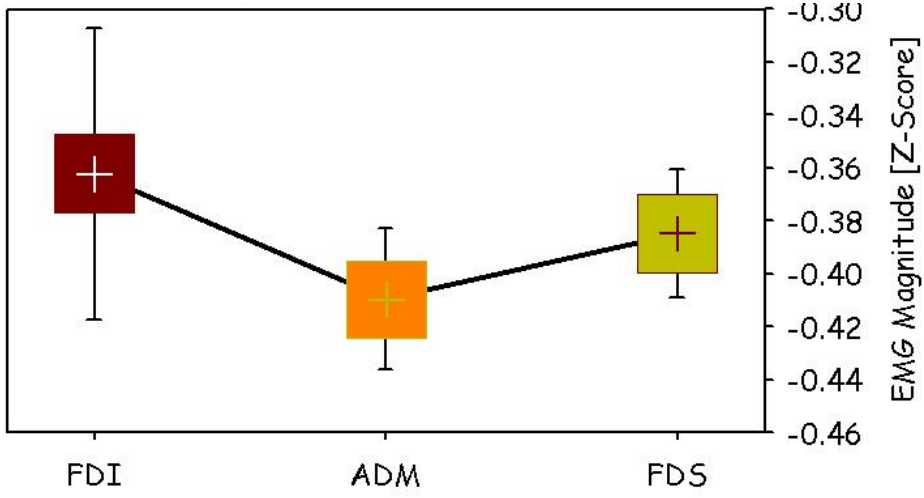


Medium spheres

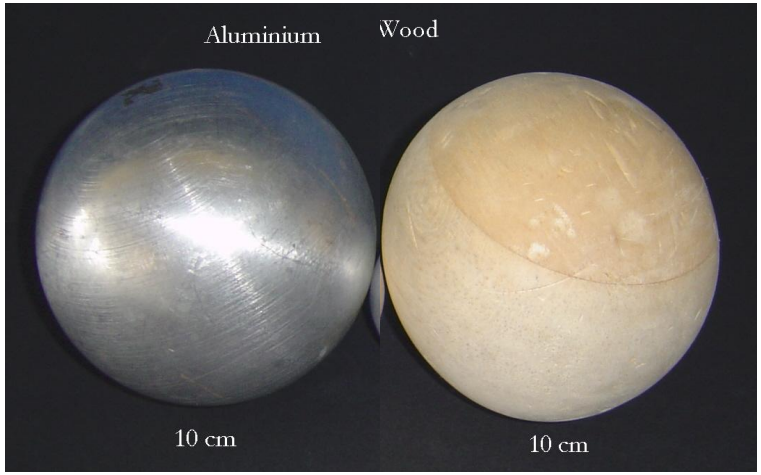
Imagination



Actual Action

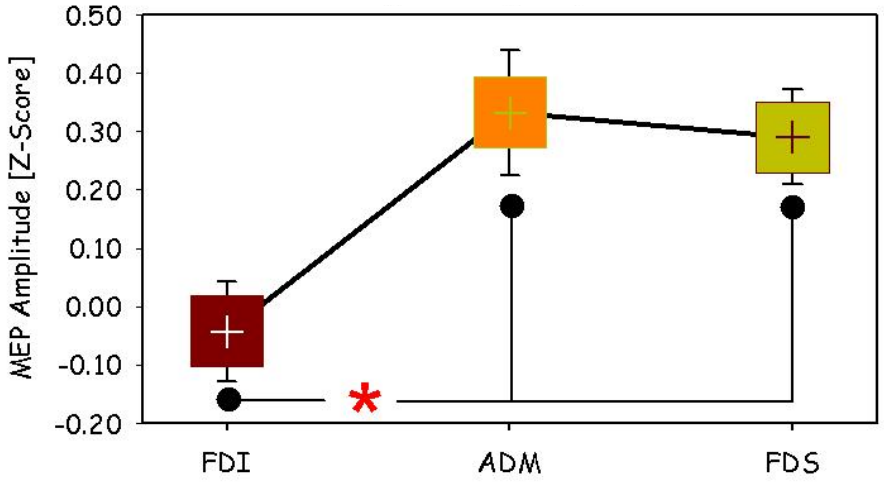


Cesari et al. Neuropsychologia 2011

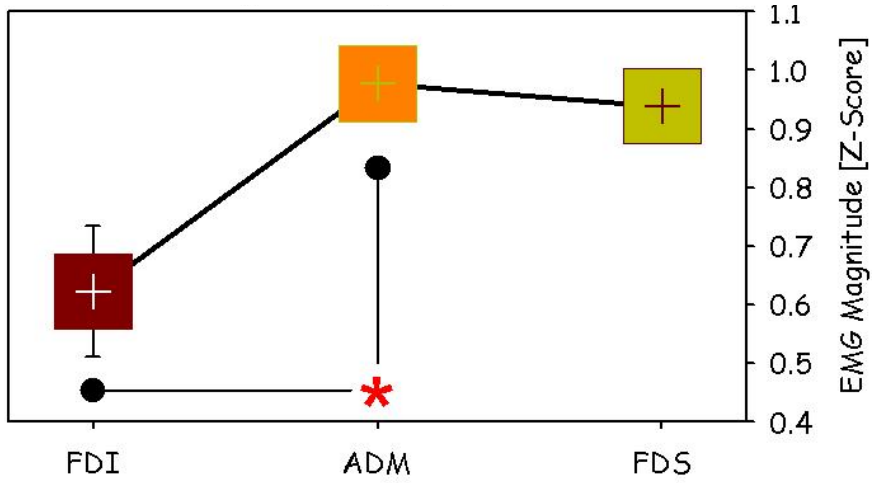


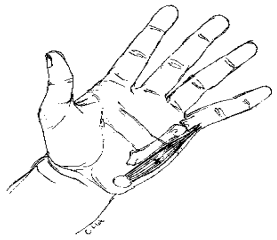
Large Spheres

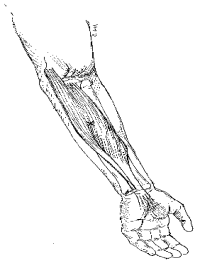
Imagination



Actual Action



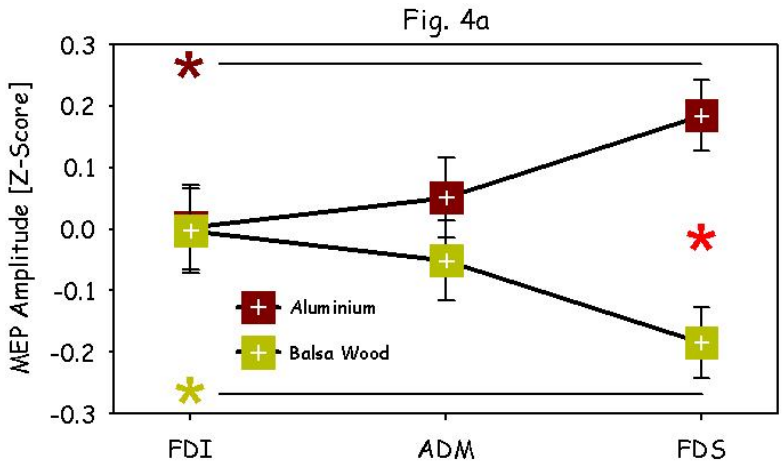




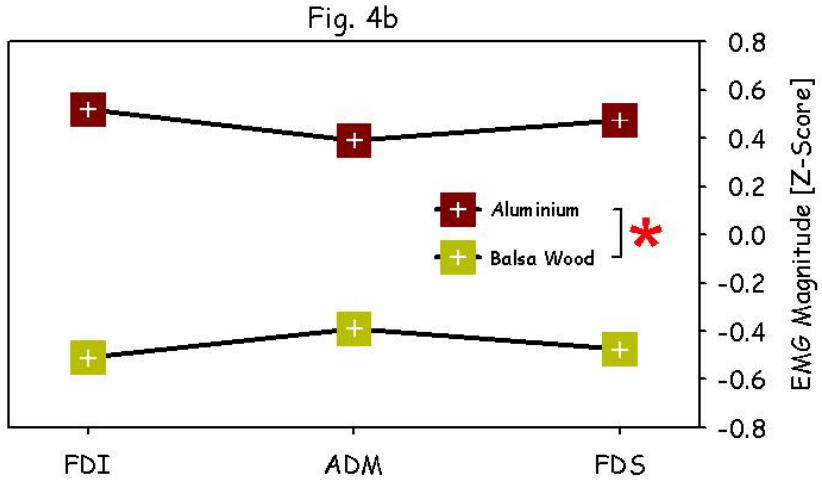
Cesari et al. Neuropsychologia 2011

the density

Imagination

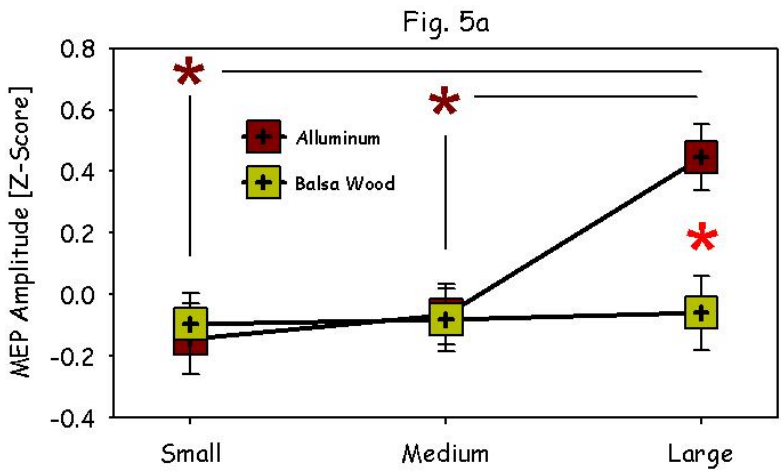


Actual Action

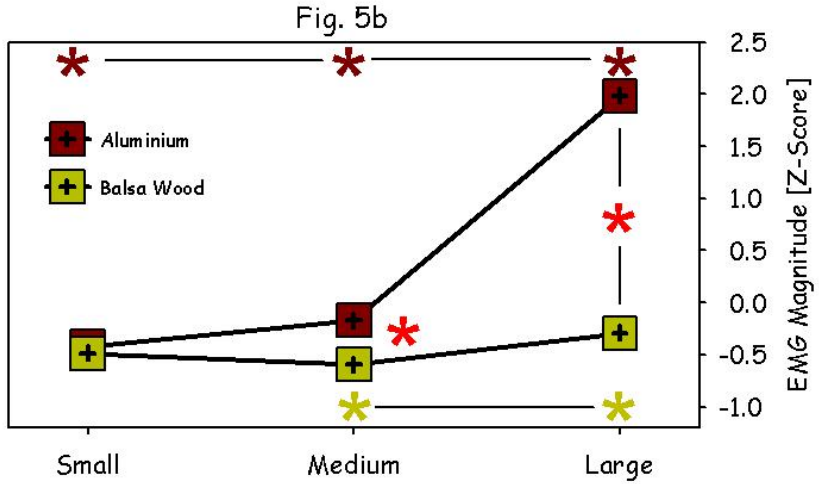


density

Imagination

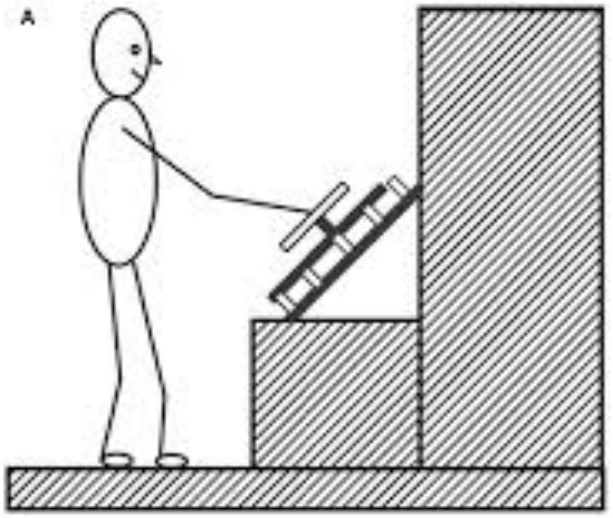


Actual Action



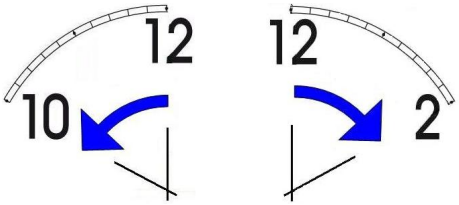
Cesari et al. Neuropsychologia 2011

Movement direction and amplitude

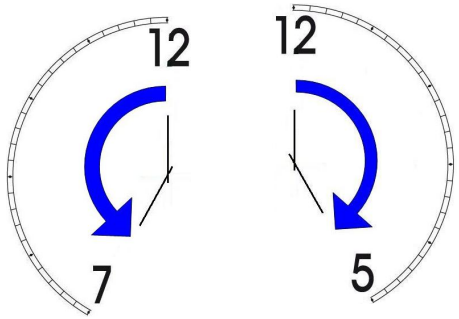


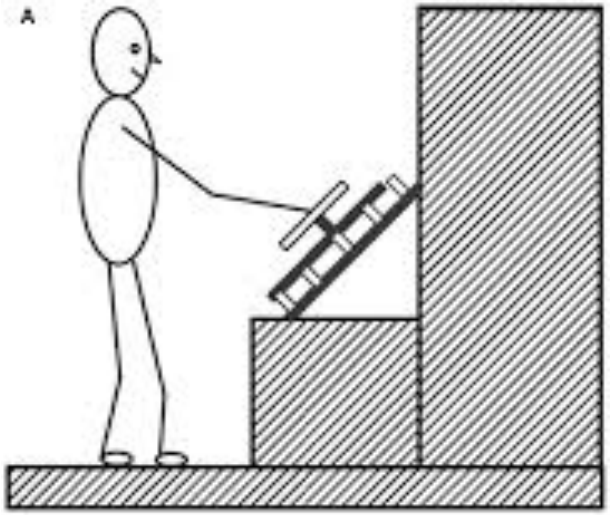
Pizzolato et al. Neuroscience 2012

Small Amplitude

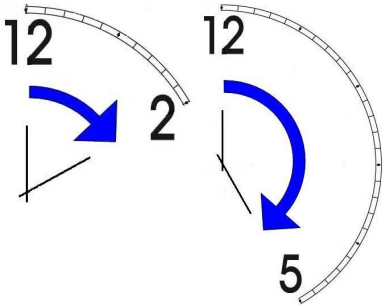


Large Amplitude

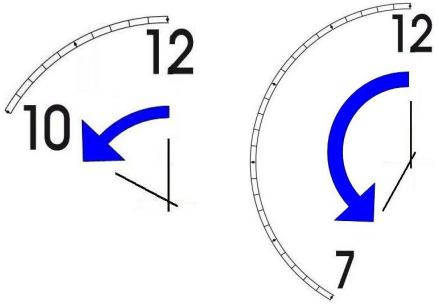




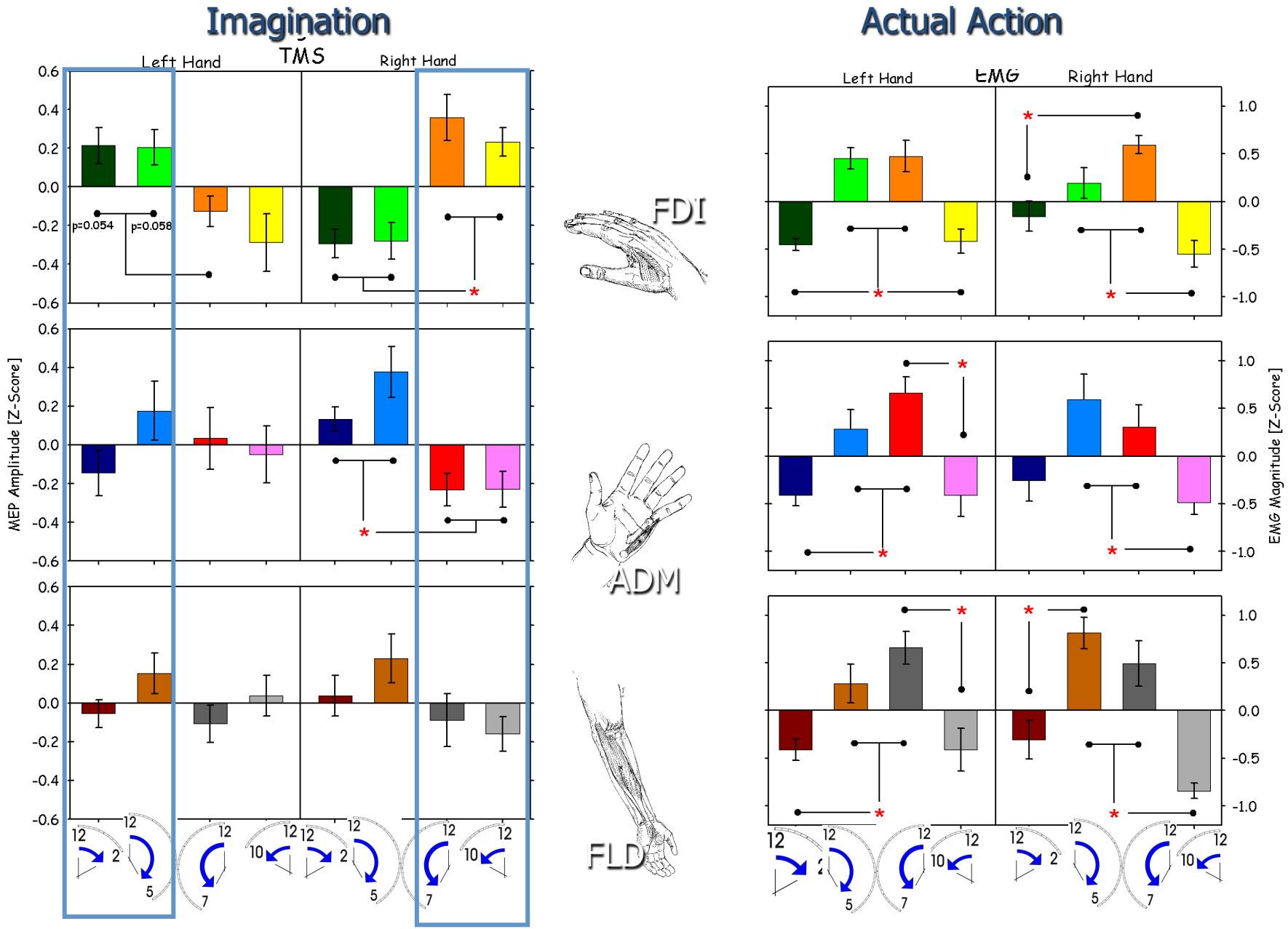
