UNDERSTANDING THE SENSORIMOTOR BASIS OF HUMAN COMMUNICATION

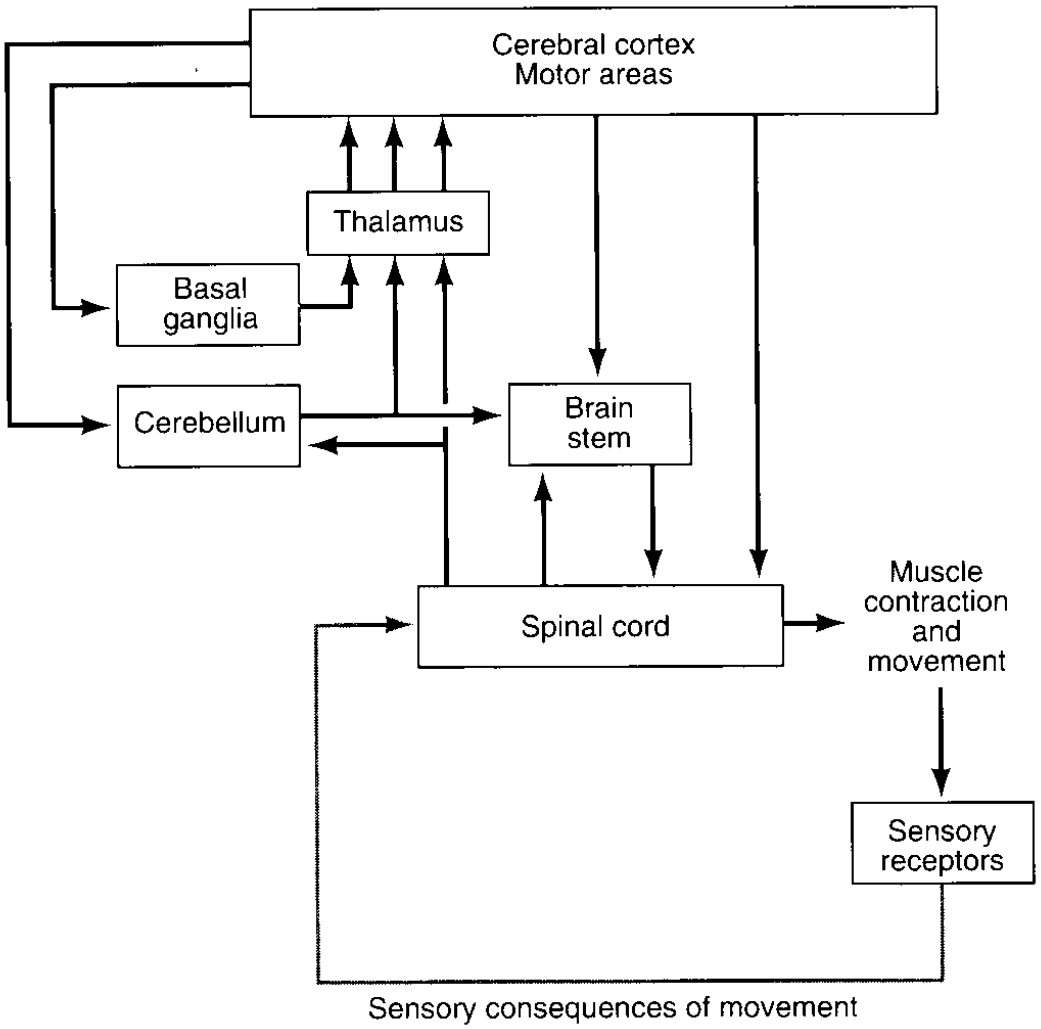
ALESSANDRO D'AUSILIO

HRI14 – BIELEFELD

3 MARCH 2014

iit istituto italiano di tecnologia

MOTOR HIERARCHY



SIMPLE MOVEMENTS AND ACTION GOALS

- **Simple movements constitute only a small part of human motor repertoire**
- ***Human behavior is constituted by goal-directed actions based on the synergic composition of simpler motor constituents***


Mountain Gun


Guido Poggi 2002

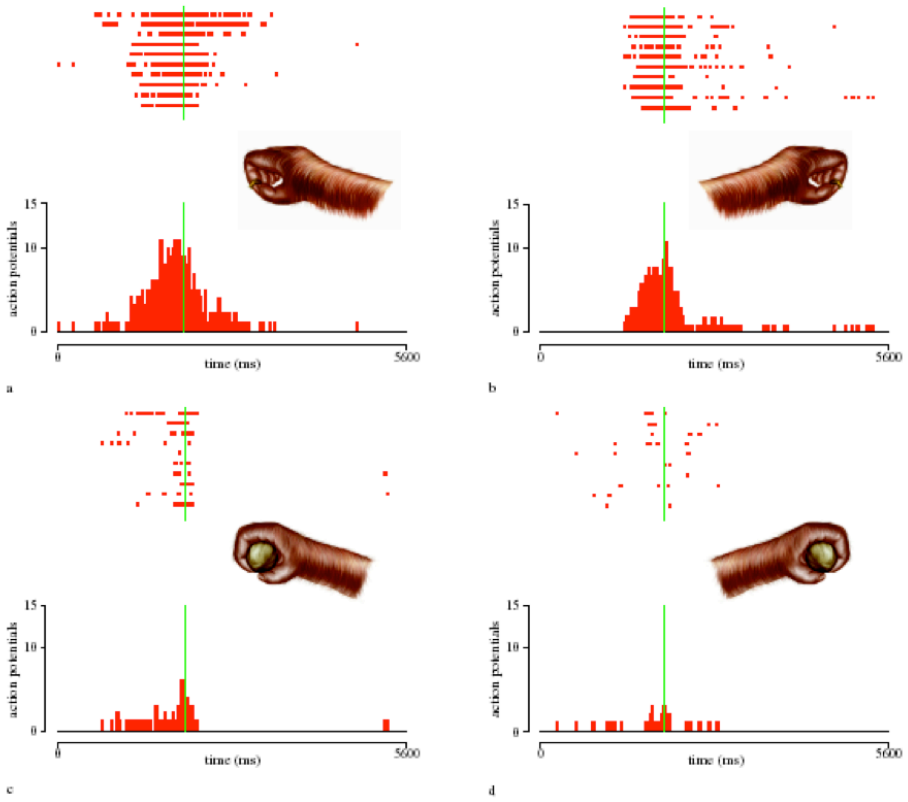
ACTION HIERARCHY

- **Bernstein (1967) integrated evolutionary biology and musculoskeletal biomechanics to explain goal-driven motor behavior**
  - Introduced the centrality of action goals
  - Actions are composed of simple motor constituents that can be chained together
  - Separate motor elements are chunked into a single unit

PREMOTOR CORTEX

- Neurons discharge during the execution of a specific goal-directed action
- They do not discharge during similar movements made with other purposes
- Active during movements that have an identical goal regardless of the effectors used

PREMOTOR CORTEX



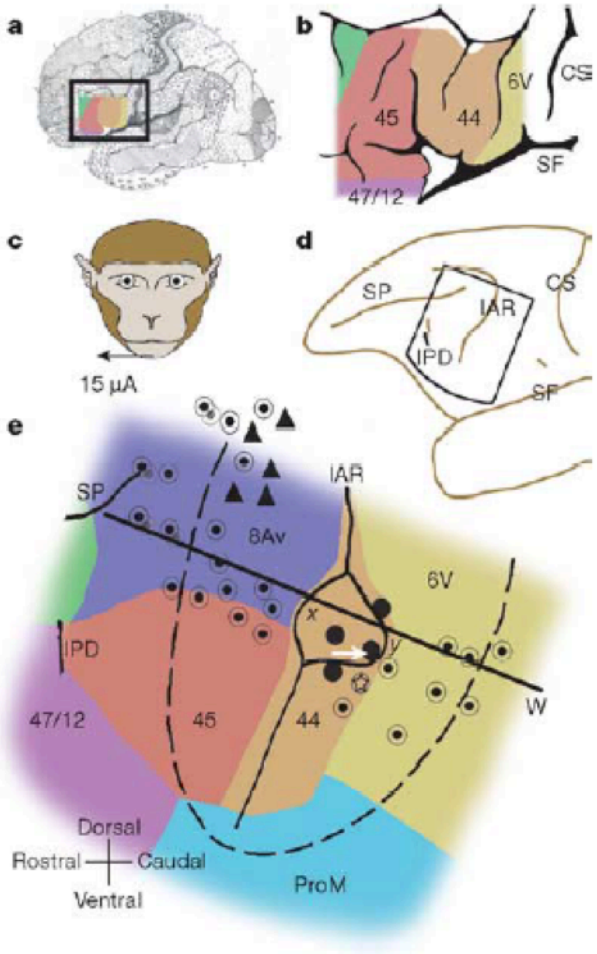
VISUOMOTOR NEURONS IN MONKEY AREA F5

- Several F5 neurons also show complex visual responses
- **CANONICAL and MIRROR neurons**
- Canonical neurons discharge when the monkey observes graspable objects or executes grasping actions upon those objects (Murata et al., 1997)
- Mirror neurons discharge both when the monkey executes and observes another individual making the same action in front of it (Gallese et al., 1996)

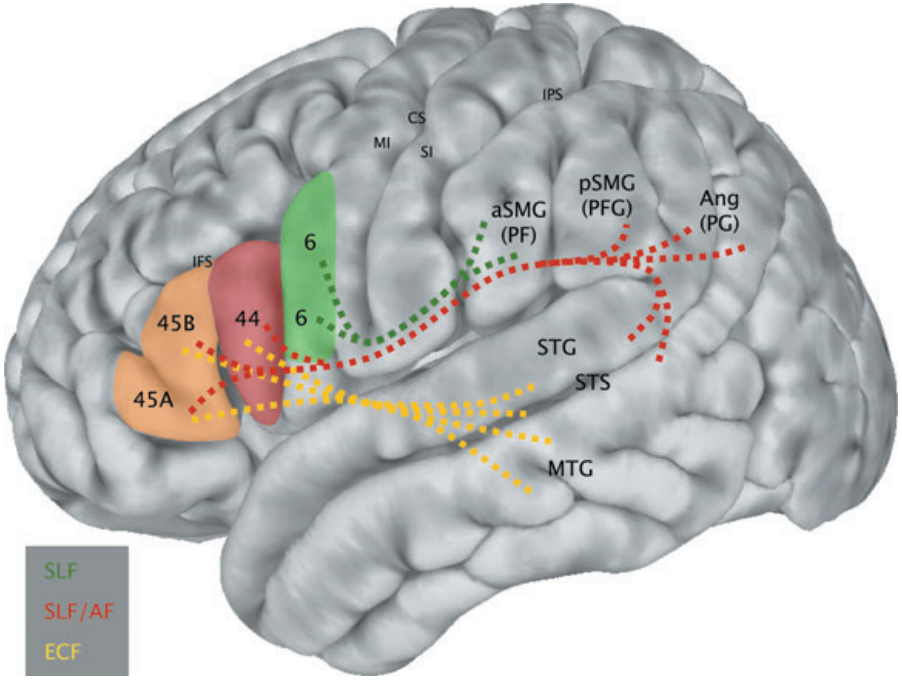
HUMAN HOMOLOGOUS

Area F5 is characterized by no granular layer IV, similarly to human ventral premotor cortex and partially to BA44 (posterior part of Broca's area)