Clockwise Direction



Counter Clockwise Direction

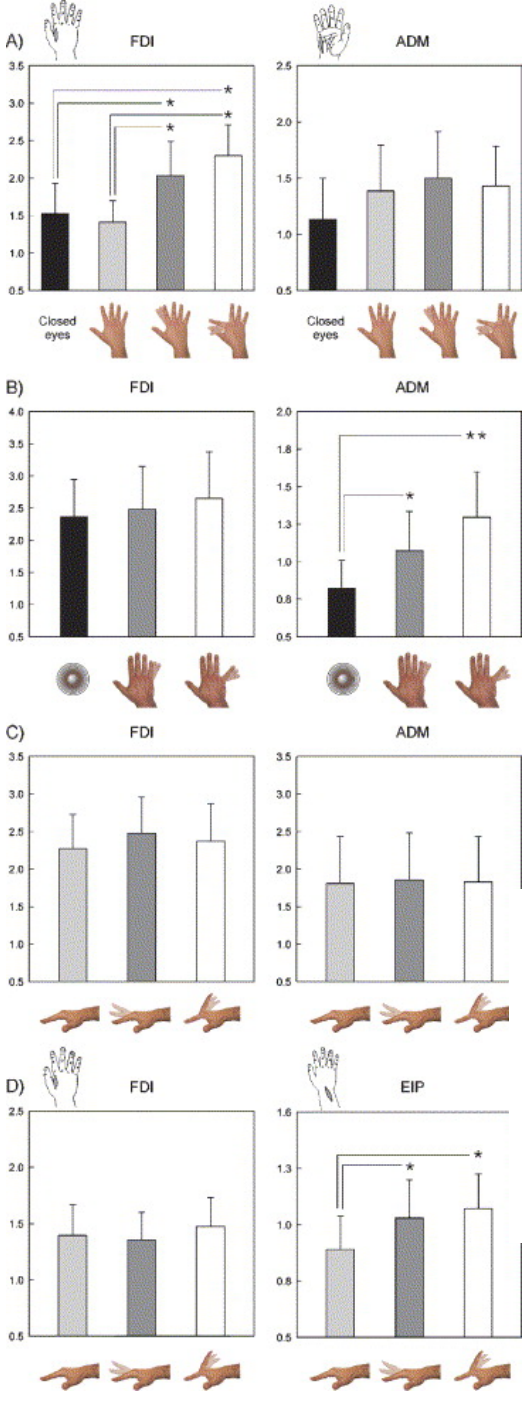


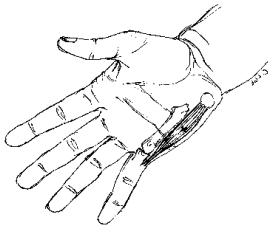
Pizzolato et al. Neuroscience 2012



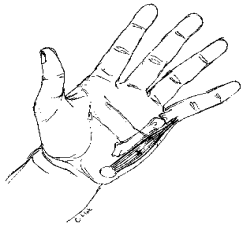
Pizzolato et al. Neuroscience 2010

Muscle specificity

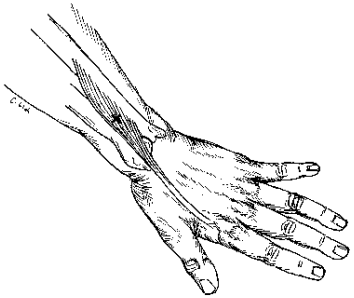




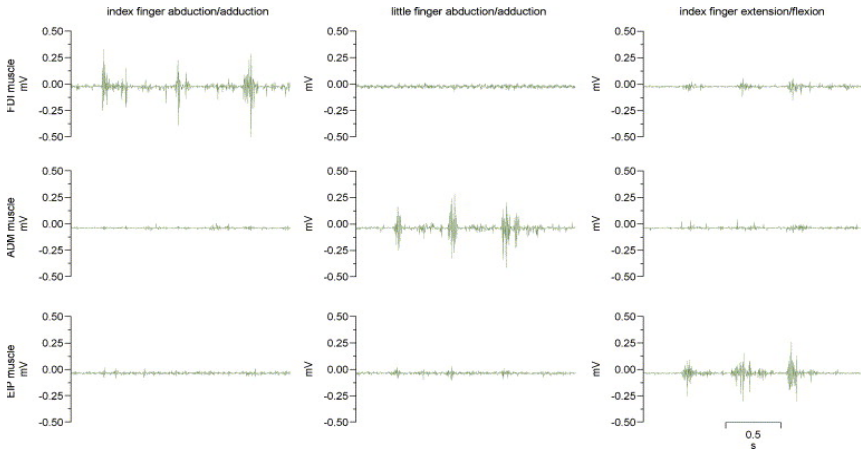
FirstDorsalInterosseus



AbducturDigitiMinimi



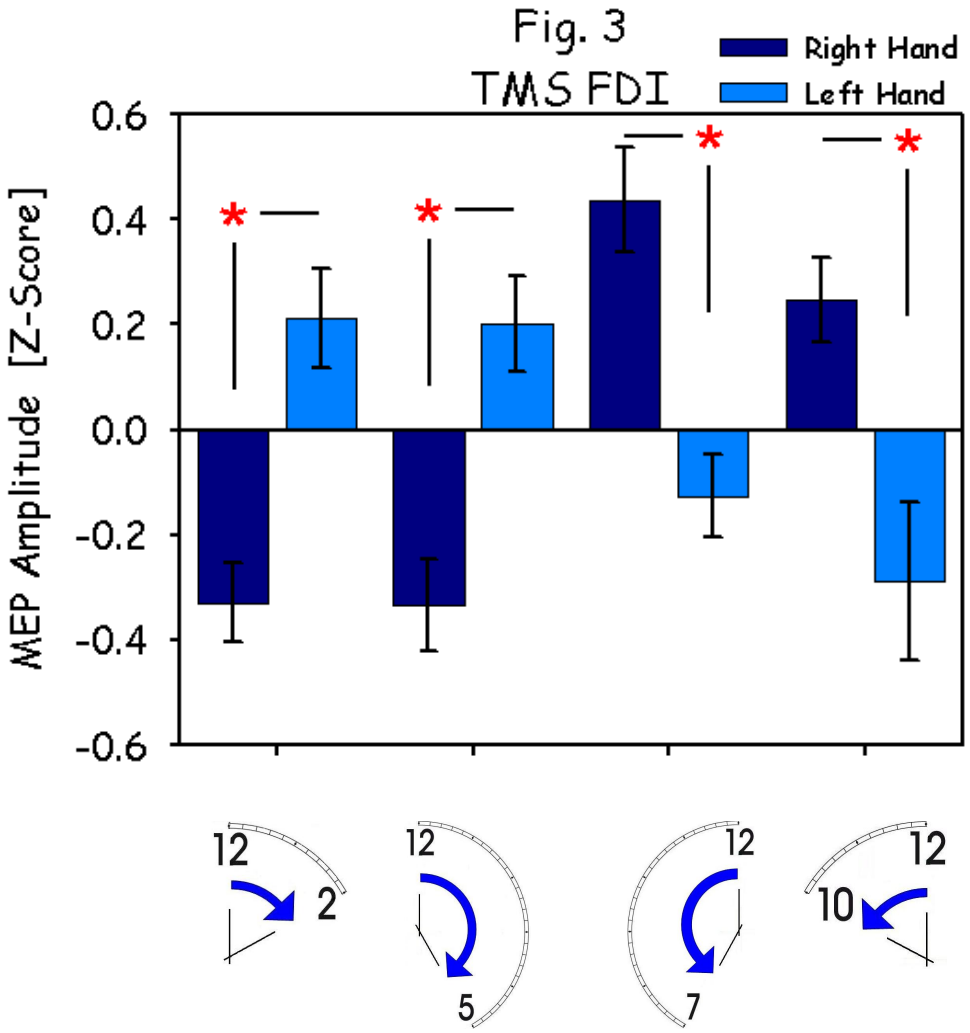
ExtensorIndicisProprius

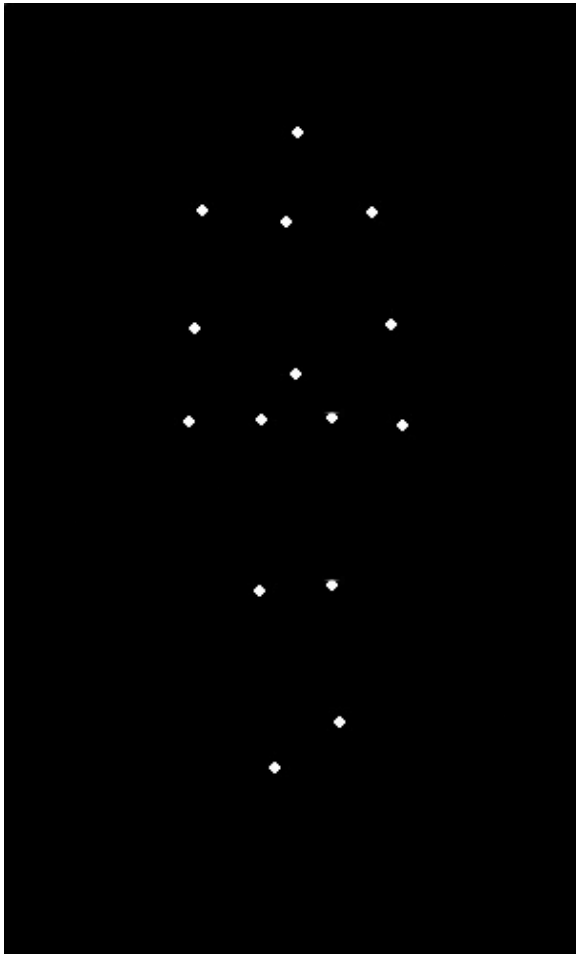


Bufalari et al. Biol. Psych. 2010

Romani et al., Neuroimage, 2005

Results: the two hemispheres





Inherent capacity to recognize other people's actions

Observing

Performing

Perfectioning

These motor ideas may provide the neurobiological basis for space representation and understanding of actions made by others

It may be hypothesized that motor knowledge can be used to anticipate a sequence of actions when perceiving human motion. We may use predictive mechanisms which require pre-selection of relevant sensory information -- like athletes do!