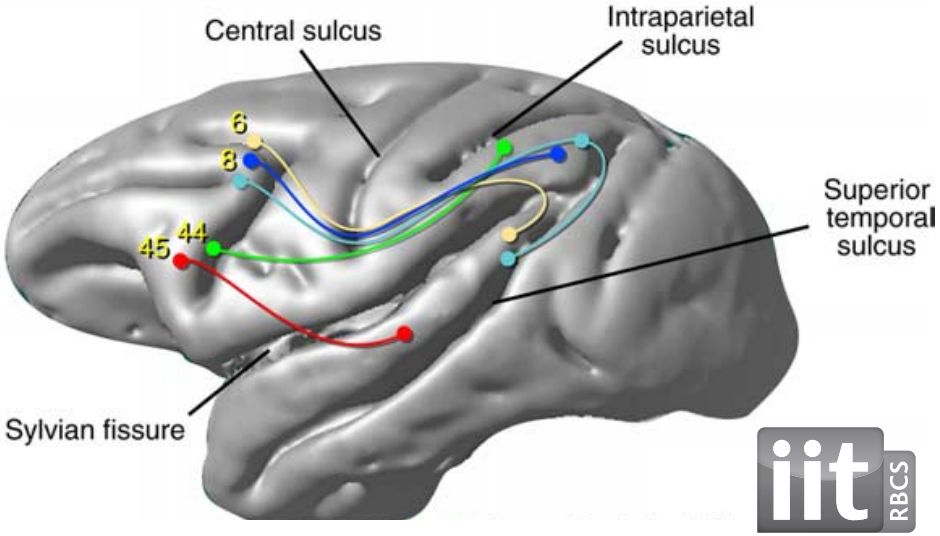
(Petrides et al., *Nature*, 2005)



COMPARATIVE HODOLOGY



Kelly et al., *Eur J Neurosci*, 2010



Frey et al., *J Neurosci*, 2008

SENSORIMOTOR HIERARCHY

- **The action hierarchy serves:**
  - The generation of own behavior
  - The understanding of others' behavior
  - The response to others' behavior
  - **…sensorimotor communication!**

NEURAL BASES OF SENSORIMOTOR INTERACTION AND COMMUNICATION

Speech

- Vocal tract gesture

Non verbal

- Body movement

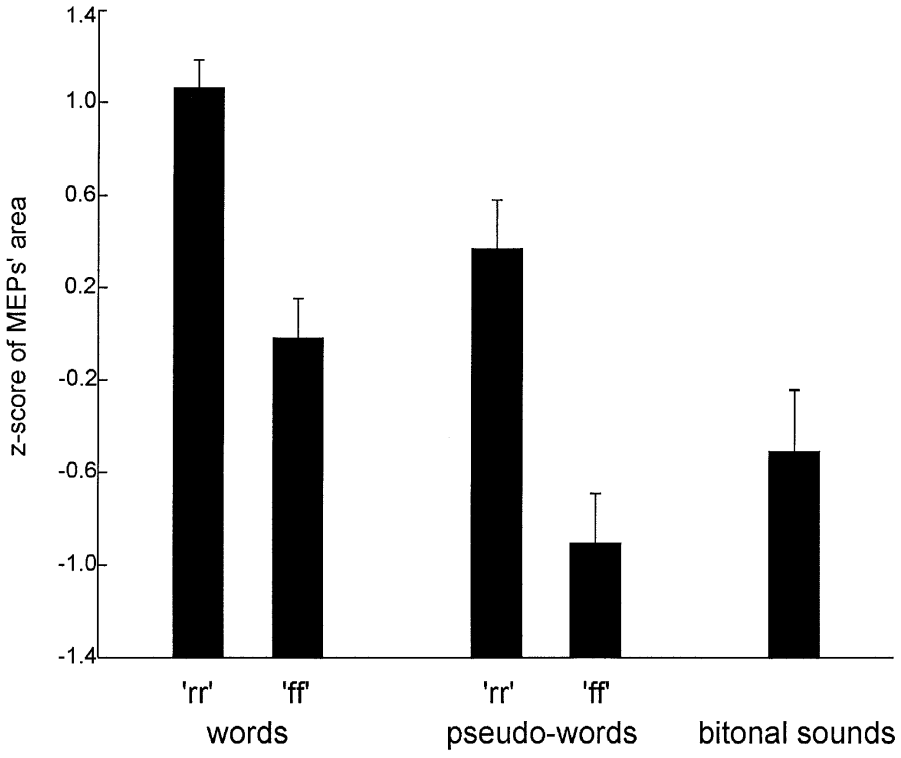
SPEECH / VOCAL GESTURES

Motor contribution to speech perception

- Mirror Neurons, canonical neurons and Motor Theories in the 90's
- Fadiga et al., 2002
- Curr Biol 2009; Hum Brain Mapp 2010; Brain & Lang 2010, 2011; Neuropsychologia 2011; Cortex 2012; Cereb Cortex 2013; Phil Trans R Soc:B In Press; …

IS THE MOTOR CORTEX ACTIVE DURING SPEECH PERCEPTION?

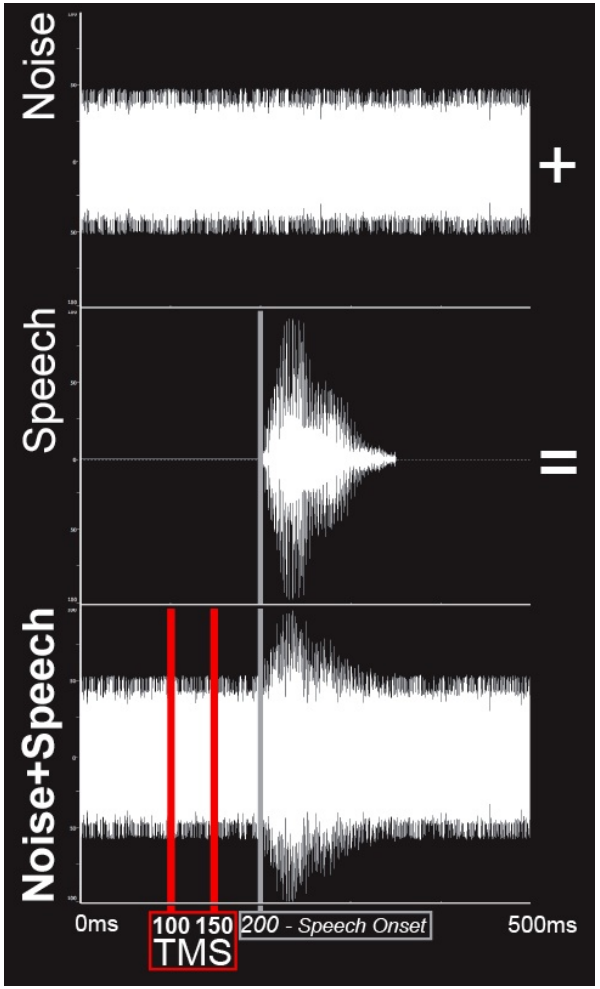
Fadiga et al., *Eur J Neurosci* 2002

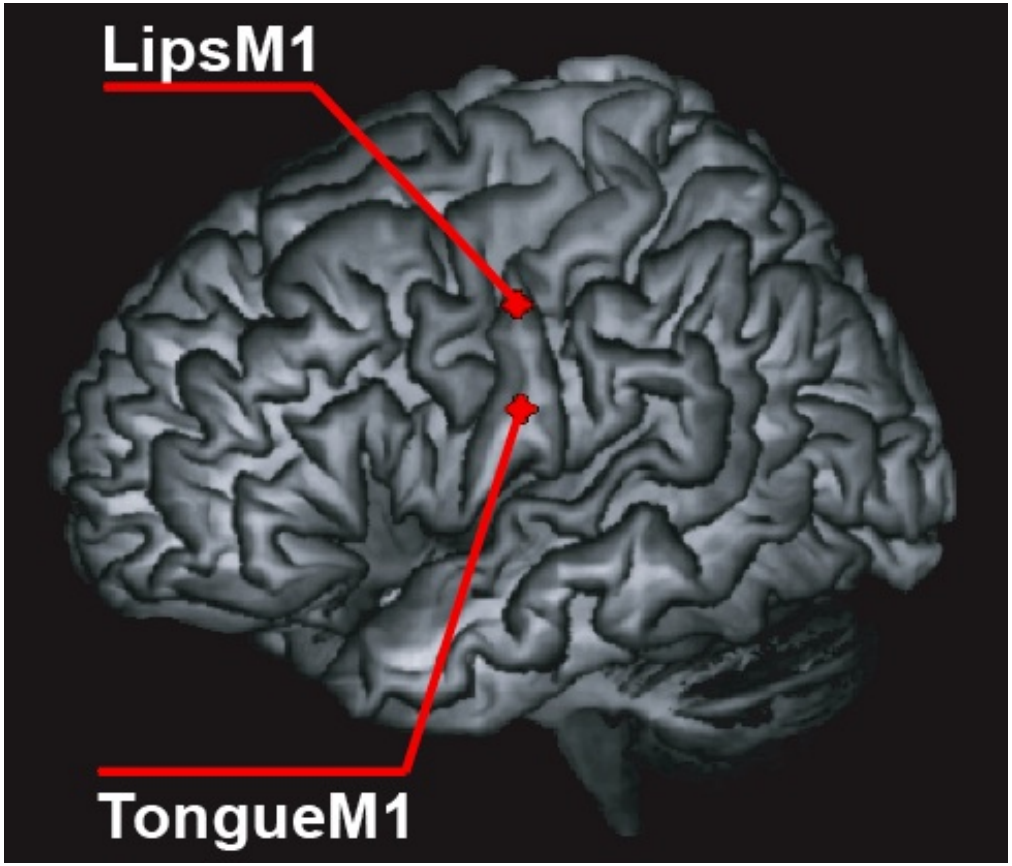


CAUSAL OR CORRELATIONAL?

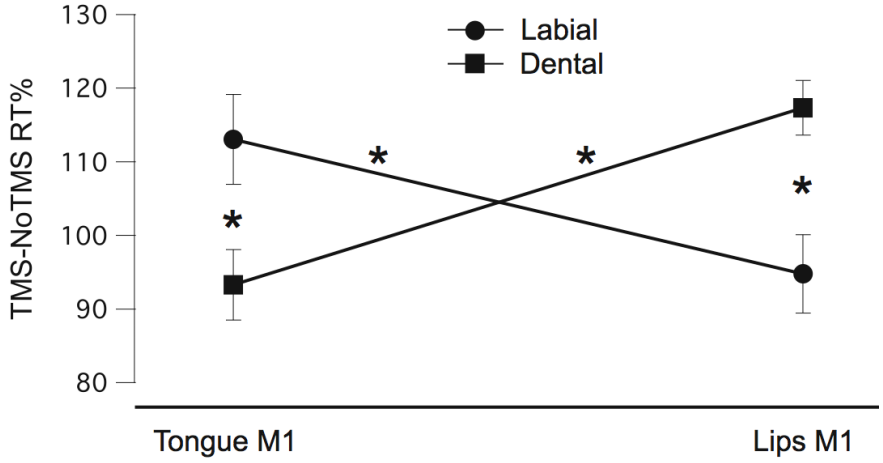
Previous neuroimaging data offer only a correlation between comprehension and motor areas (Toni et al., 2008)