Combining the two areas of research:

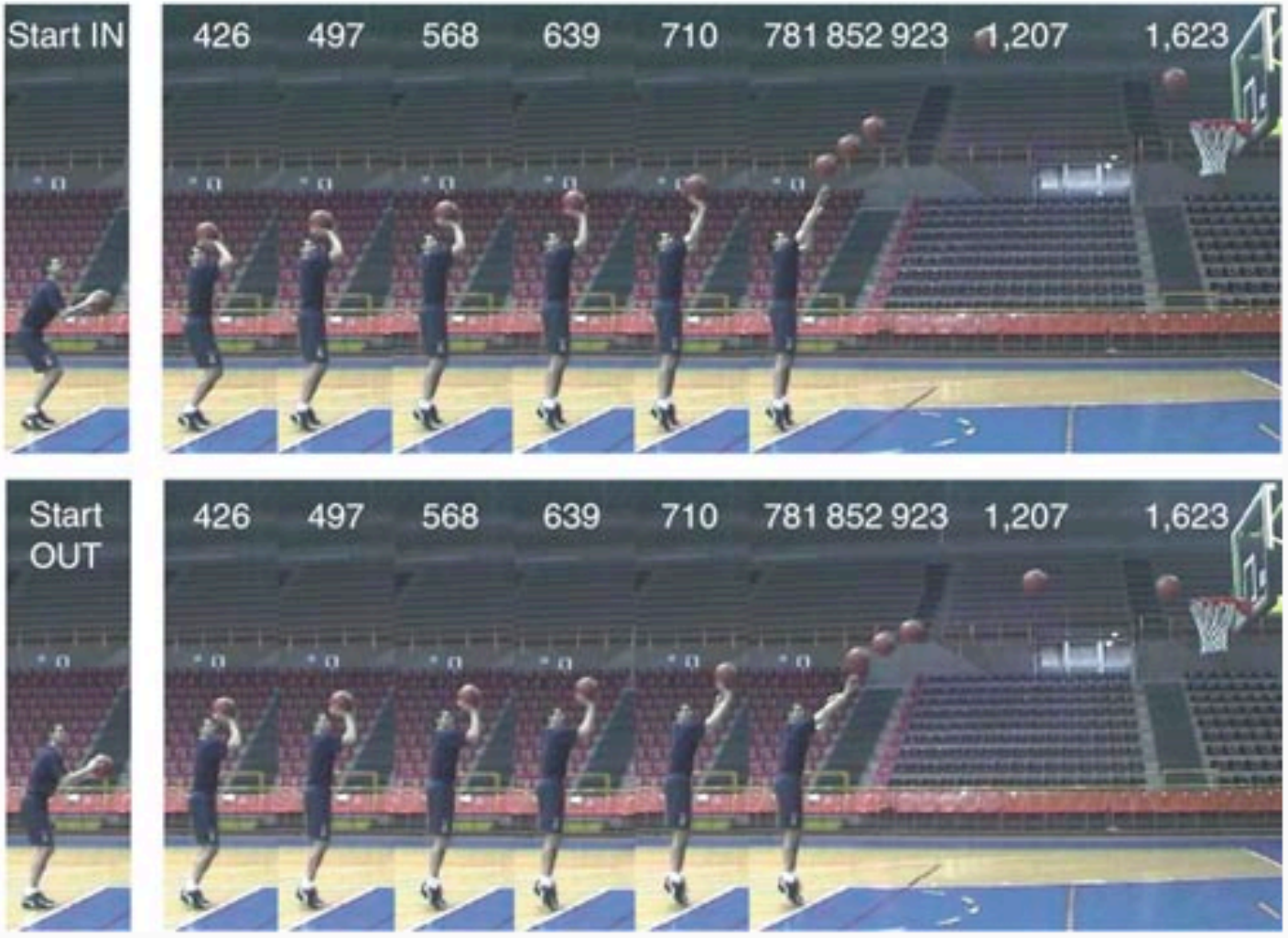
Bridging the gap between psychological research on experties and neuroscintific models of the basic mechanism that support sporting success

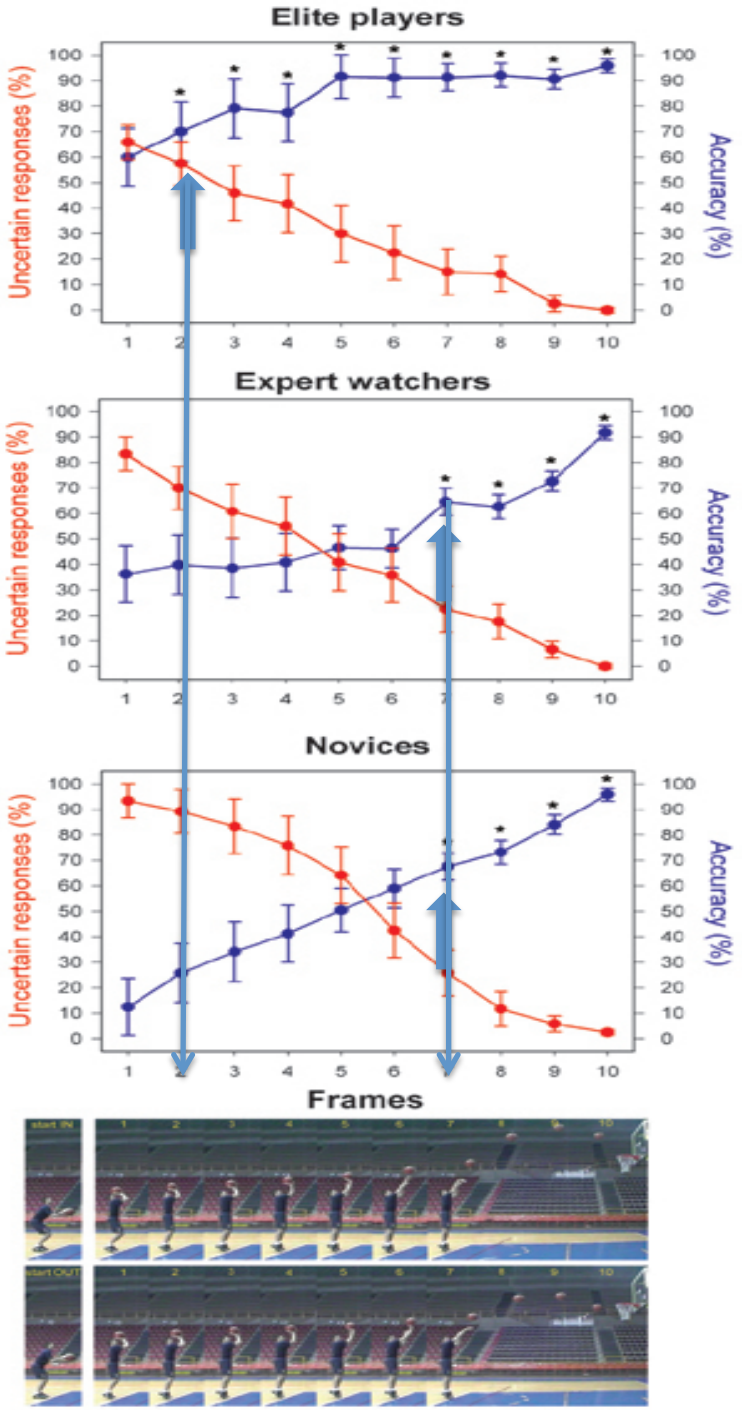
Observer → Athletes vs sport-journalist/non-athlets

Action Observed → Specific vs non-specific Sport action

Measures → Psychophysics/TMS

We asked whether there is a correlation between the ability to perform and to recognize an action


Start IN
426
497
568
639
710
781 852 923
1,207
1,623
Start OUT
426
497
568
639
710
781 852 923
1,207
1,623

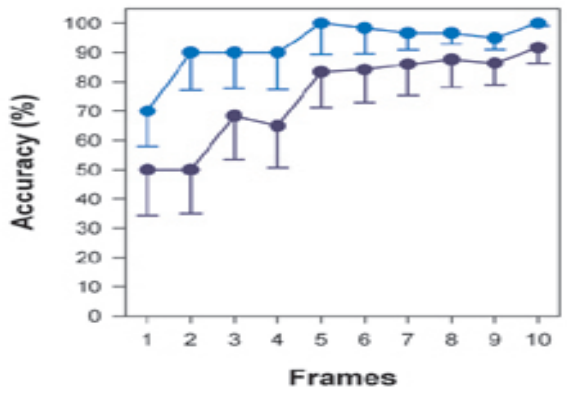


Players

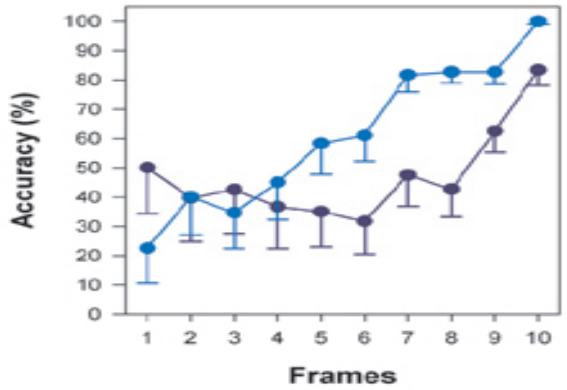
Journalists

Non-Players

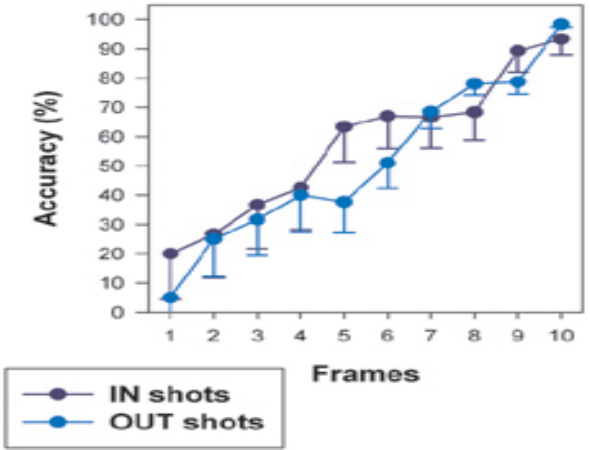
Aglioti et al. Nature Neuroscience 2008



Players



Journalists

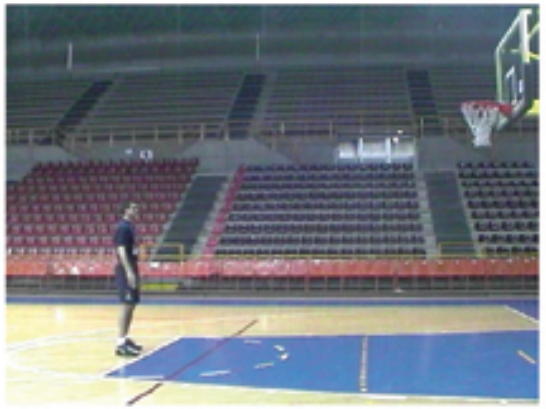


Non-Players

Aglioti et al. Nature Neuroscience 2008

A

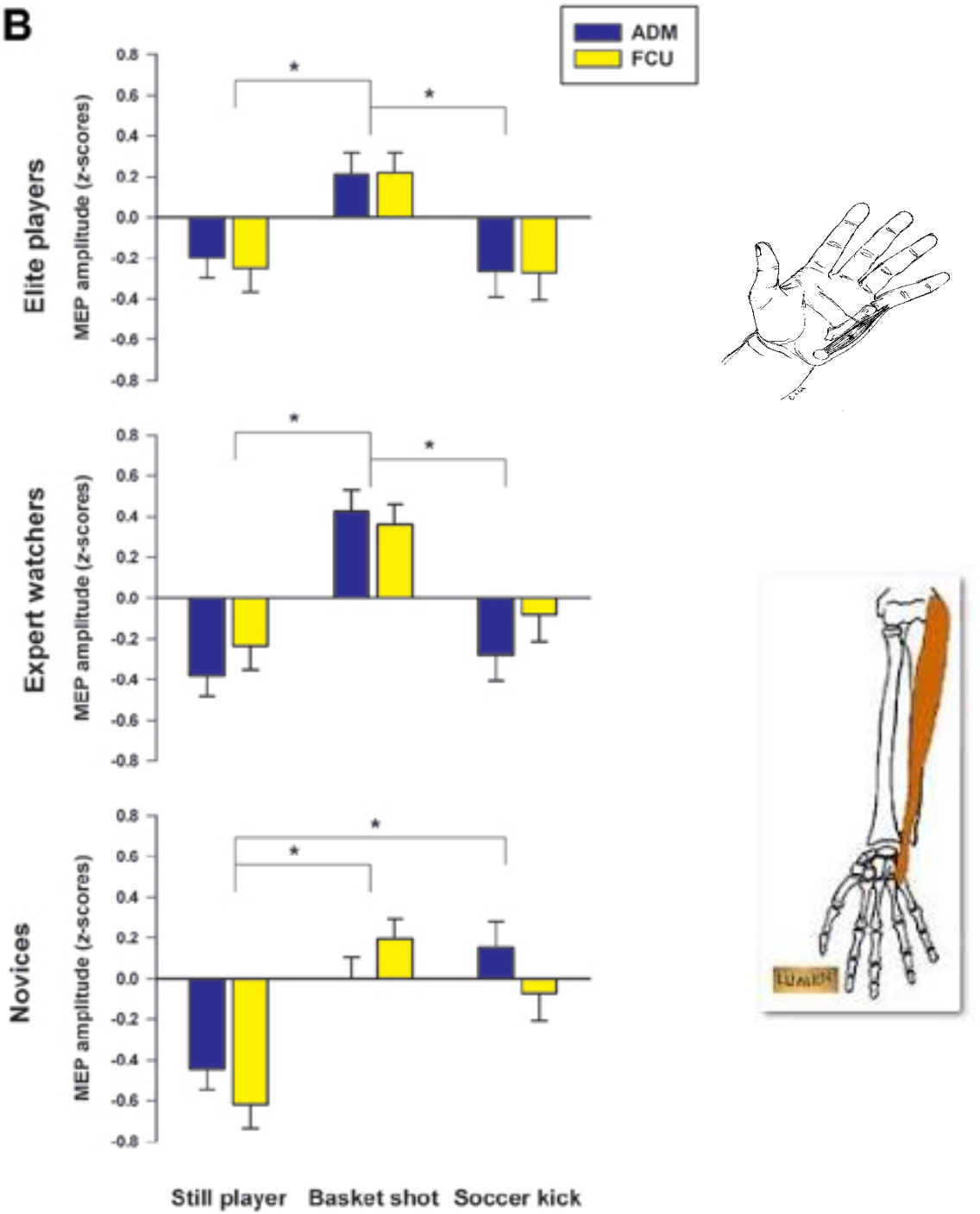
Still player

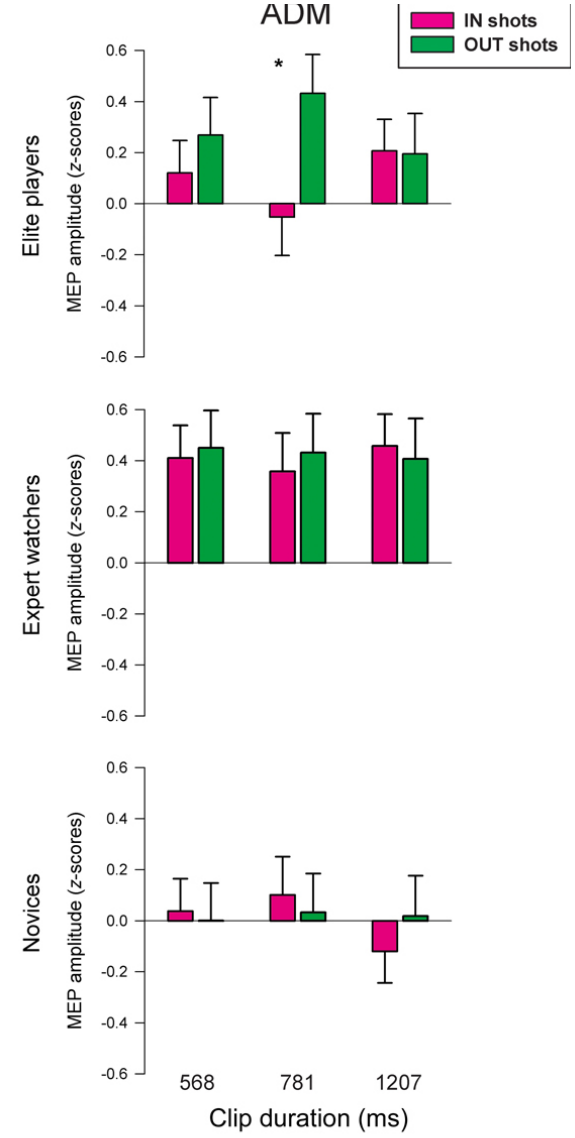


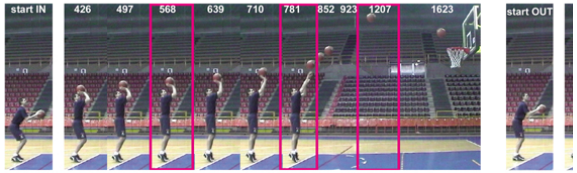
Basket shot

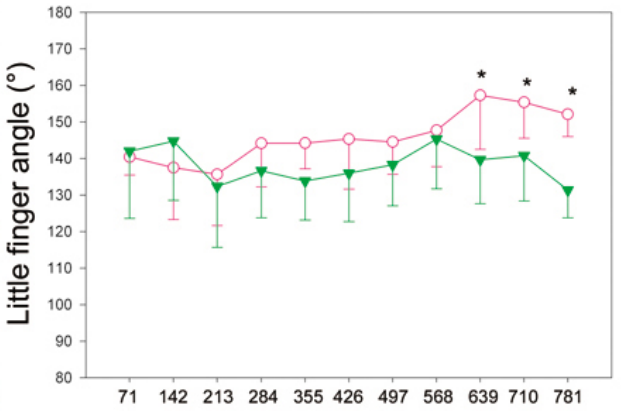
Soccer kick

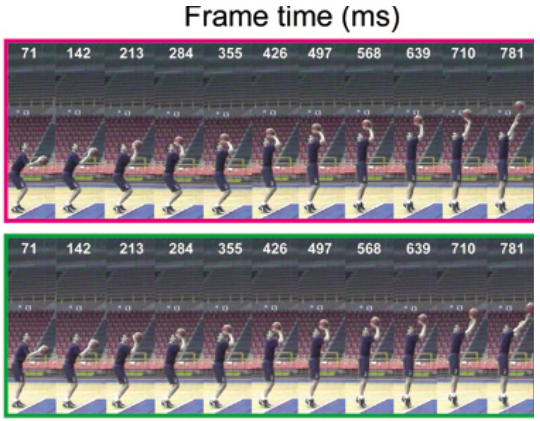
B







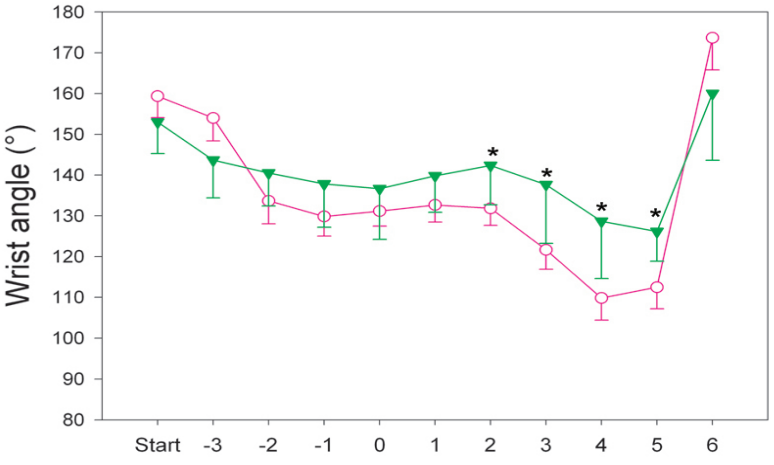




Aglioti et al. Nature Neuroscience 2008

IN shots

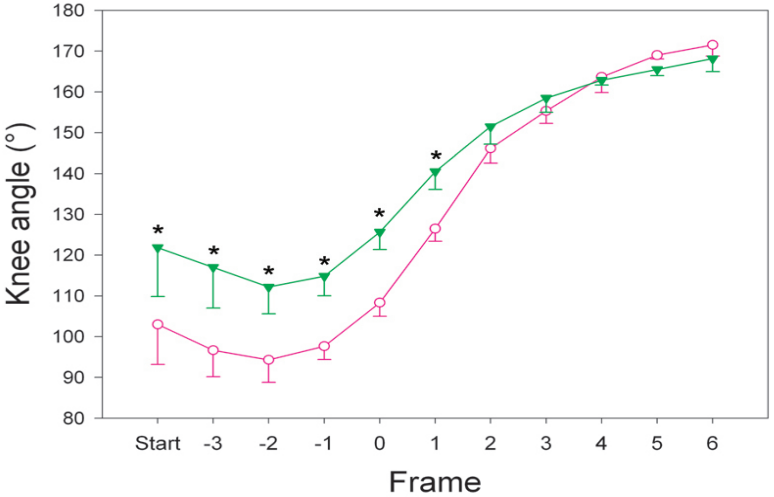
OUT shots



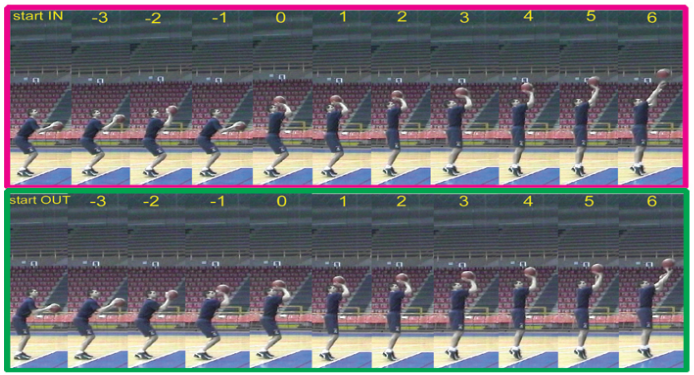
The wrist angle different between IN and OUT at the instant of the ball throw