TONGUE & LIP STIMULATION

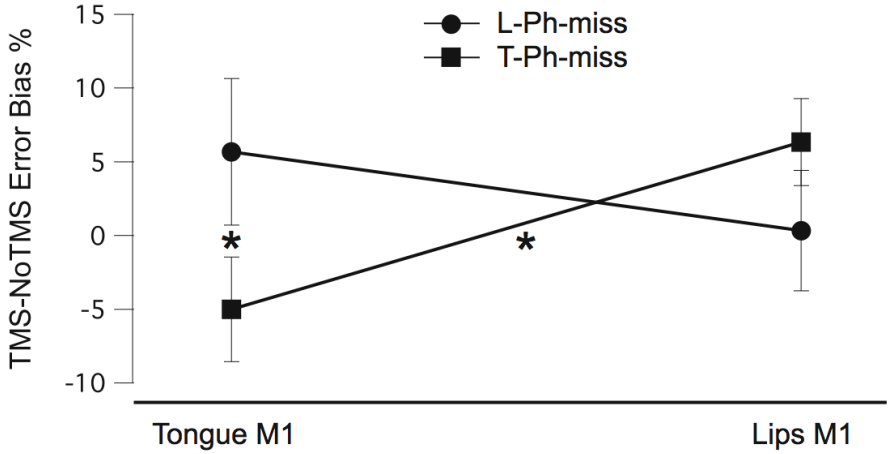




RESULTS



RT: Double dissociation



ACC: partial dissociation congruent with RT data

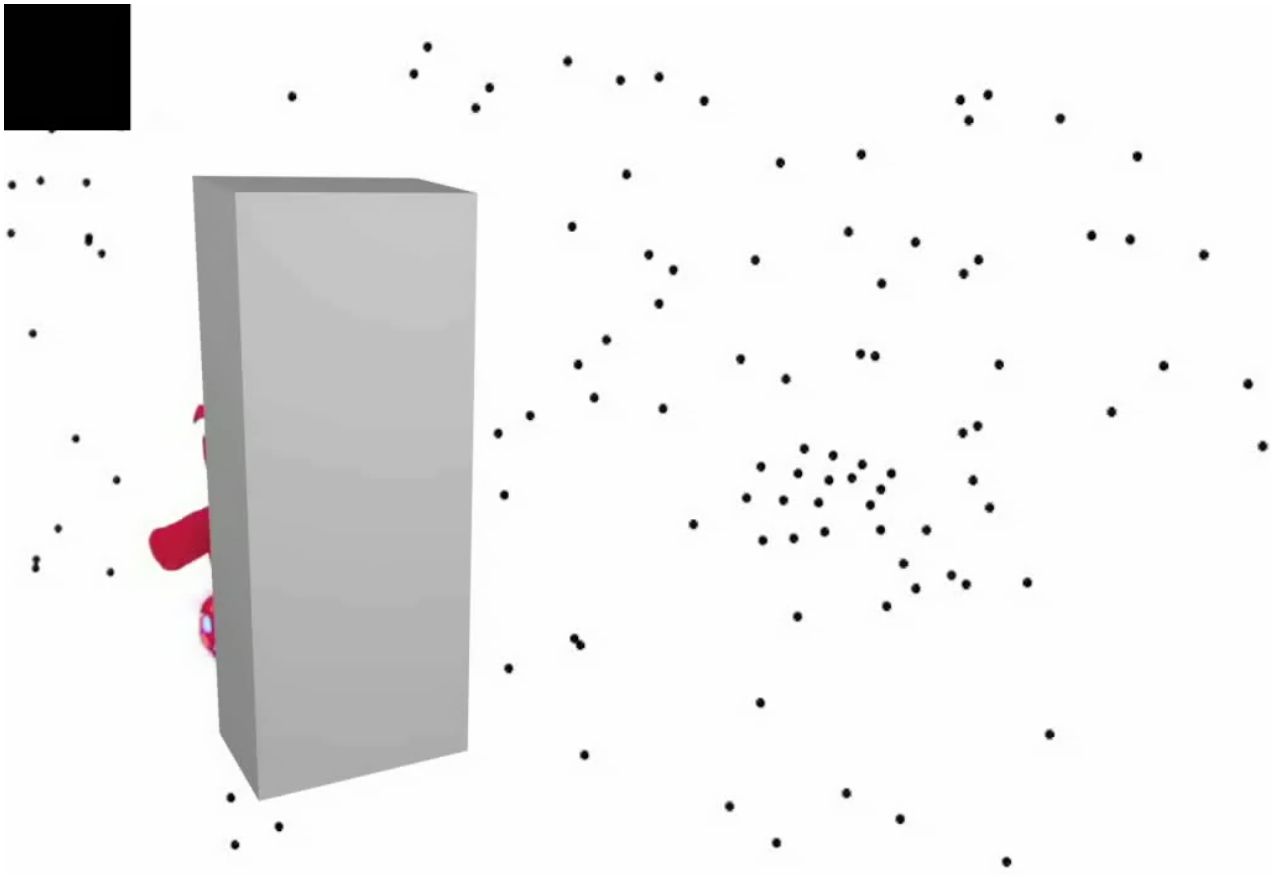
D'Ausilio et al., *Curr Biol*, 2009

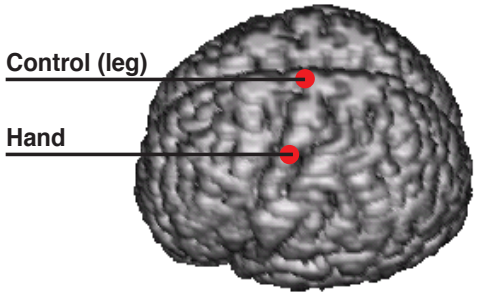
NON VERBAL / BODY MOTION

Motor contribution to body motion perception

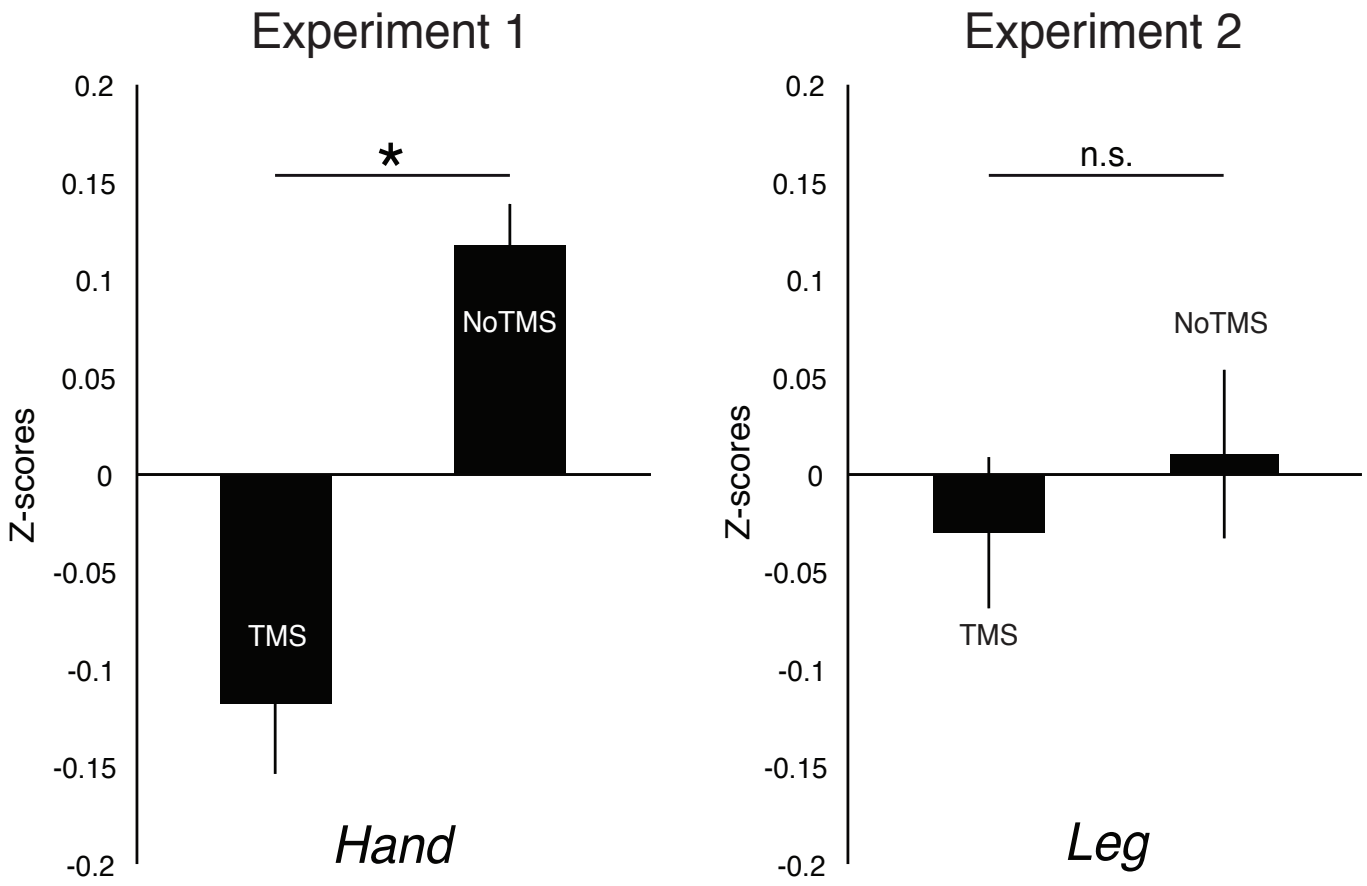
- Mirror Neurons, canonical neurons and Motor Theories in the 90's
- Fadiga et al., 1995
- Brain 2009; Exp Brain Res 2010, 2011; Behav Brain Res 2011; Plos ONE 2012; Neuropsychologia 2013, In Press; …