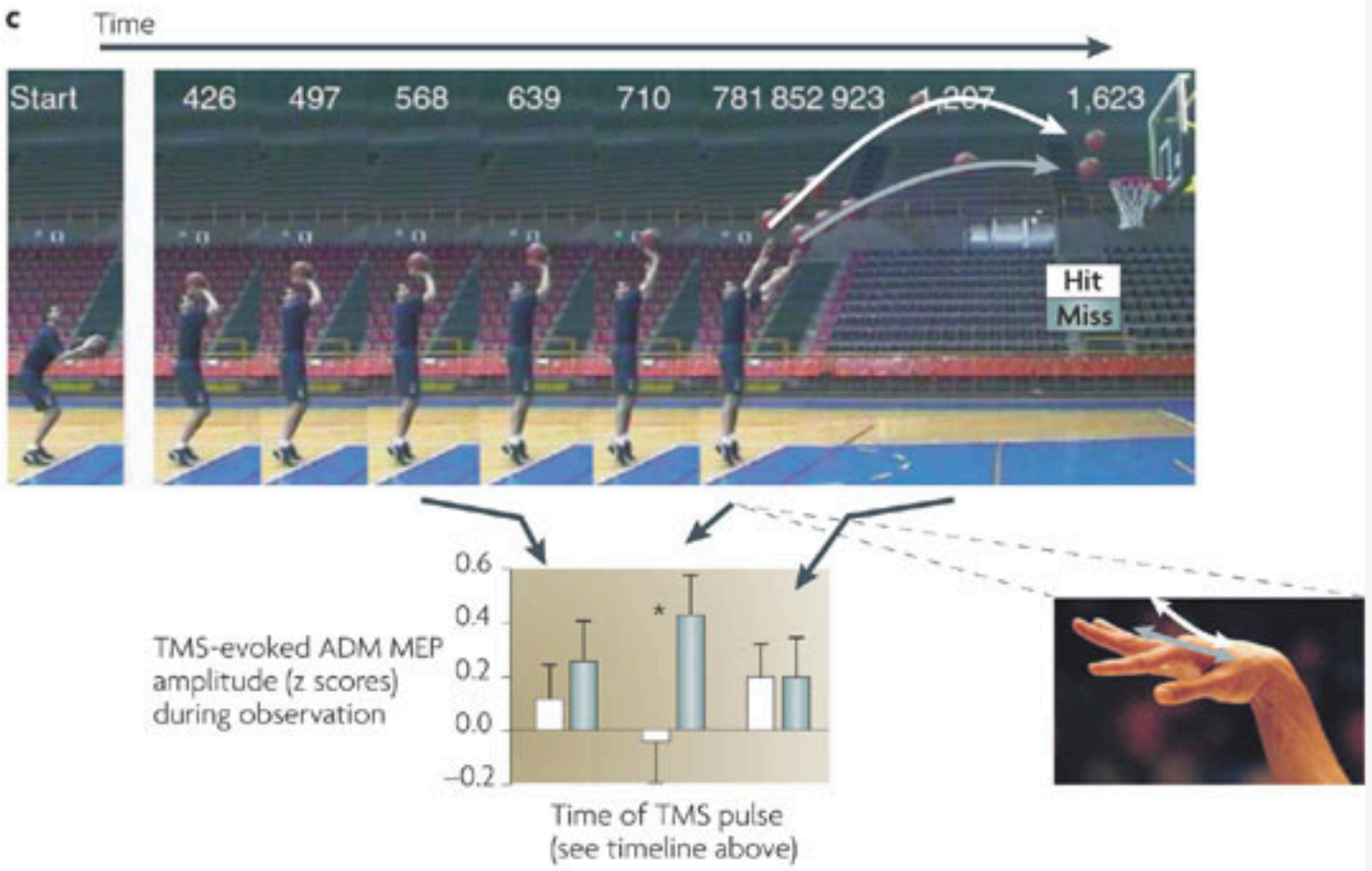
IN shots

OUT shots

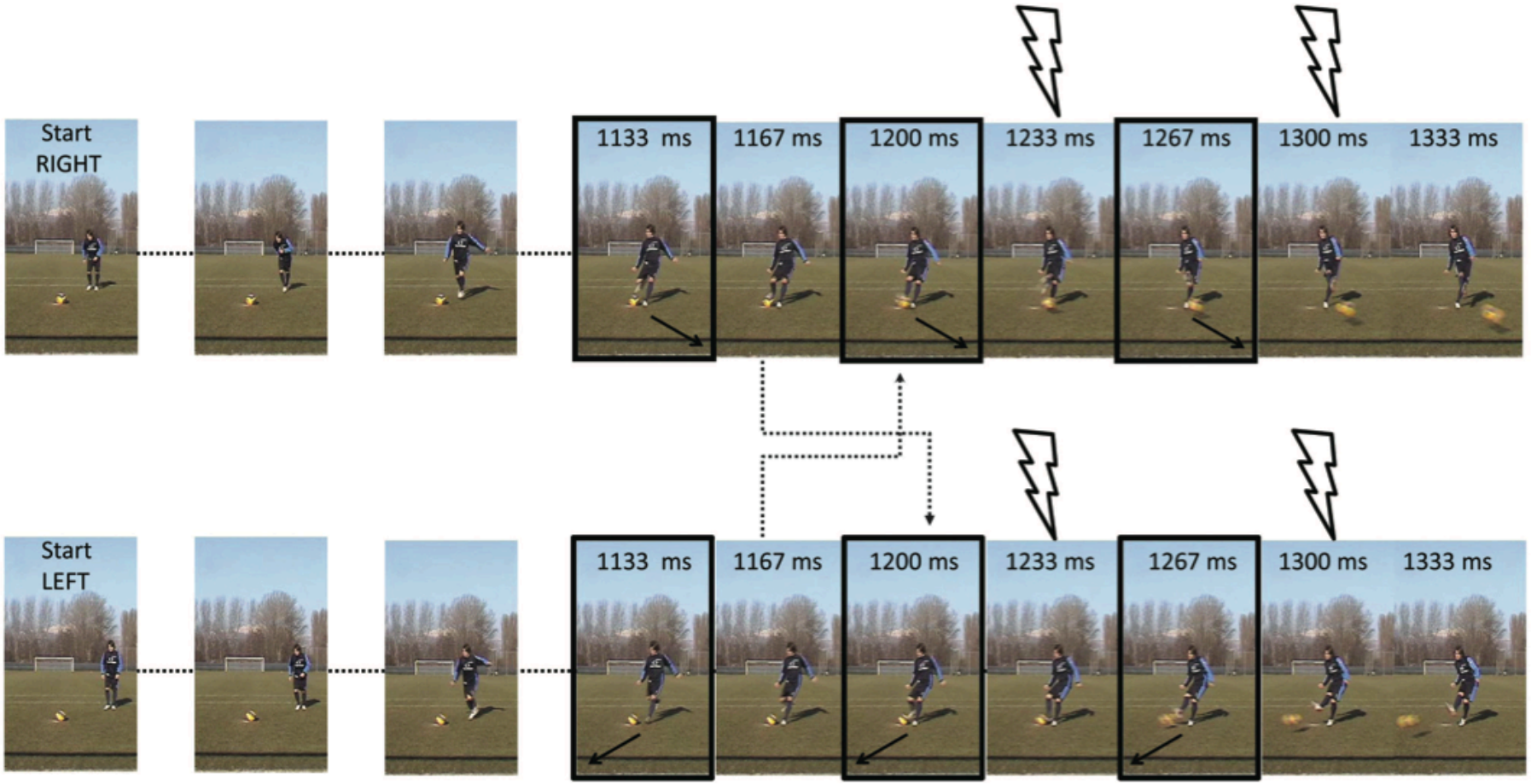


The knee angle different between IN and OUT at the very beginning of the action

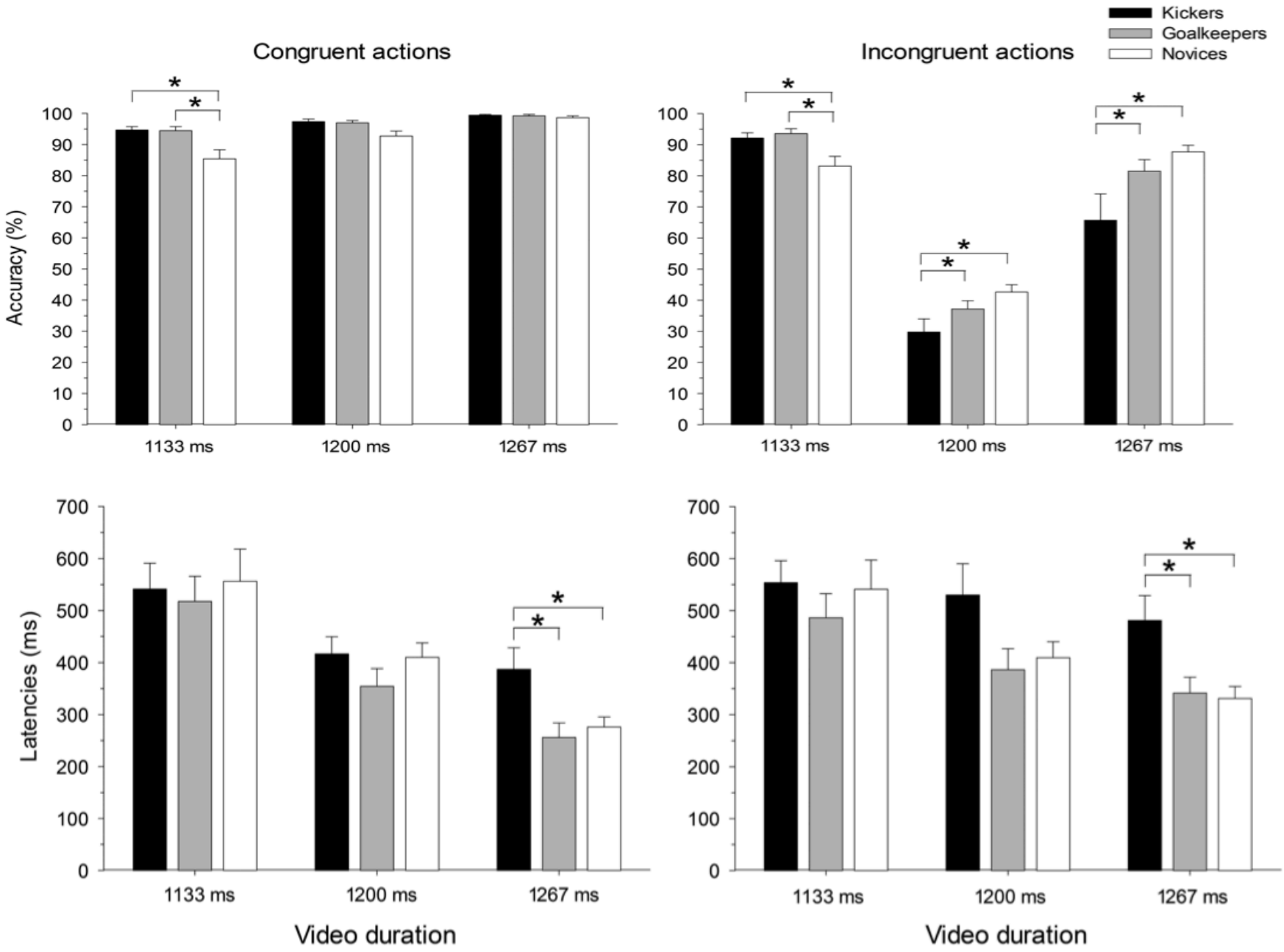




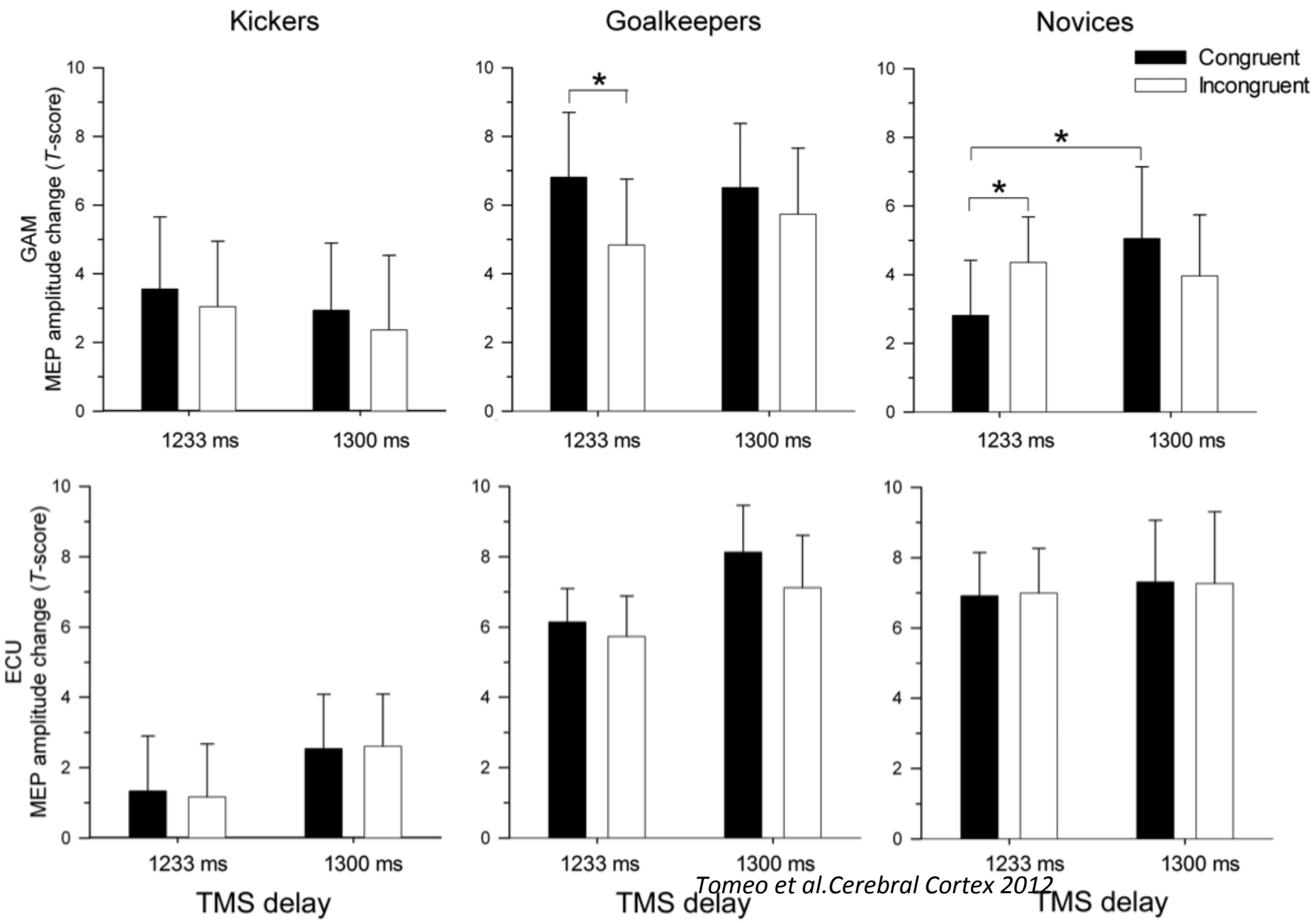
Aglioti et al. Nature Neuroscience 2008



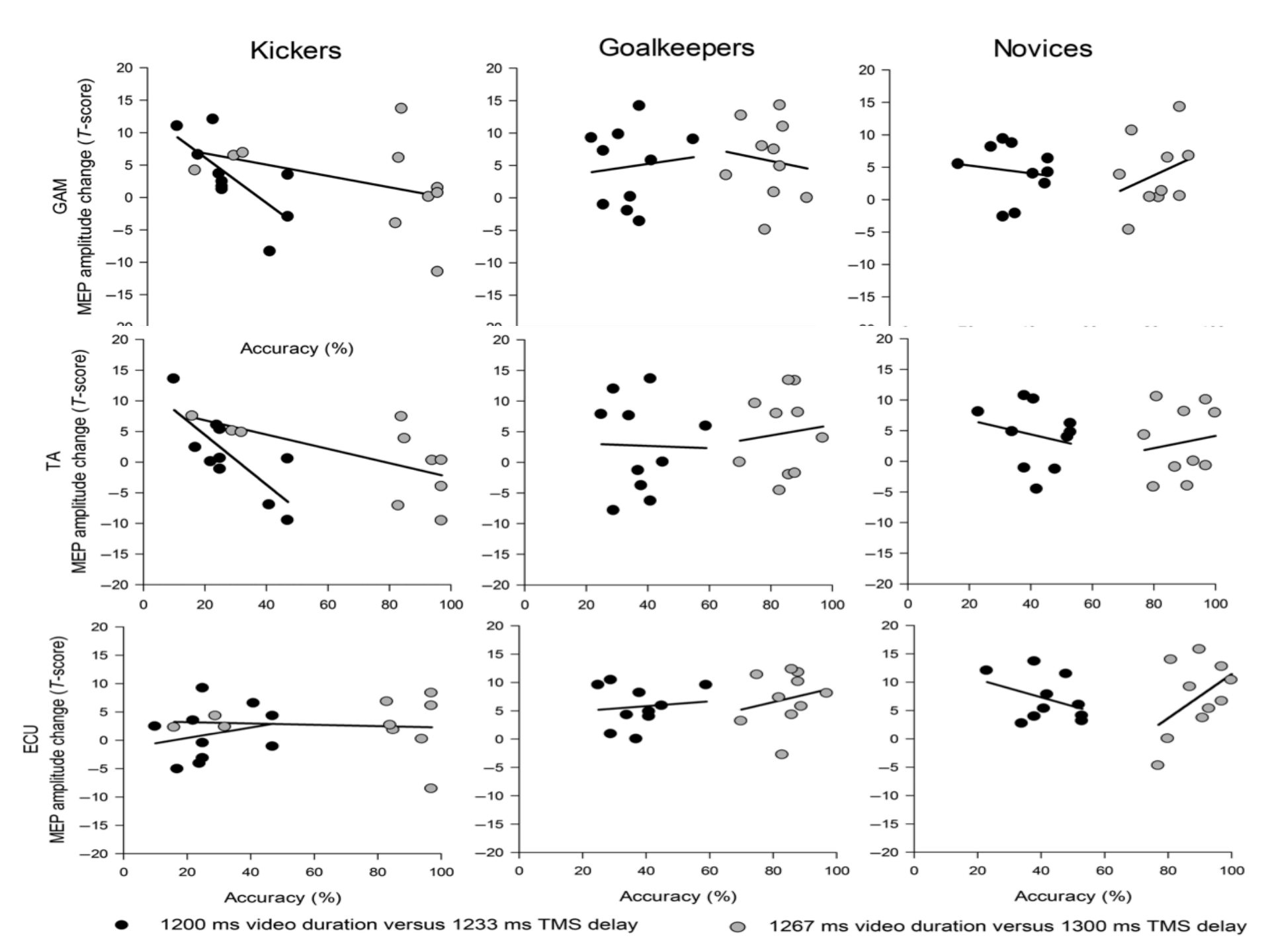
Tomeo et al.Cerebral Cortex 2012



Tomeo et al.Cerebral Cortex 2012



Tomeo et al.Cerebral Cortex 2012


Kickers
Goalkeepers
Novices
GAM
TA
ECU
MEP amplitude change (T-score)
Accuracy (%)
1200 ms video duration versus 1233 ms TMS delay
1267 ms video duration versus 1300 ms TMS delay

Kinesthetic Imagery and Tool-Specific Modulation of Corticospinal Representations in Expert Tennis Players

Alissa D. Fourkas1,4, Valerio Bonavolonta` 2, Alessio Avenanti1,3,5 and Salvatore M. Aglioti1,3

Expert (n = 8) and novice (n = 8) tennis players were matched on age and gender (20--33 years; 14 male).

Players ranked in the B and C categories typically compete at a national level and may also compete in regional or international tournaments. The experts had mean (M) = 12.4

[standard deviation (SD) = 2.4] years experience

All novices were athletic, regularly participating recreationally in football (i.e., soccer), weightlifting, kickboxing, or aerobics, or competitively in swimming (master) or football (i.e., soccer) (semiprofessional). Four of the novices have played tennis recreationally (usually in summer), whereas 4 reported having never played. None had trained or competed in tennis, and none had played in the previous 7 days.

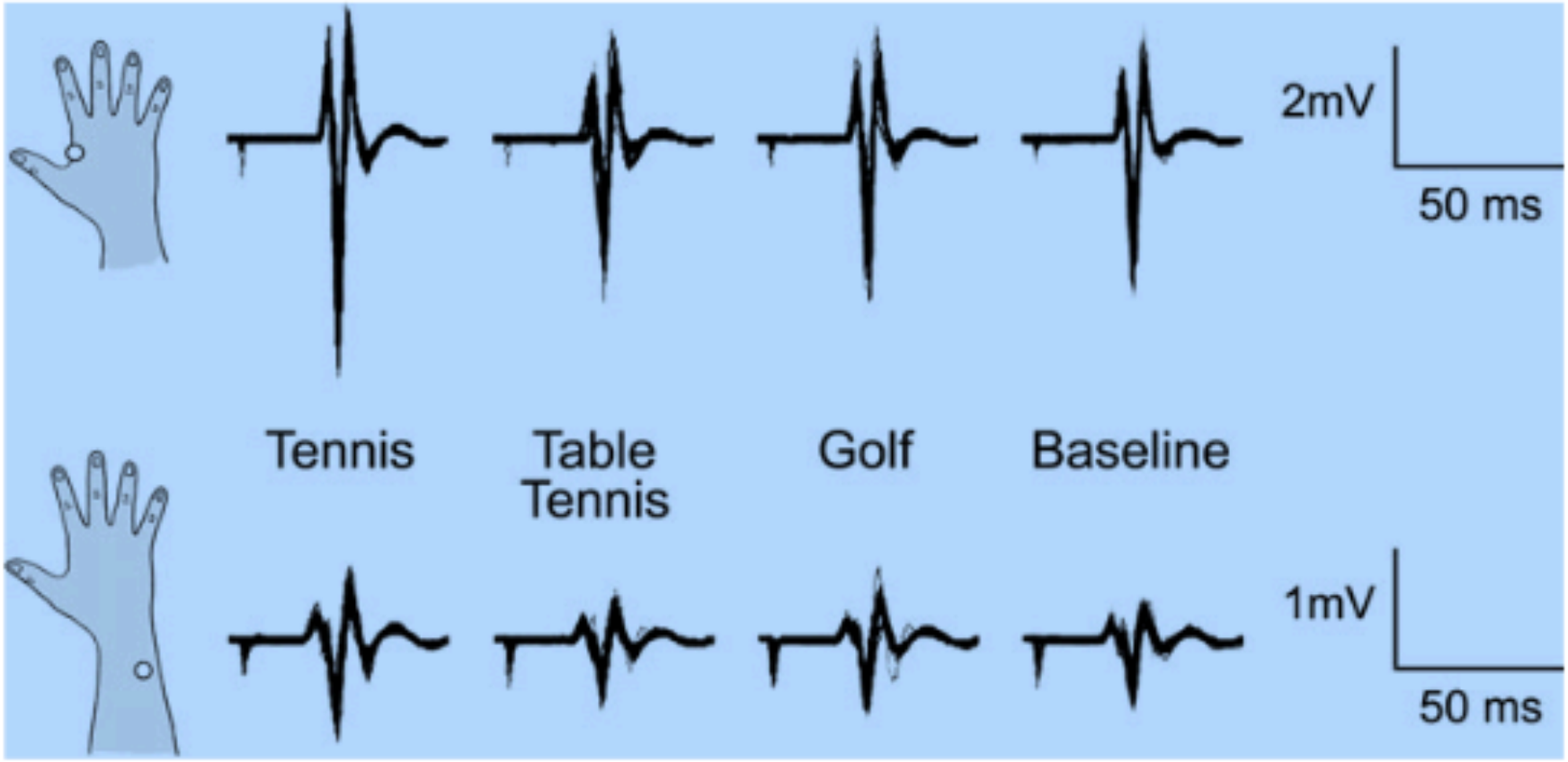


Figure 1. Representative MEP data. Raw MEP data from 1 representative expert tennis player. Peak to peak amplitude traces (18 per sport imagery task, 36 in baseline) are superimposed, with FDI presented in the upper panel and EIP in the lower panel.

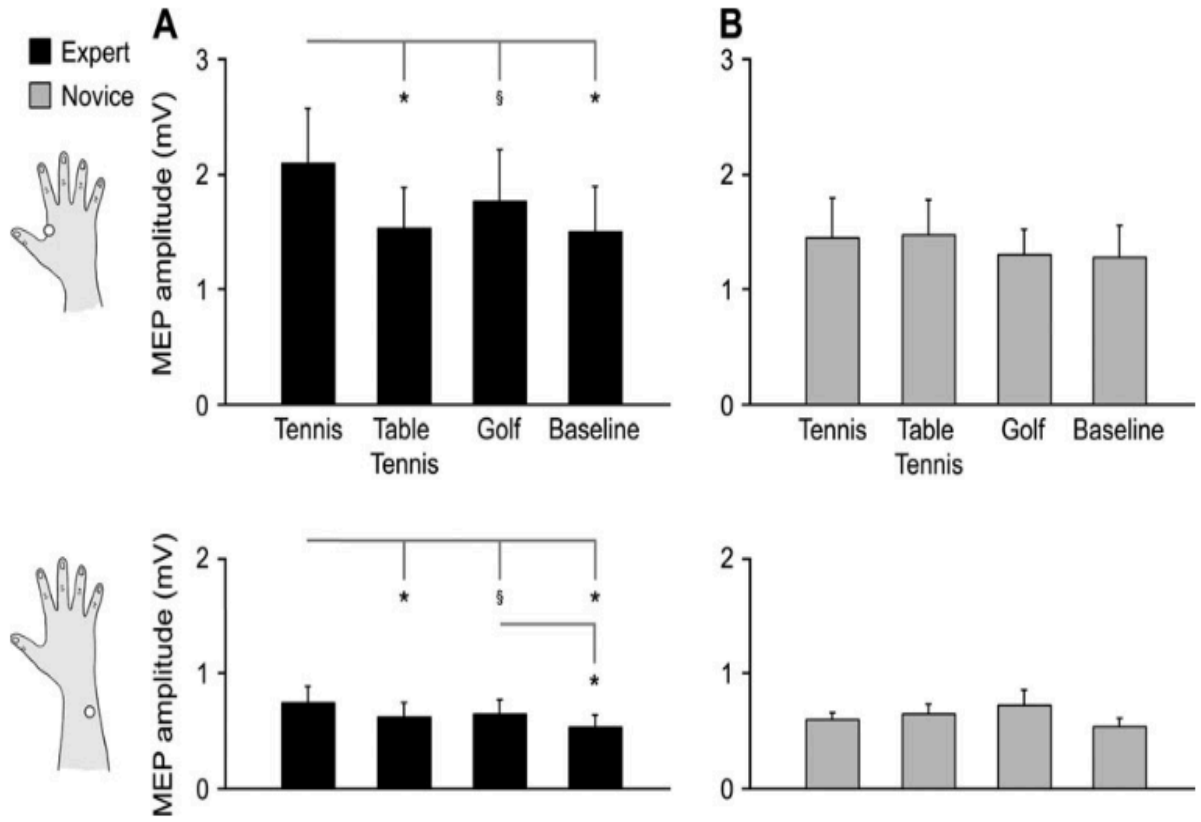


Figure 3. MEP amplitude in the different imagery conditions in the 2 groups. Raw peak to peak amplitude (mean and standard error) in each condition for each muscle. Panel (*A*) depicts data for expert tennis players: in the hand (FDI) muscle mental practice of tennis lead to significant MEP facilitation compared with table tennis and baseline and tended to lead to facilitation compared with golf imagery; in the forearm (EIP) muscle the same pattern was present for tennis, and golf was facilitated compared with baseline. Panel (*B*) illustrates that there were no significant differences in the novice tennis players across conditions in either muscle. $^{*}P < 0.05$, $\S P < 0.07$

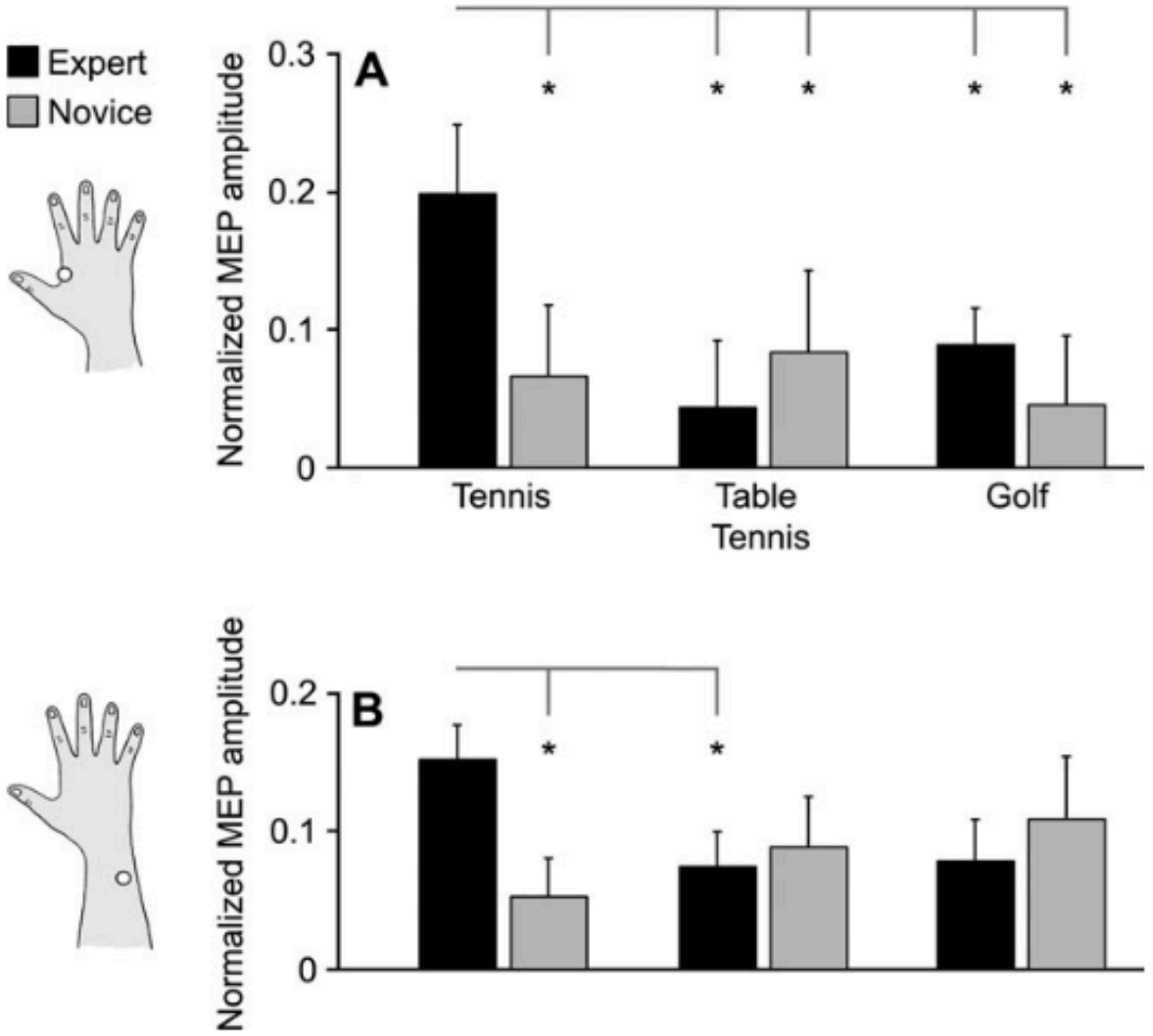


Figure 4. Comparison of groups using normalized data. Means and standard errors are reported. Panel (*A*) shows higher levels of corticospinal facilitation in the hand muscle (FDI) of experts during tennis imagery compared with table tennis and golf imagery and compared with all novice conditions. Panel (*B*) shows higher levels of facilitation in the forearm muscle (EIP) of experts during mental practice of tennis compared with novices and compared with themselves mentally practicing table tennis; experts tended to be facilitated during tennis compared with golf. *$P < 0.05$

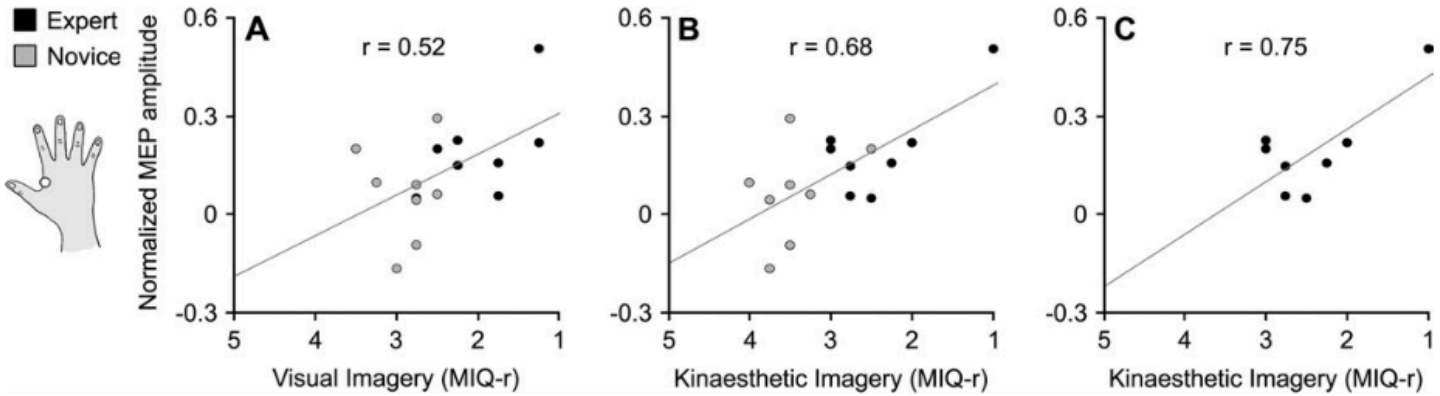


Figure 5. Correlation between MEP facilitation and the MIQr. Scatterplots show significant correlations between corticospinal facilitation in the tennis condition and visual (*A*) and kinesthetic (*B* and *C*) subscales of the imagery questionnaire. The scale on the *x*-axis is reflected for intuitive clarity, making the *r* value positive: 1 indicates a subjective rating of very easy, 2 easy, 3 fairly easy, 4 not easy or hard, and 5 fairly hard.