GAZE ANTICIPATION



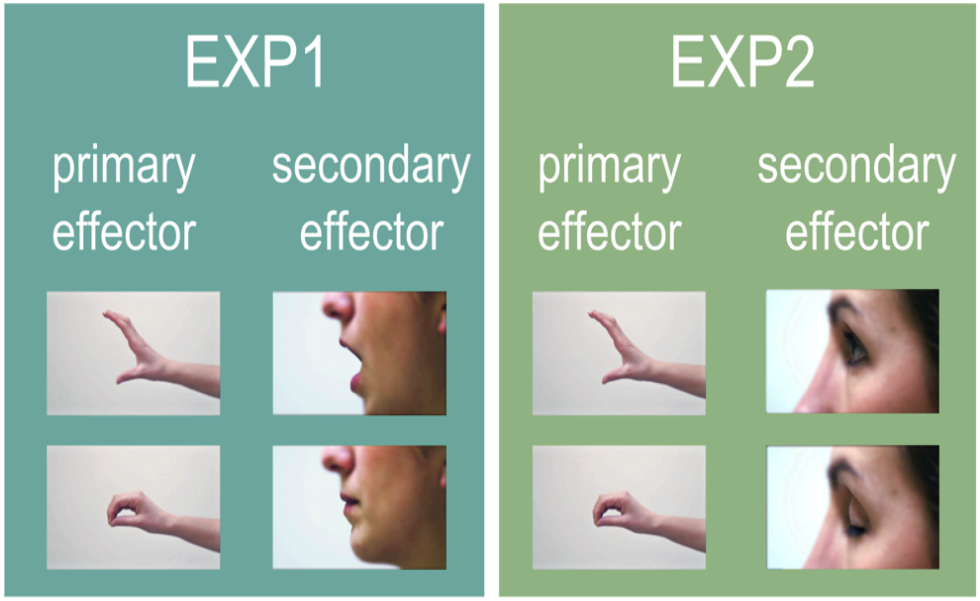


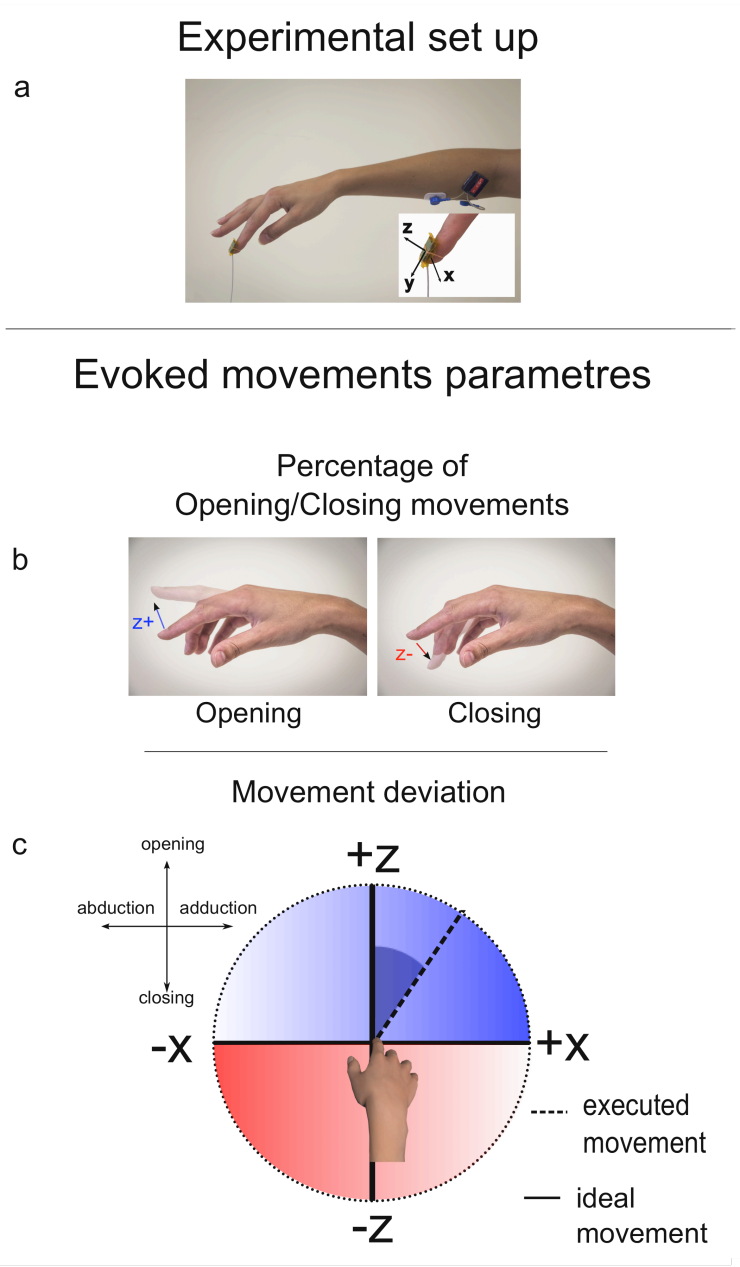
RESULTS



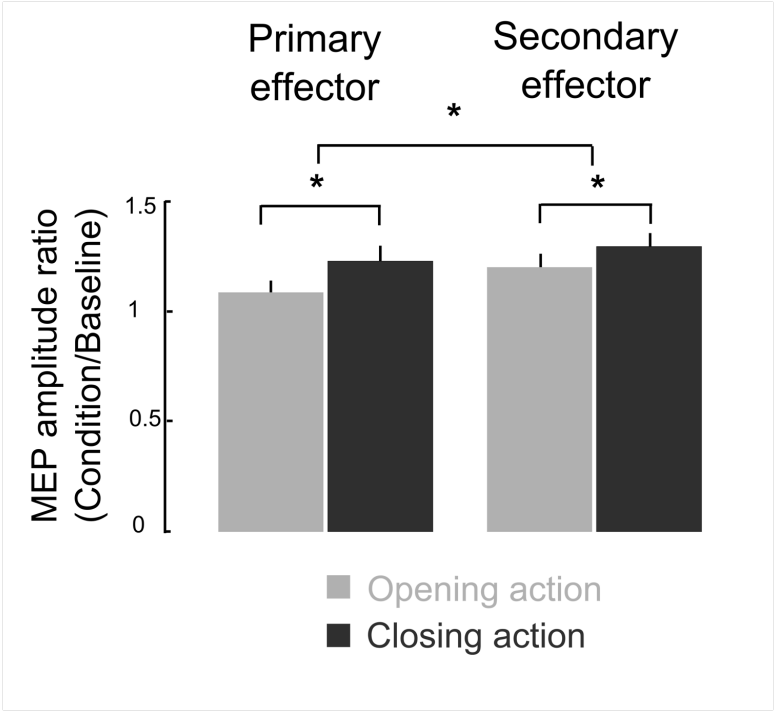
Elsner et al., Neuropsychologia, 2013

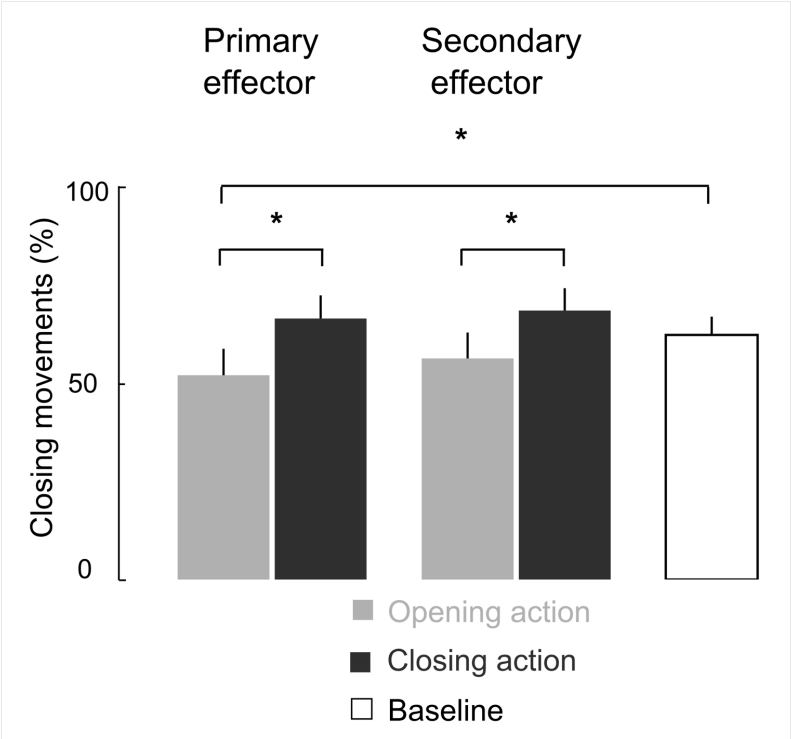
GOAL GENERALIZATION





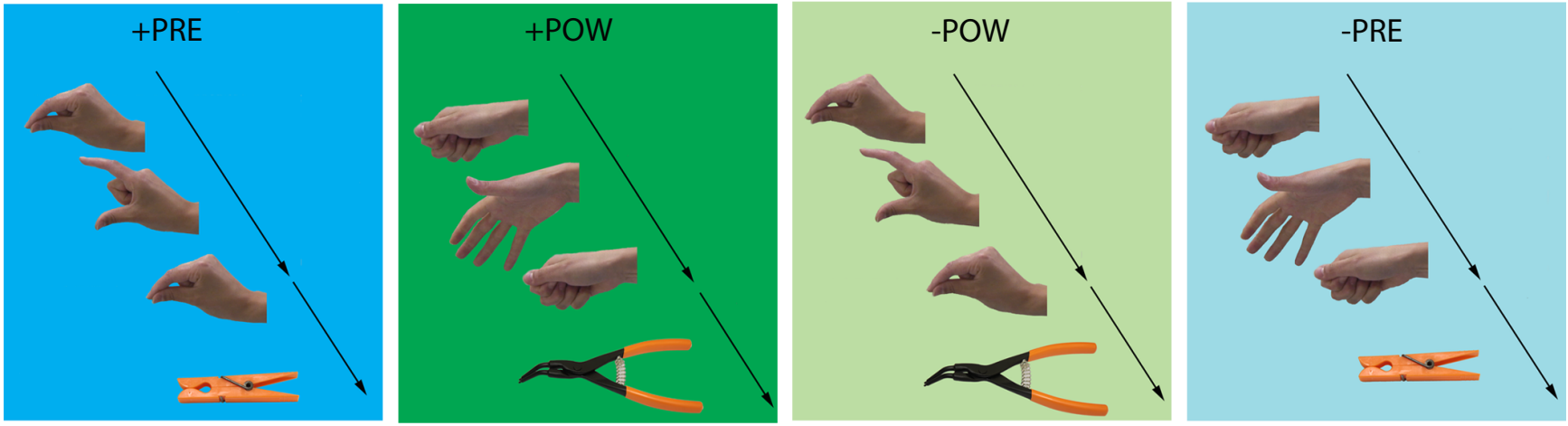
RESULTS



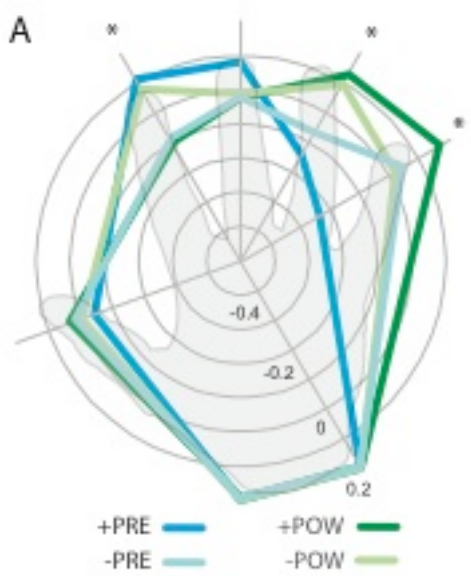


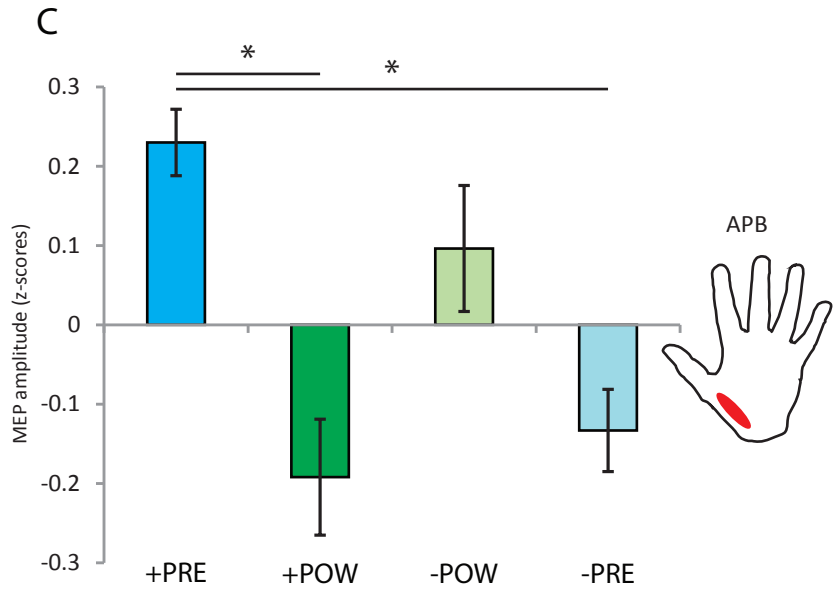
Finisguerra et al., In Preparation

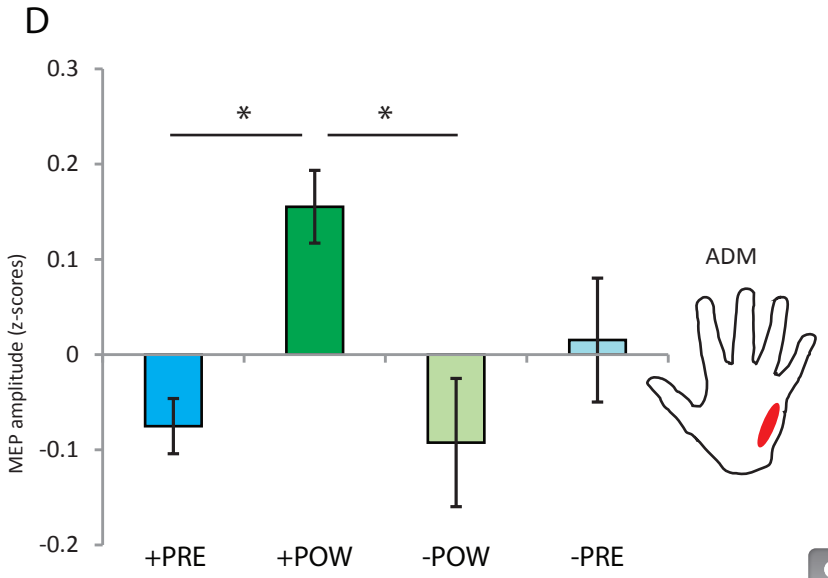
CANONICAL – MIRROR INTERACTION



RESULTS

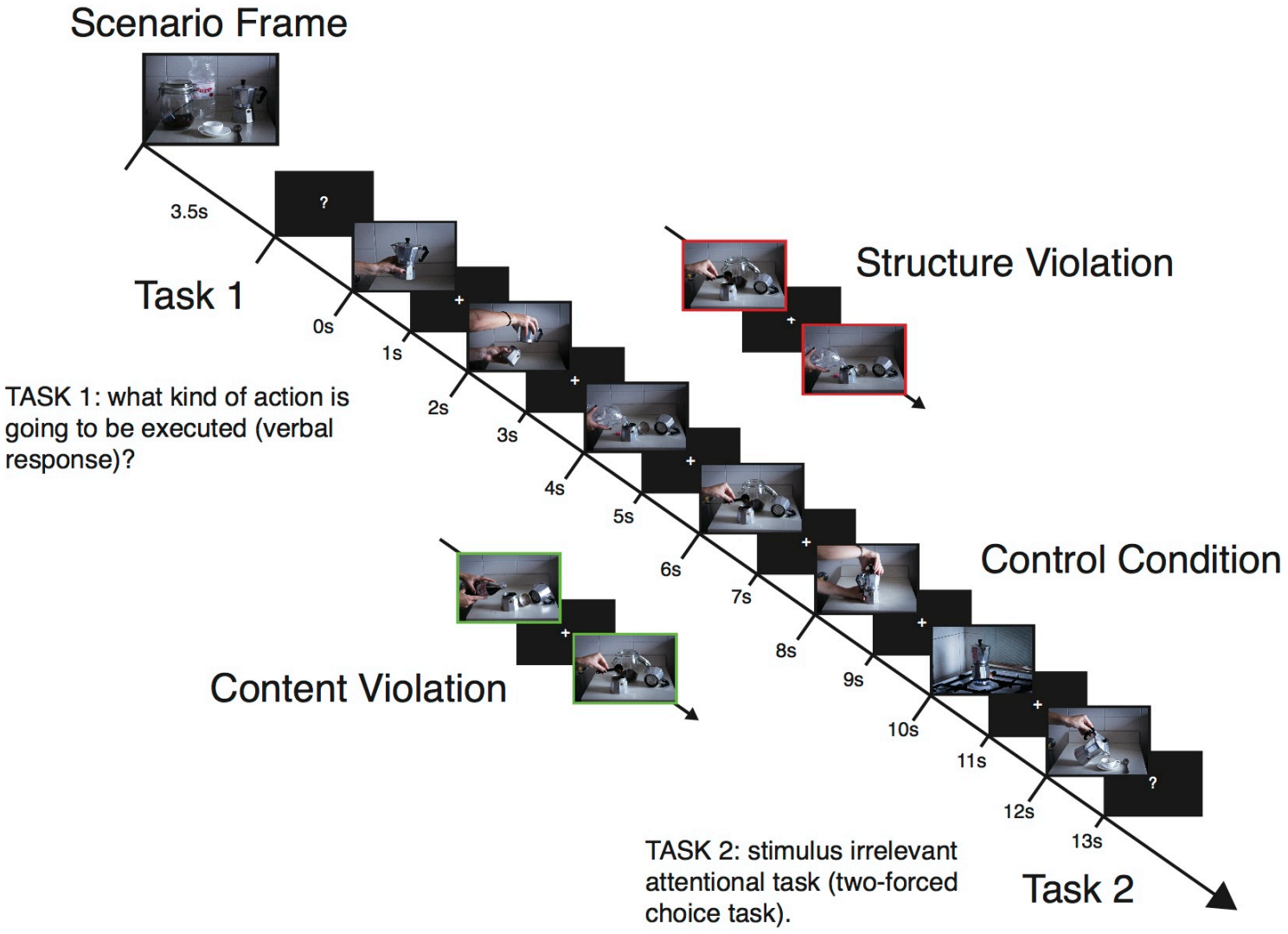




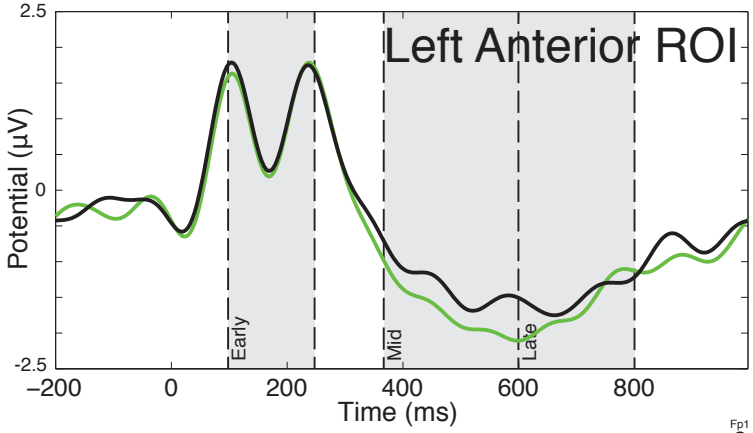