Action Observation and Acquired Motor Skills: An fMRI Study with Expert Dancers

B. Calvo-Merino1, D.E. Glaser2, J. Gre` zes3, R.E. Passingham4 and P. Haggard2

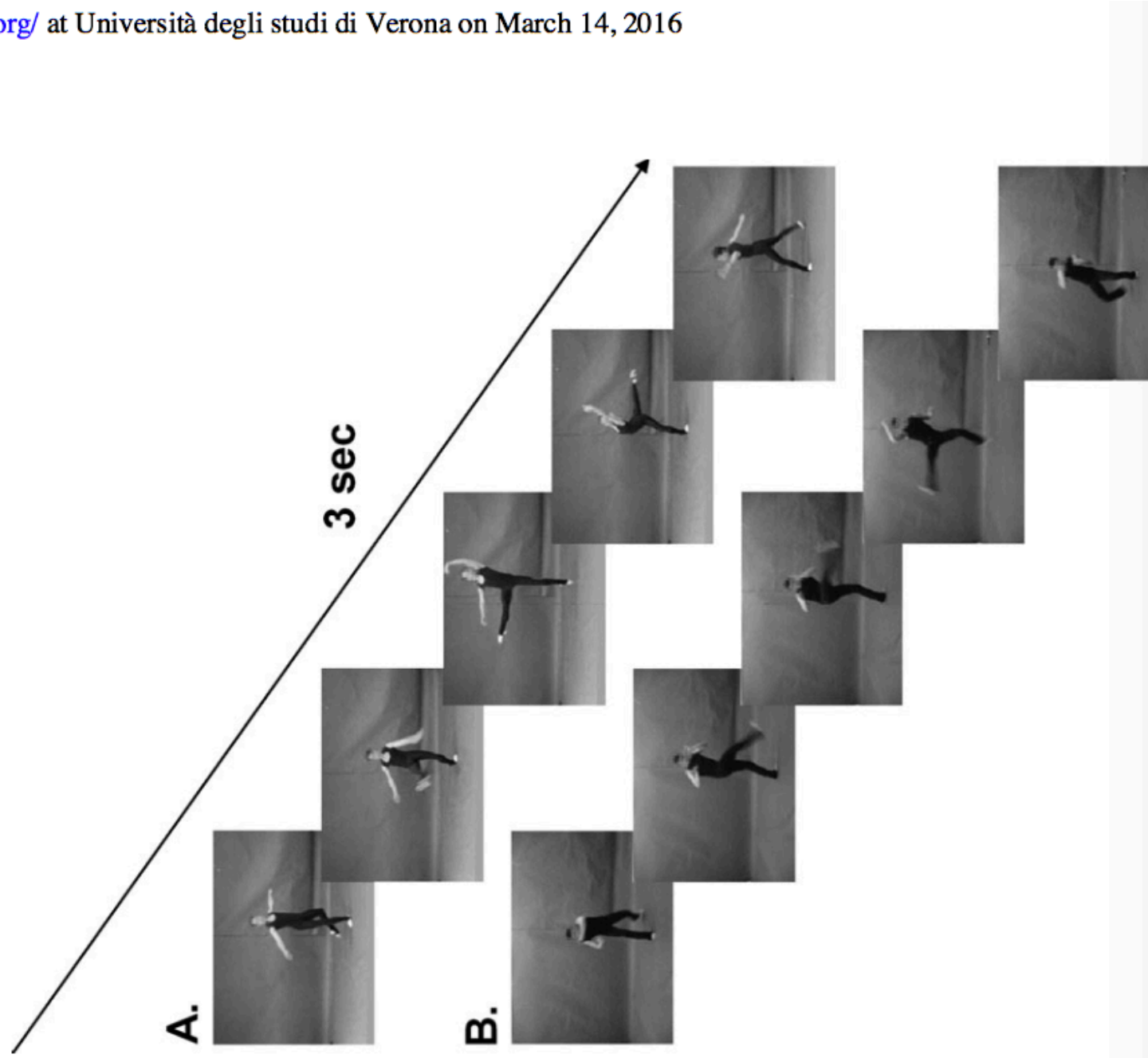
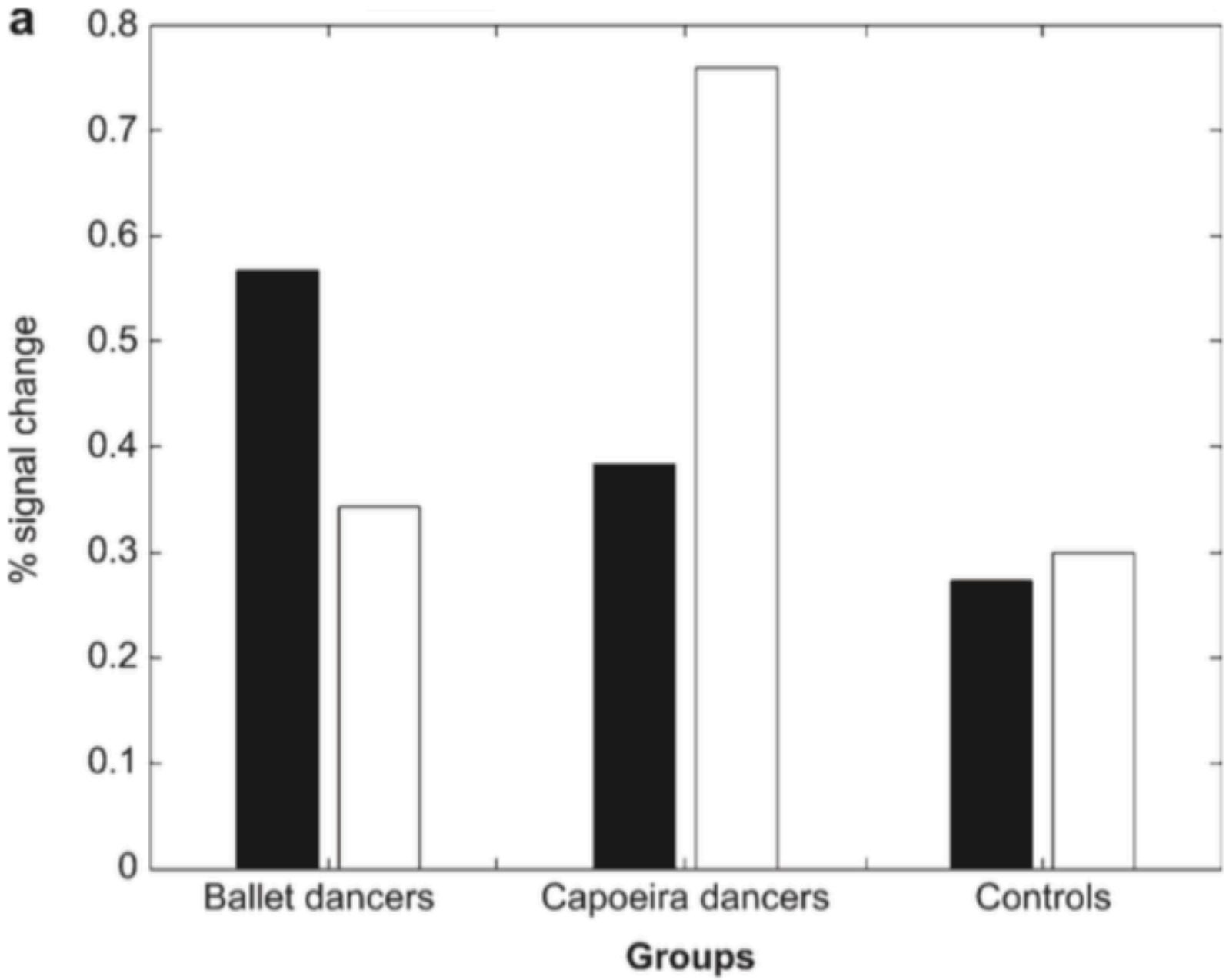
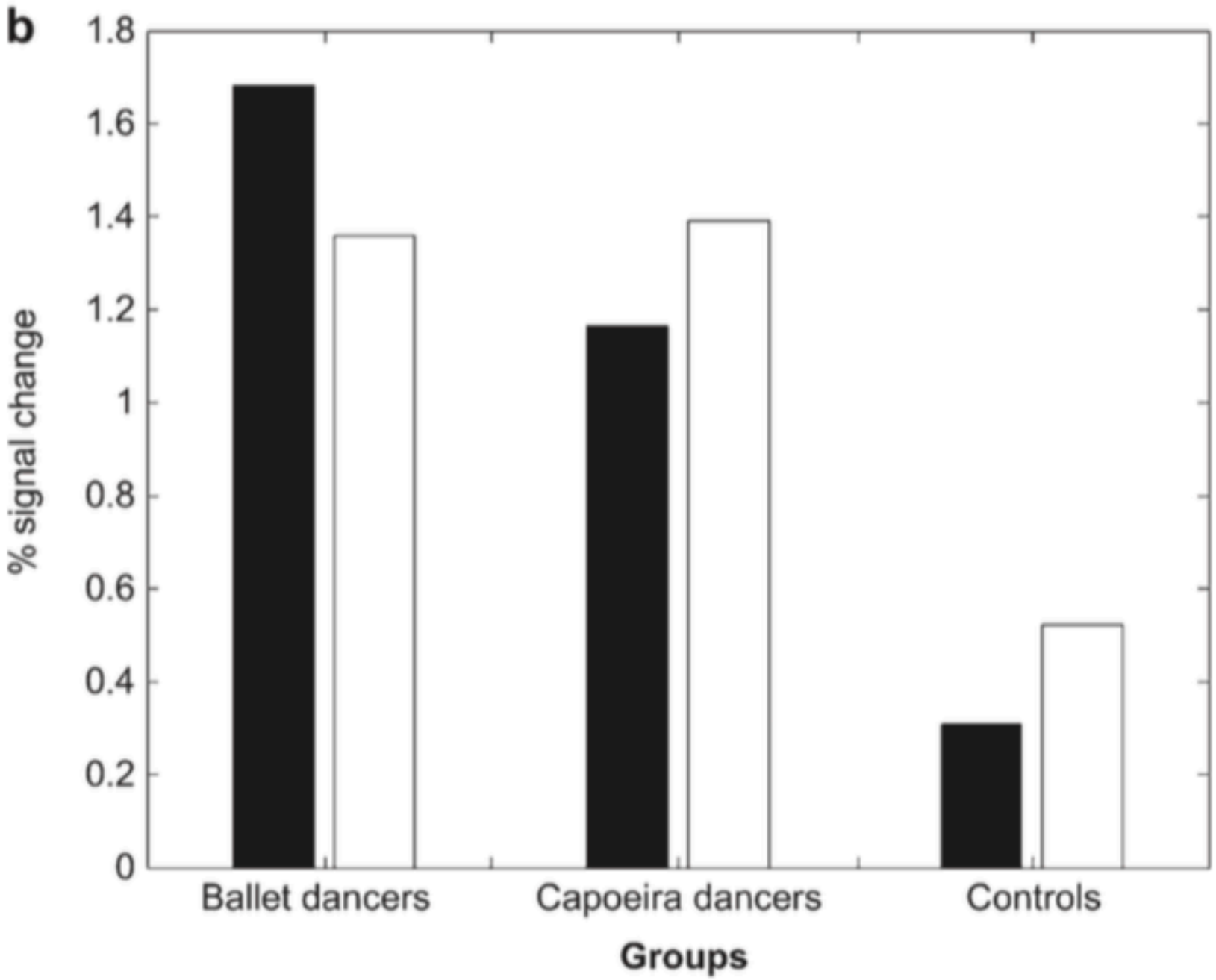


Figure 1. Stimuli: Colour videos of standard classical ballet and capoeira movements were performed by professional dancers. Twelve different moves of each style (*a*, ballet; *b*, capoeira) were matched by a professional choreographer for kinematic features (for examples see videos in the supplementary information online).

Subjects

Ten professional ballet dancers from the Royal Ballet, London, 9 professional capoeira dancers and 10 non-expert control subjects participated. These dance styles were selected because of the kinematic comparability of specific male ballet and capoeira moves. All subjects were right-handed males aged 18–28 with normal vision and no past neurological or psychiatric history. The professional dancers were screened to ensure that they had no training in the other dance style. All gave written informed consent and were paid for their participation. The protocol was approved by the Ethics Committee of the Institute of Neurology, London.


a
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
% signal change
Ballet dancers
Capoeira dancers
Controls
Groups


b
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
% signal change
Ballet dancers
Capoeira dancers
Controls
Groups

The multiform motor cortical output: Kinematic, predictive and response coding

Luisa Sartori a,b,*, Sonia Betti a, Eris Chinellato c and Umberto Castiello a,b

Cortex in press

Prima ipotesi

A growing body of neurophysiologic studies have, demonstrated that action observation selectively activates the effector muscles involved in performing that action (for review see Fadiga, Craighero, & Olivier, 2005). The motor potentials (MEPs) evoked by transcranial magnetic stimulation (TMS) during action observation appear, in fact, to be specifically attuned to the muscles involved in the action being observed (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Sartori, Bucchioni, & Castiello, 2012; Strafella & Paus, 2000; Urgesi, Candidi, Fabbro, Romani, & Aglioti, 2006) and to its temporal pattern (Aglioti, Cesari, Romani, & Urgesi, 2008; Borroni & Baldissera, 2008; Borroni, Montagna, Cerri, & Baldissera, 2005; Gangitano, Mottaghy, & Pascual-Leone, 2001; Janssen, Steen- bergen, & Carson, 2015; Kilner, Vargas, Duval, Blakemore, & Sirigu, 2004; Montagna, Cerri, Borroni, & Baldissera, 2005; Urgesi et al., 2010).

Seconda ipotesi

On the other hand, the simulation theory specifically argues that observing another person's action is not simply a reconstruction of visual input, but an intrinsically predictive activity (Gallese & Goldman, 1998). When we observe another person's actions, we automatically anticipate their future ones. At the most basic level, humans can predict how a movement will evolve simply by watching how it was begun. For example, by observing how a person throws a dart at a dartboard, an observer can predict where the dart will land (Knoblich & Flach, 2001). An observer can likewise anticipate the type of tennis or volleyball serve that is about to be made (Abernethy, Zawi, & Jackson, 2008), predict the success of a basketball shot (Aglioti et al., 2008), foresee if a player is about to launch a real or a mimic throw (Sebanz & Shiffrar, 2009), and forecast if an action heralds a competitive or cooperative interaction (Sartori, Becchio, & Castiello, 2011). When

Overall, these findings suggest that different coding levels develop during action observation. The kinematic coding, which operates at a simple motor level; the predictive coding, which anticipates the incoming actions; and the response coding, which allows an observer to prepare a response that is compatible with task demands. Crucially, an integrated view of these three levels has never been proposed, since a single effector can only be activated in one or the other modality in a given moment. The present experiment was specifically designed to disentangle the relationship between these levels and their relative contribution by measuring corticospinal excitability in multiple effectors at different timings. We adopted a paradigm involving the observation of a soccer player performing: (i) a penalty kick straight in the onlooker's direction and then coming to a full stop (Fig. 1a); (ii) a penalty kick straight in the onlooker's direction and then continuing to run (Fig. 1b); and (iii) a penalty kick to the side and then continuing to run (Fig. 1c). Single-pulse TMS was used to assess CS excitability of participants' arm and leg muscles as they watched the videos.