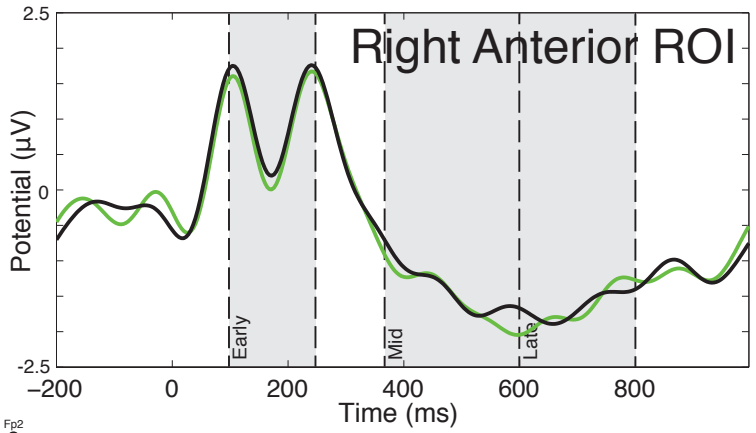
Bartoli et al., Submitted

ACTION SEMANTICS AND SYNTAX



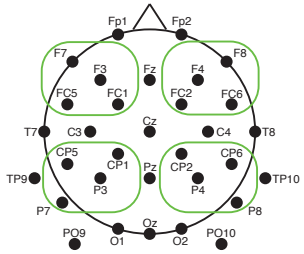
RESULTS





Content Violation

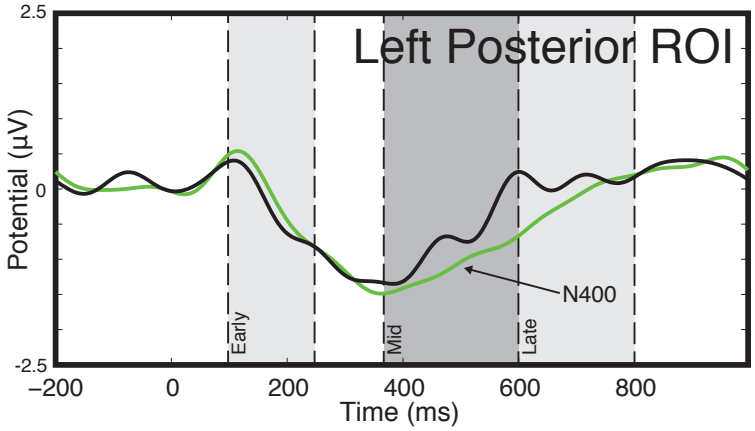
Control

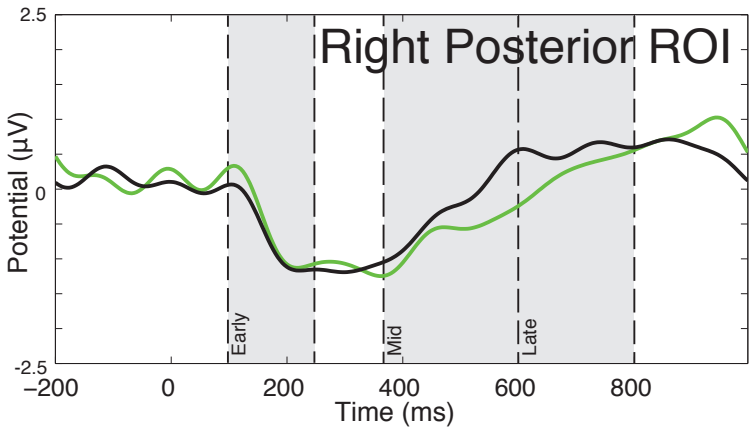


Early: 100-250ms
Mid: 380-600ms
Late: 600-800ms

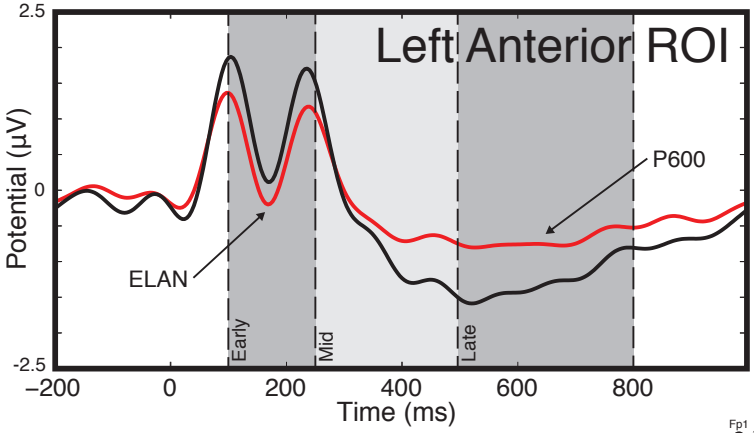
Significant Time Window

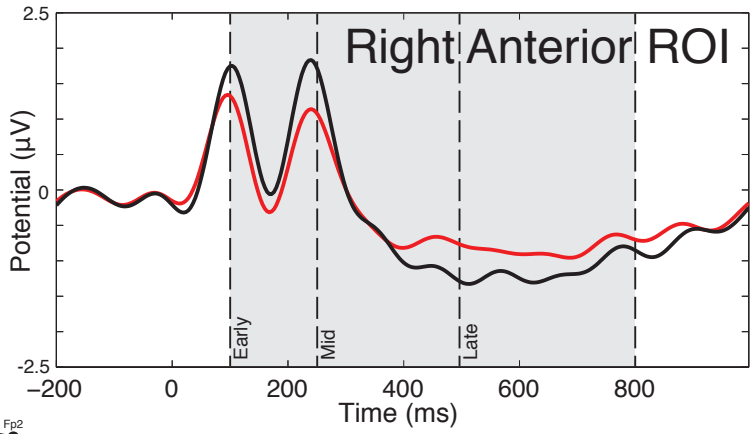
Non-Significant Time Window





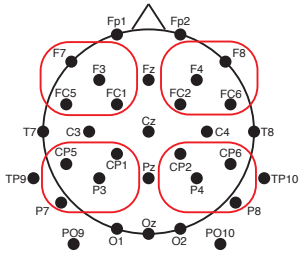
RESULTS





Structure Violation

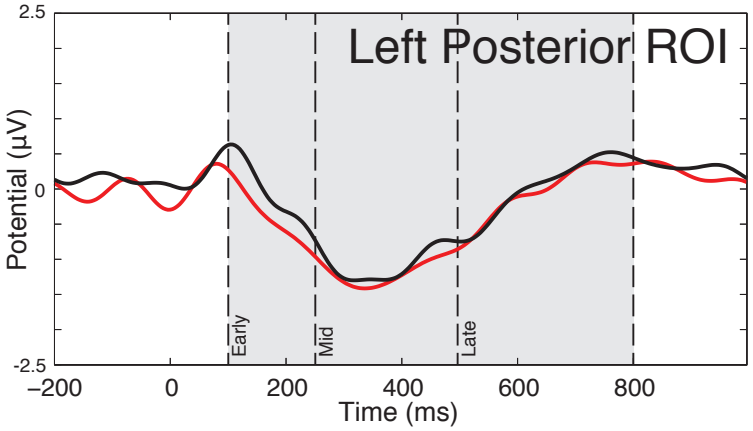
Control

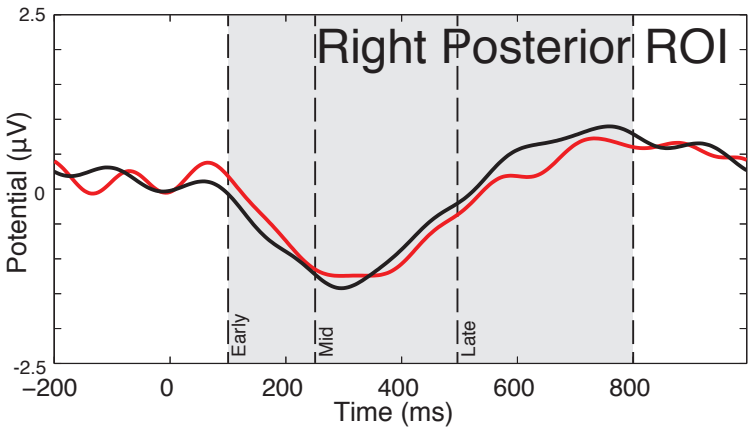


Early: 100-250ms
Mid: 250-500ms
Late: 500-800ms

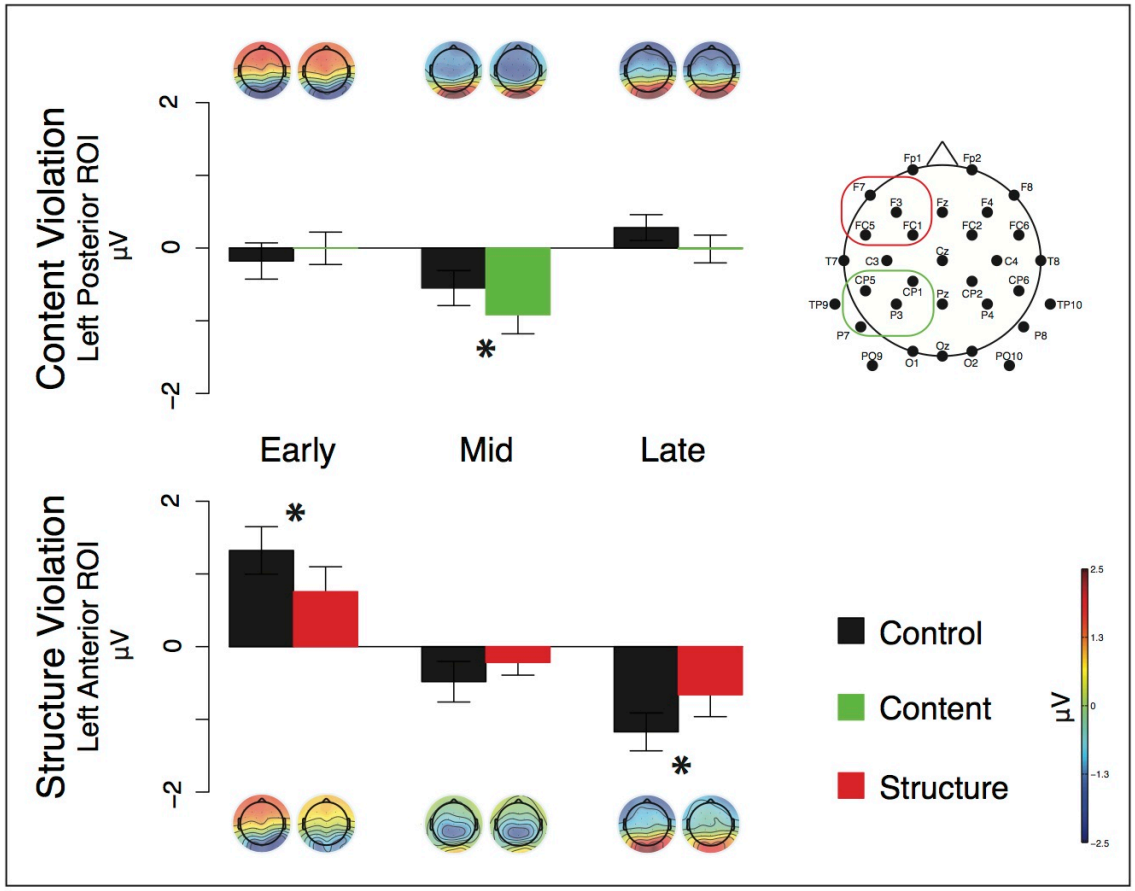
Significant Time Window

Non-Significant Time Window



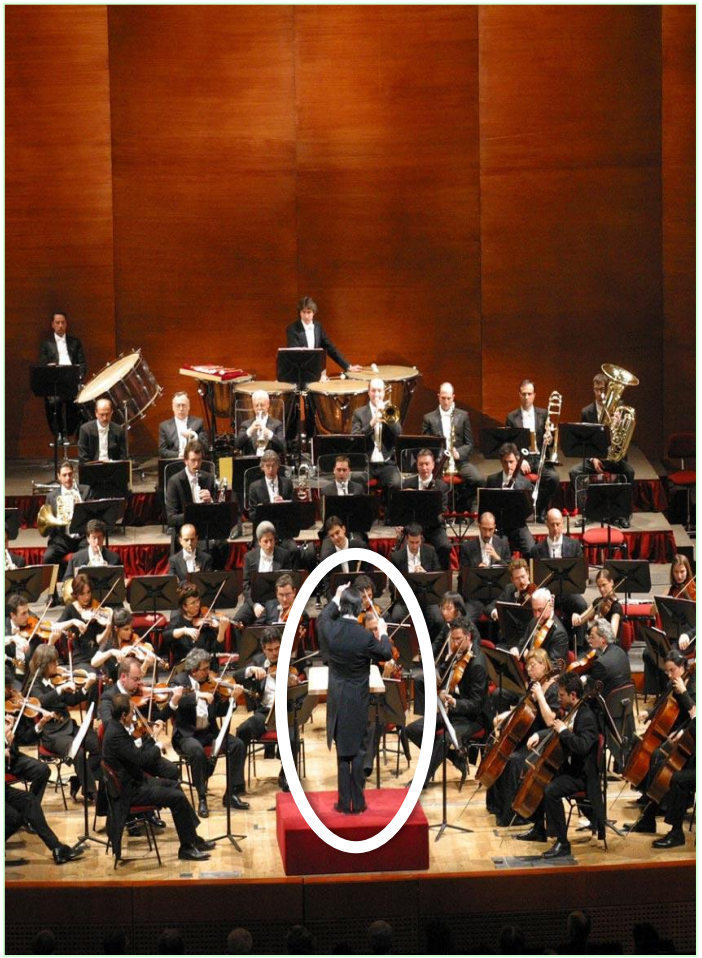


RESULTS



Maffongelli et al., In preparation

SENSORIMOTOR COMMUNICATION IN LARGE GROUPS



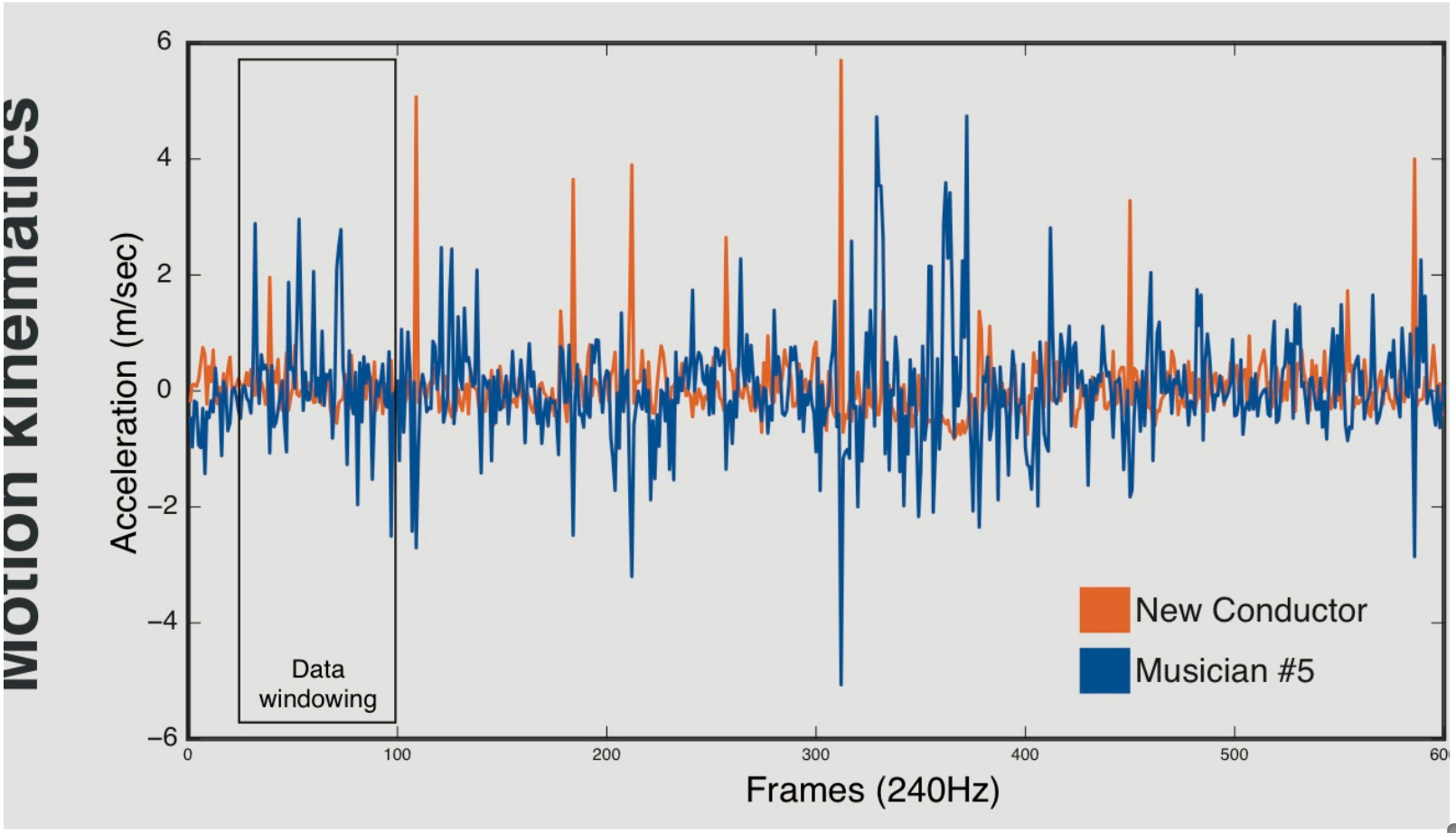
Model of inter-personal communication

Model of social leadership

ORCHESTRA SCENARIO

QUARTET SCENARIO

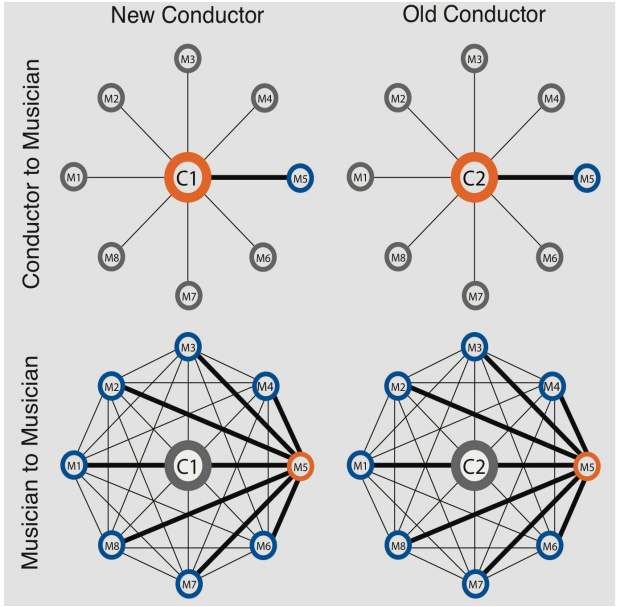
DATA


Motion Kinematics
Acceleration (m/sec)
6
4
2
0
−2
−4
−6
0
100
200
300
400
500
Frames (240Hz)
Data windowing
New Conductor
Musician #5