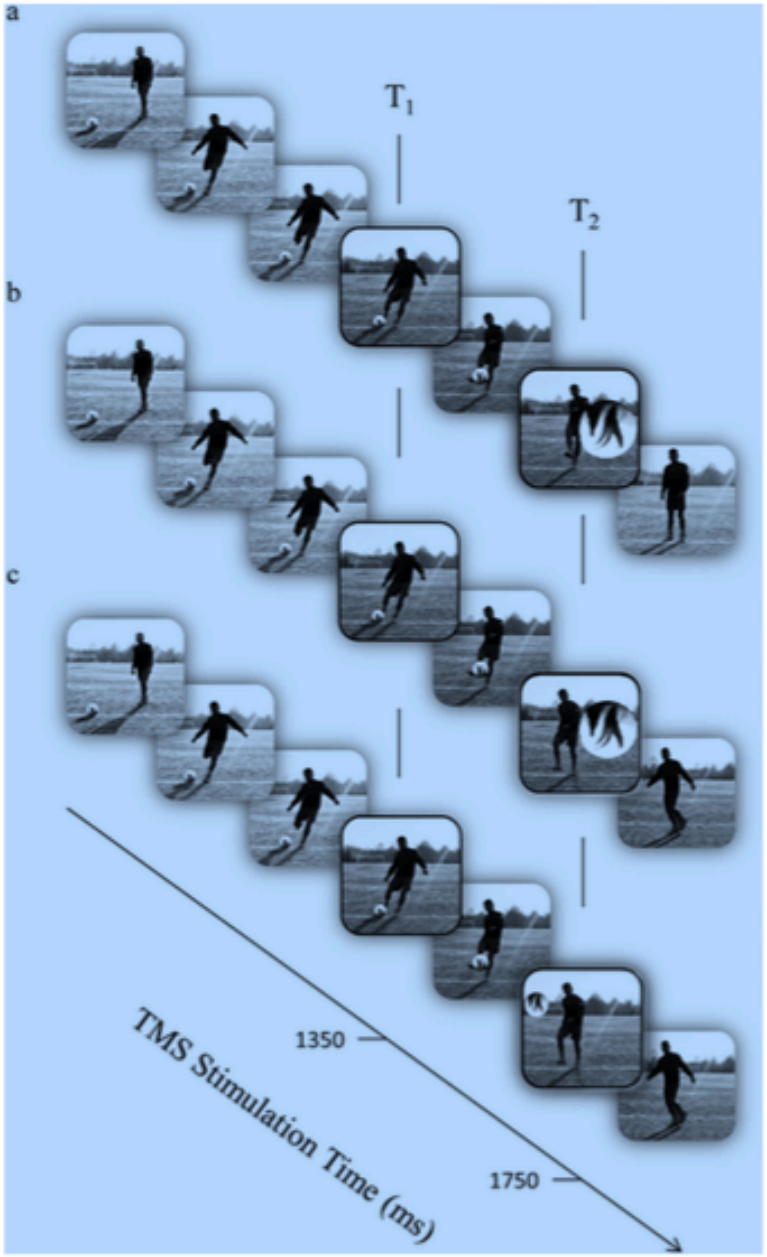


Fig. 1 – Sequence of events taking place for each condition: (a) Still, (b) Run, (c) Side. The vertical lines denote the time points when single TMS pulses were delivered: at T1 (when the player's foot makes contact with the ball) and at T_2

Se la codifica motoria riflette esattamente quello che si vede

Allora si dovrebbe vedere attivi gli arti inferiori in tutte e tre le condizioni

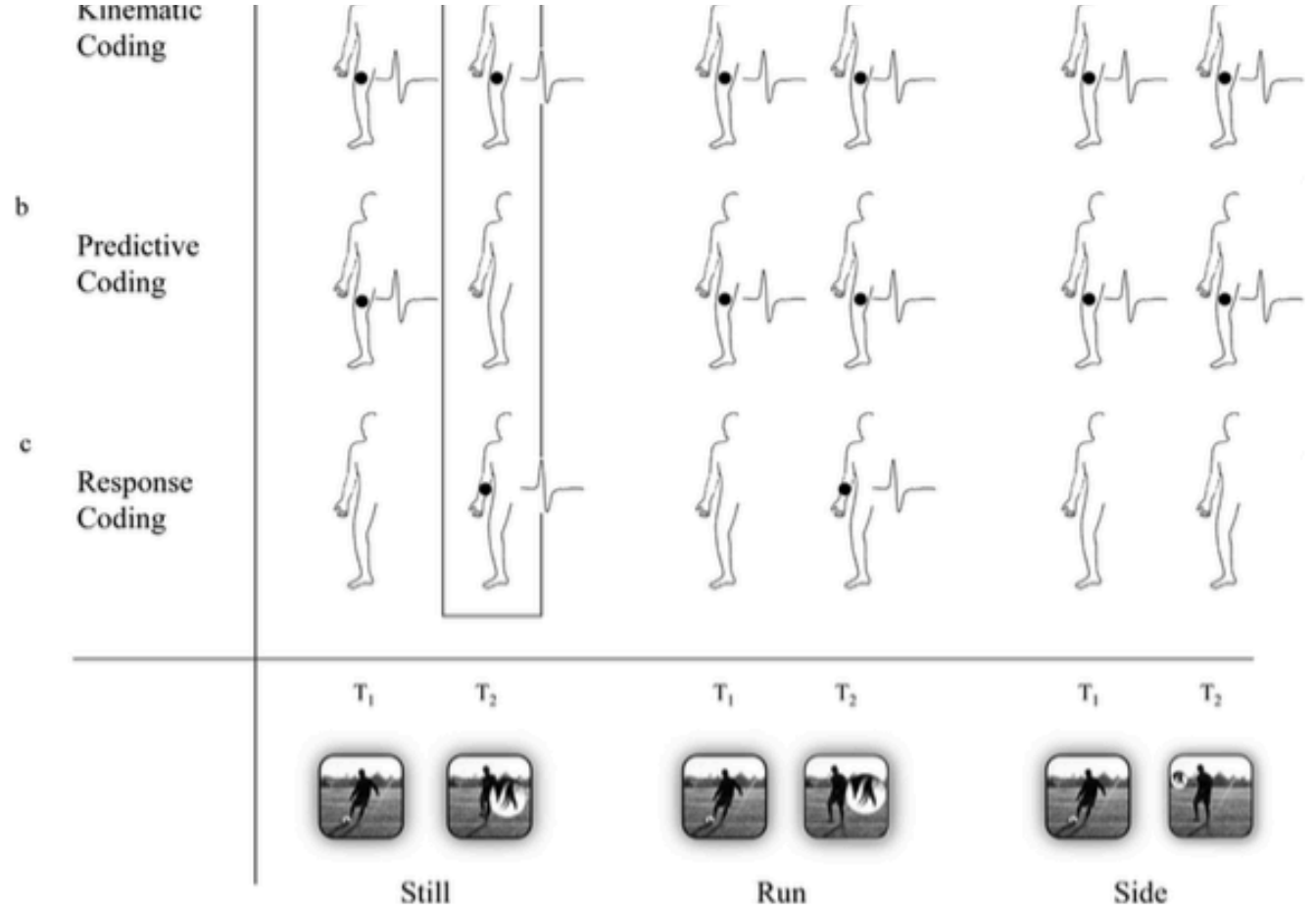
Se invece c’è un meccanismo predittivo

- Allora gli arti inferiori non dovrebbero essere attivi nella condizione in cui il giocatore si ferma

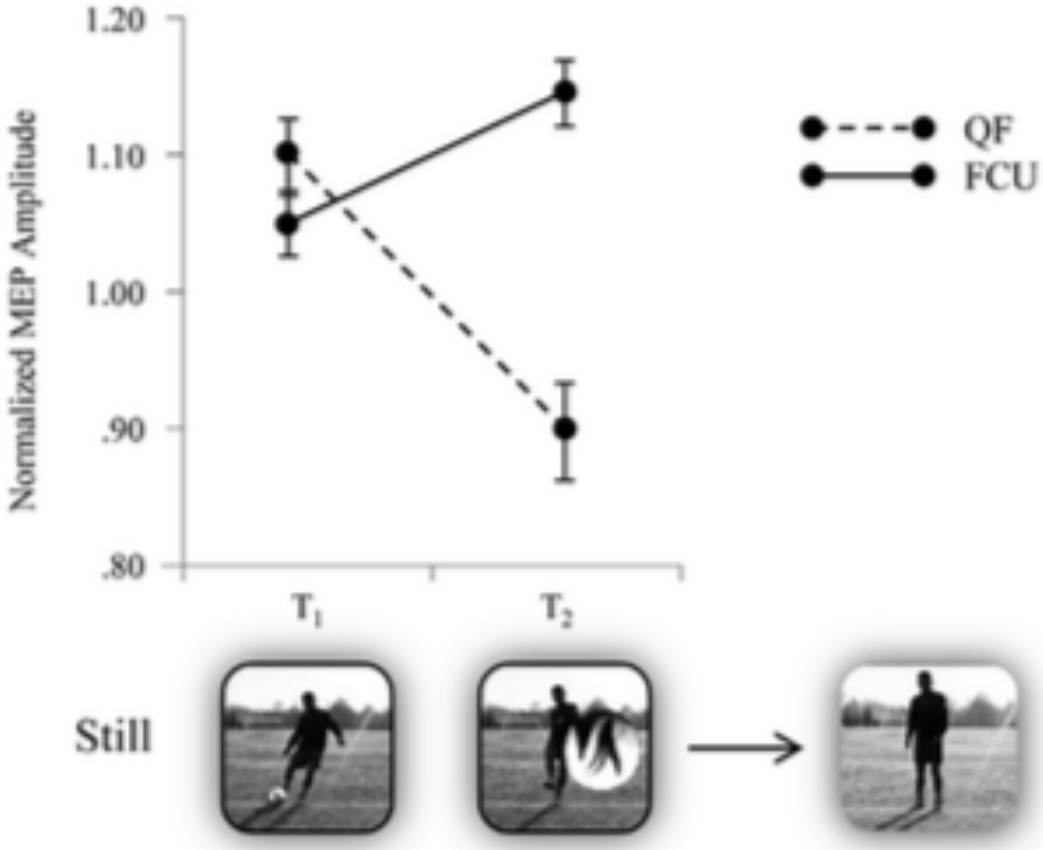
Se invece motor coding riflette la risposta al gesto motorio con un effettore specifico

- Allora l'attivazione dovrebbe essere sugli arti superiori ma solo nella fase finale del gesto di approccio della palla

ipotesi

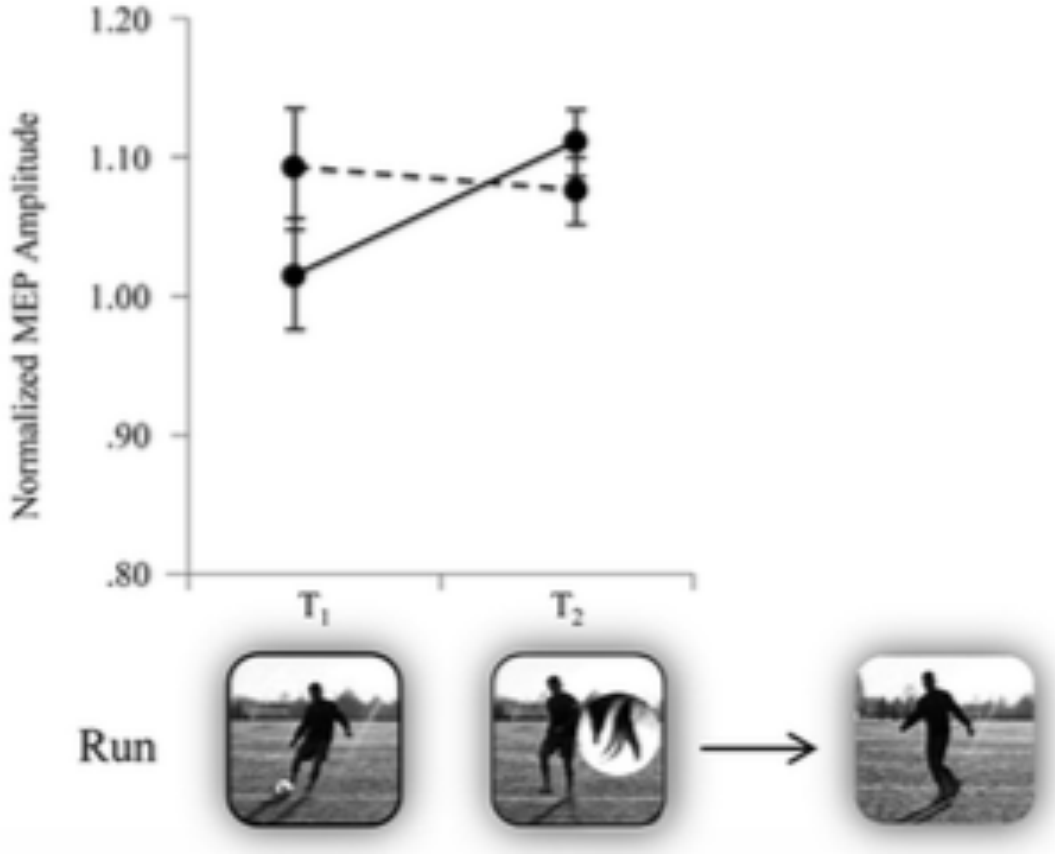

Kinematic Coding
b
Predictive Coding
c
Response Coding
T1
T2
T1
T2
T1
T2
Still
Run
Side

a



b

b



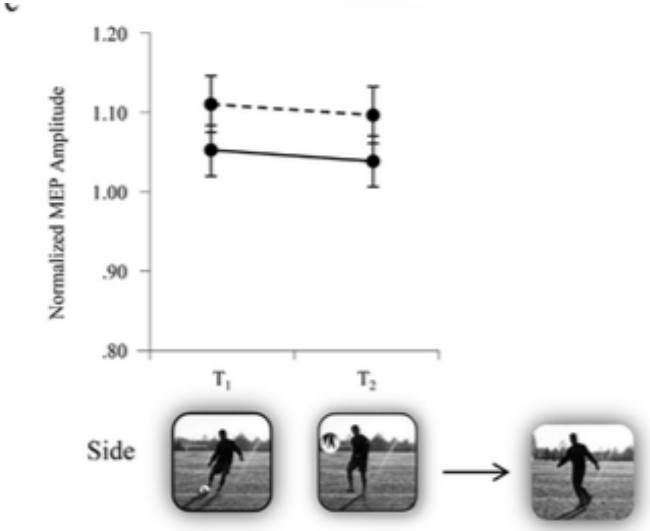


Fig. 3 – Corticospinal activations during observation of a soccer player: (a) kicking the ball straight and then coming to a full stop (Still), (b) kicking the ball straight and then continuing to run (Run), (c) kicking the ball to the side and then continuing to run (Side). Note that the following contrasts were significant: the normalized mean MEP amplitudes in the lower limb muscle (QF) were lower at T2 compared to T1 in the 'Still' condition ($p < .05$) and were higher at T2 both in the 'Run' ($p < .001$) and the 'Side' conditions ($p < .05$) compared to the 'Still' condition. The normalized mean MEP amplitudes recorded from the flexor