GRANGER'S CAUSALITY

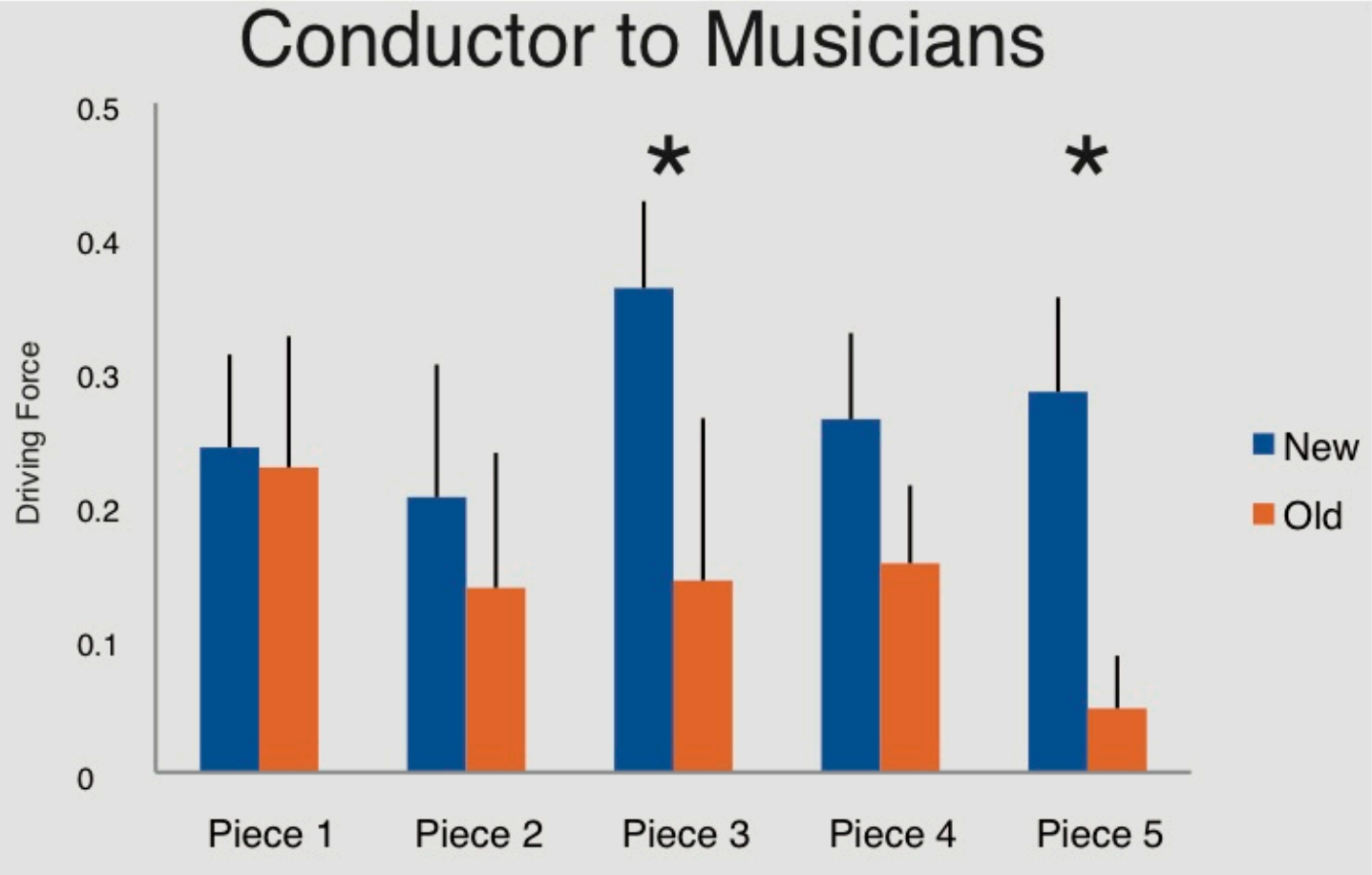
Method to estimate causality between two signals

- Given two time series x and y, x "G-causes" y if the past values of x contain information that helps predict y above and beyond the information contained in the past values of y

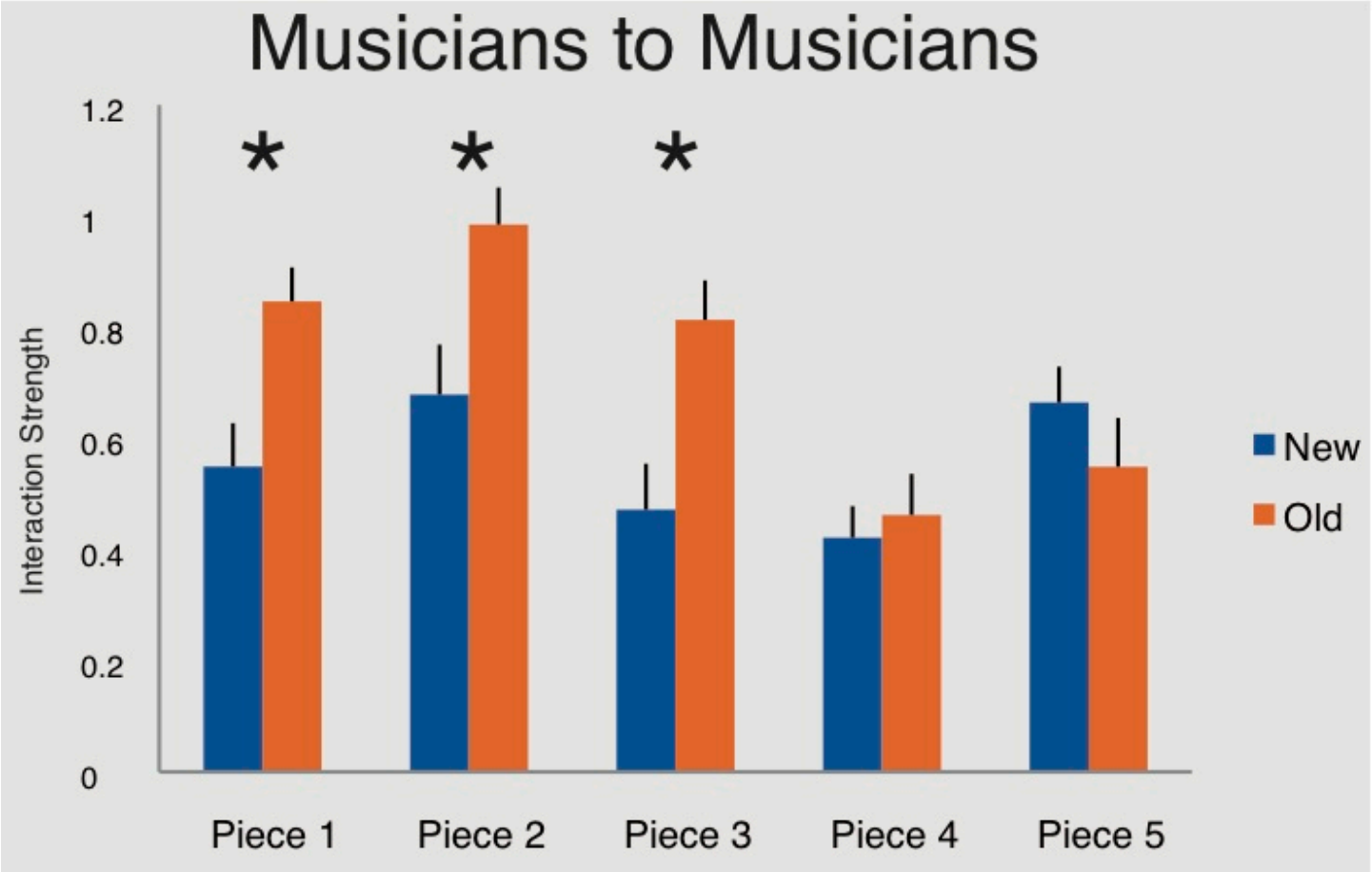


D'Ausilio et al., PlosONE, 2012;
Badino et al., Neuropsychologia, 2013

RESULTS *CONDUCTOR TO MUSICIANS*



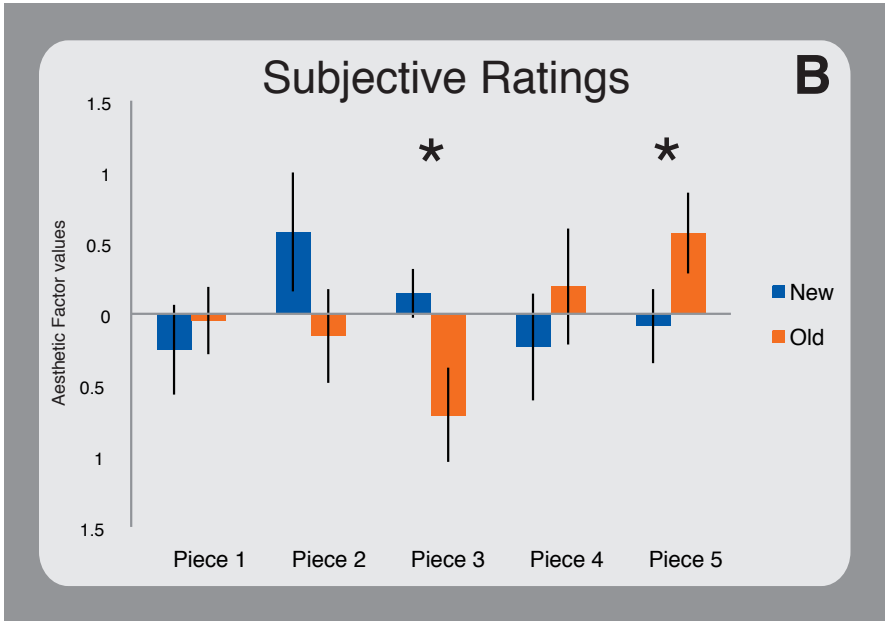
RESULTS *MUSICIANS TO MUSICIANS*



RESULTS *AESTHETIC JUDGMENTS*

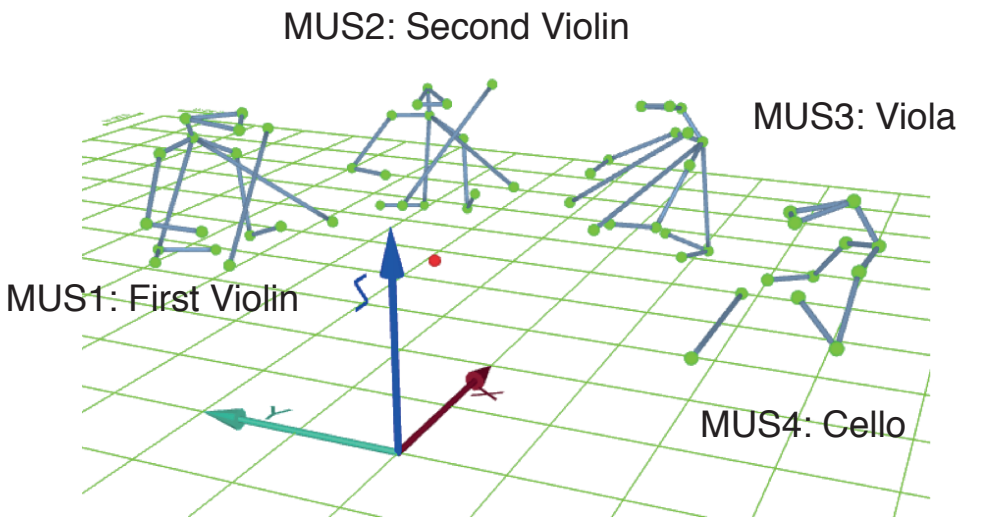
Expert musicians (10) rated the audio tracks on:

- Their ability to follow the melody
- Their ability to follow the rhythm
- The degree of musical entrainment
- The emotional involvement



QUARTET SCENARIO

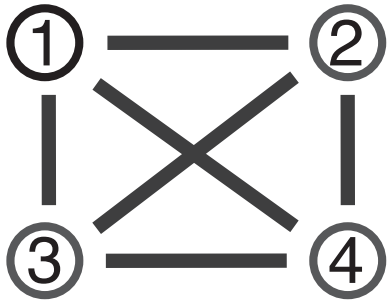
A



B

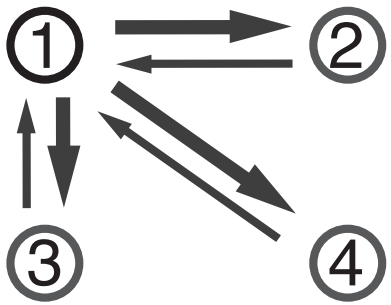
IMC

Inter-musicians communication

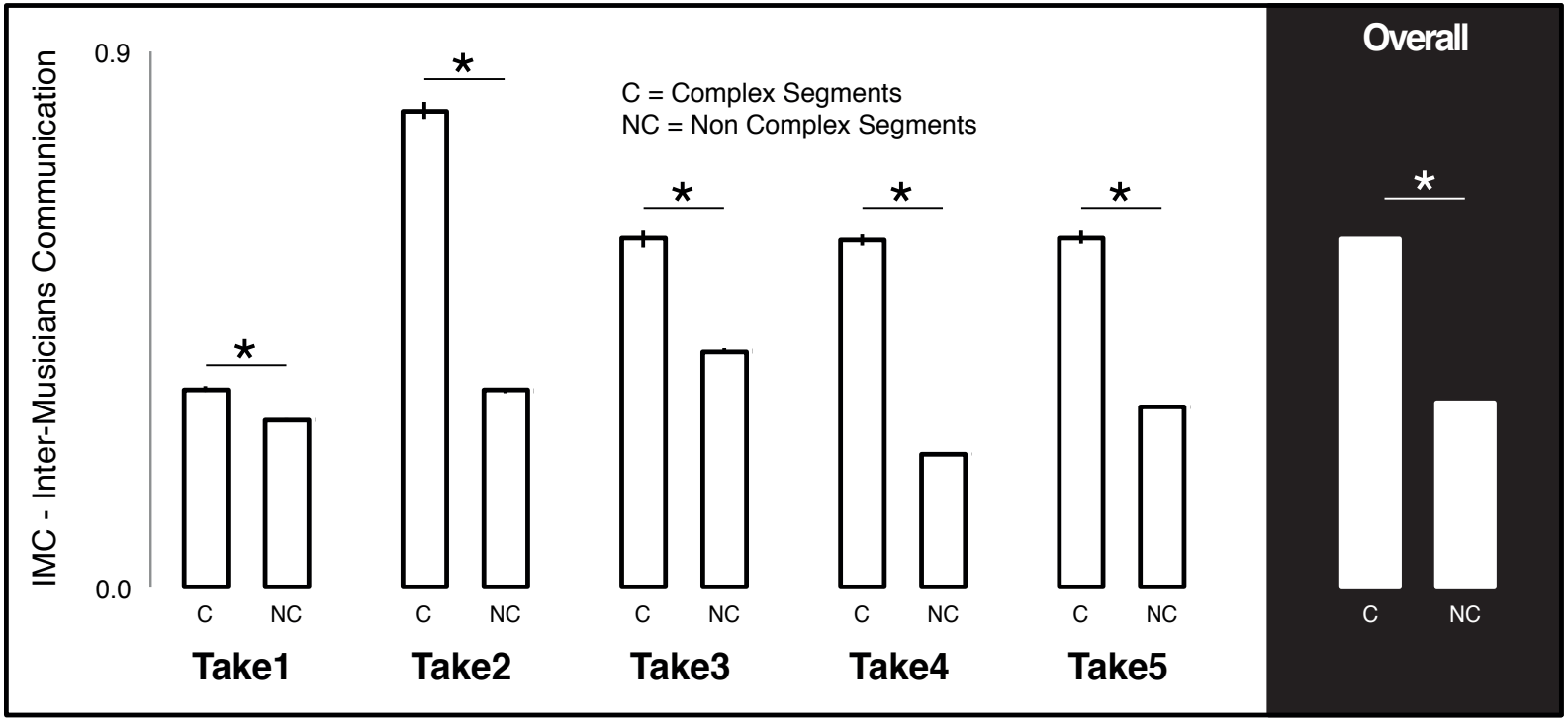


MDF

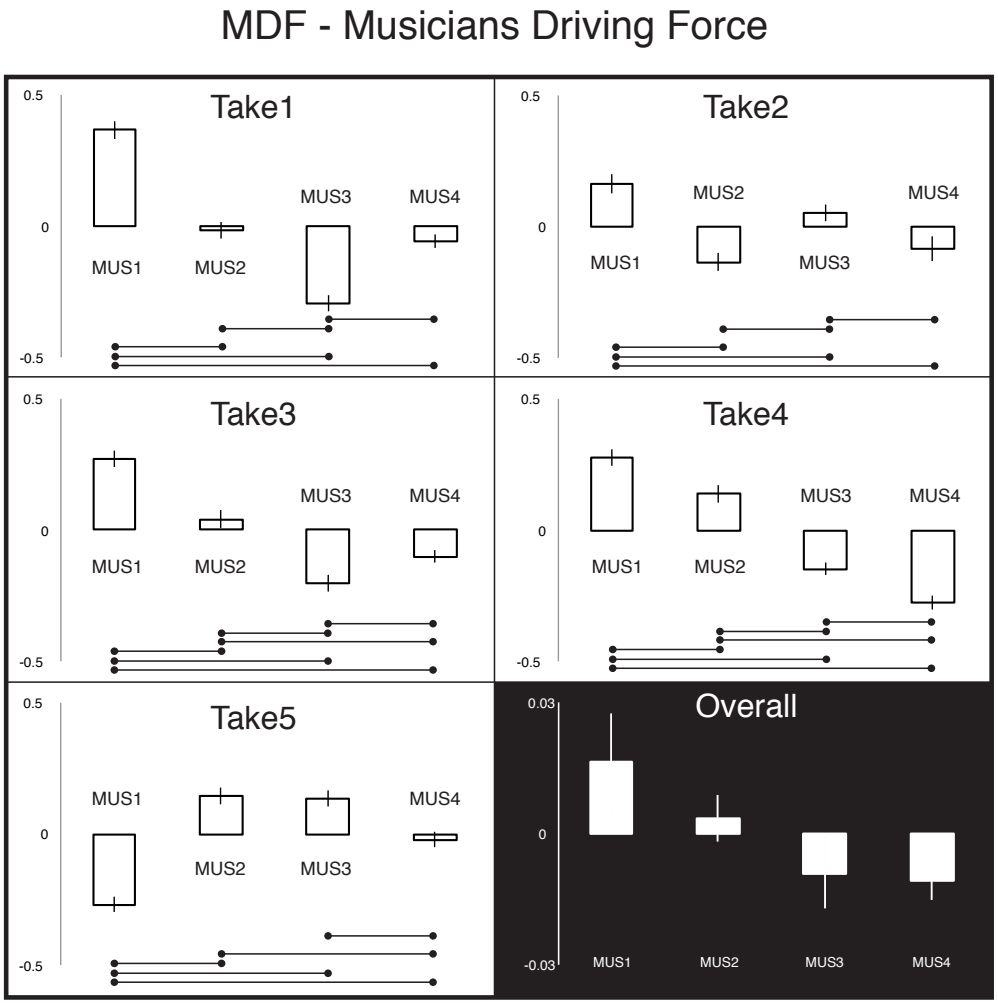
Musician Driving force



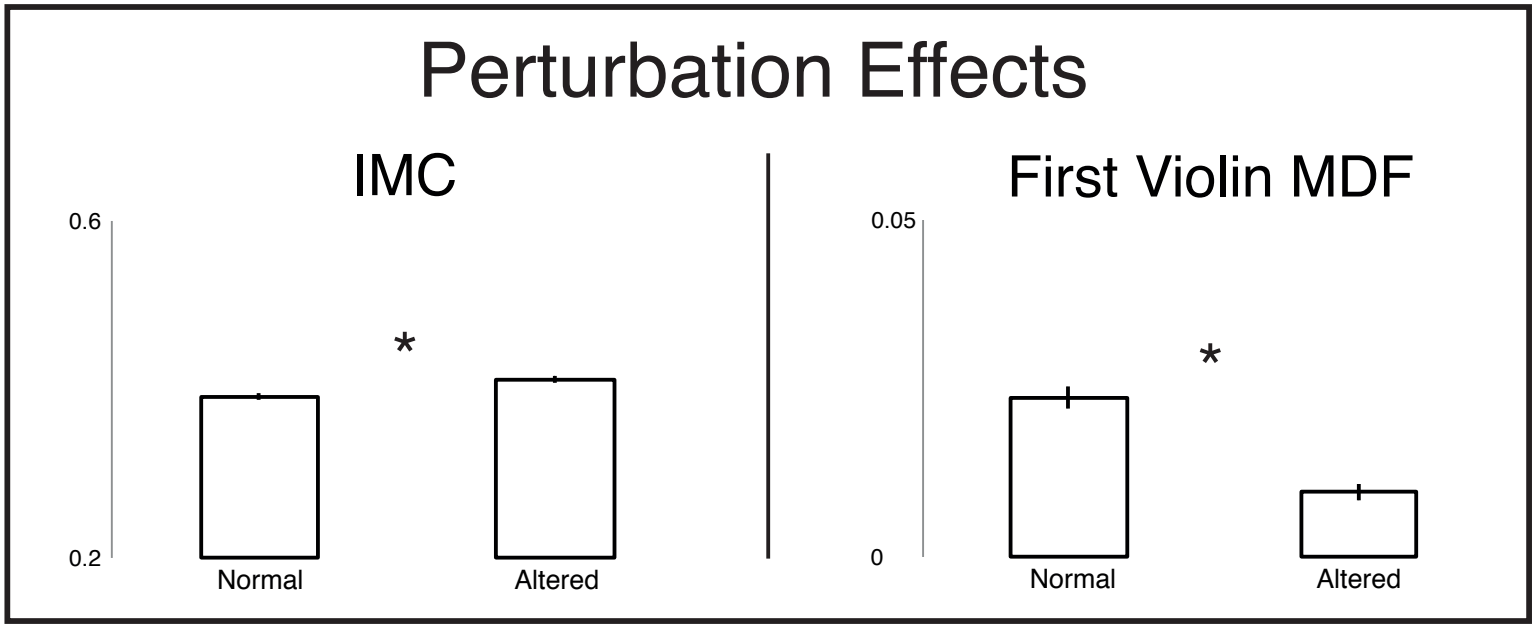
COMPLEX VS SIMPLE SEGMENTS



LEADERSHIP EXTRACTION



PERTURBING THE INFORMATION FLOW



ACKNOWLEDGEMENTS

Luciano Fadiga

Alessandro D'Ausilio

Leonardo Badino

Eleonora Bartoli

Claudia Canevari

Laura Maffongelli

Elisabetta Ferrari

SIEMPRE, POETICON, POETICON++ Projects

THANKS!

ALESSANDRO D'AUSILIO

iit istituto italiano di tecnologia