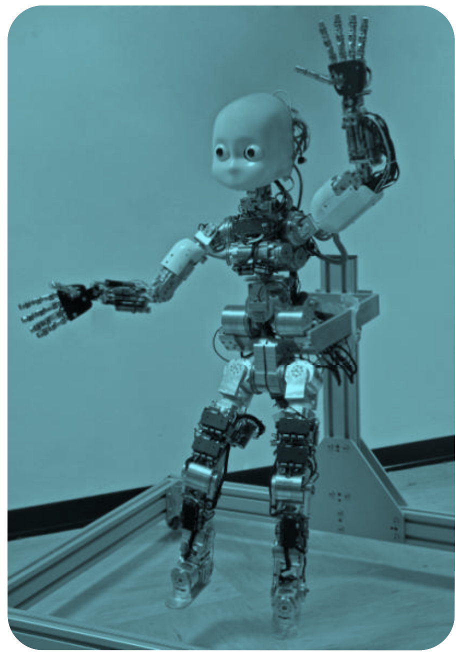
ISTITUTO ITALIANO DI TECNOLOGIA

The Mirror-Neurons System: data and models



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Our approach

Guiding Philosophy

- Cognition cannot be hand-coded
- It is necessarily the product of a process of embodied development
- Initially dealing with immediate events
- Increasingly acquiring a predictive capability

COGNITION = PREDICTION

Why?

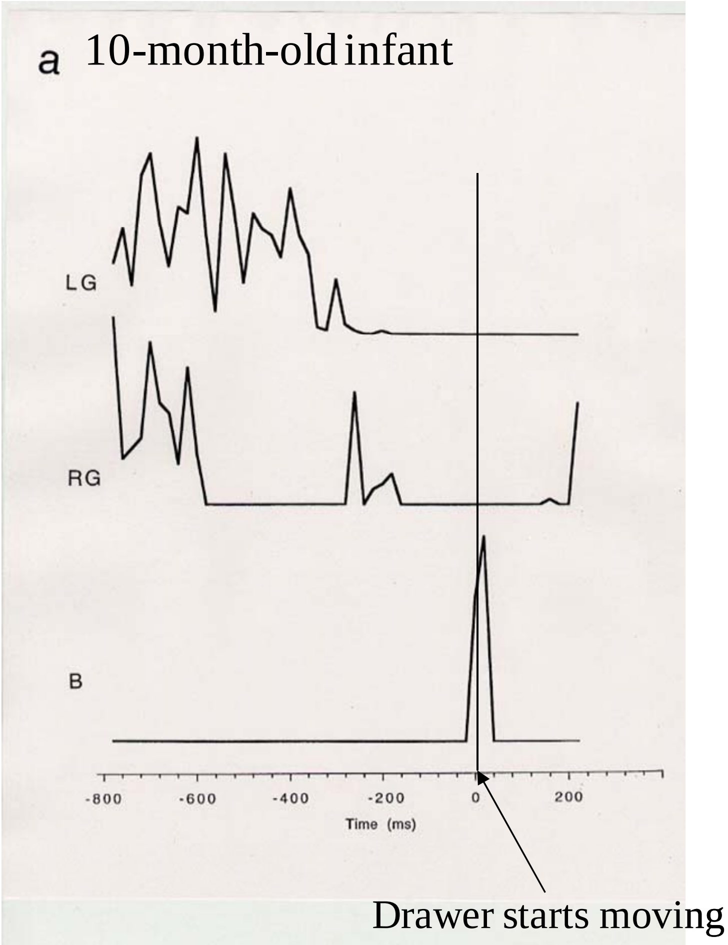
- Purposeful manipulatory actions are founded on predictions of physical events and the effects of one's own actions

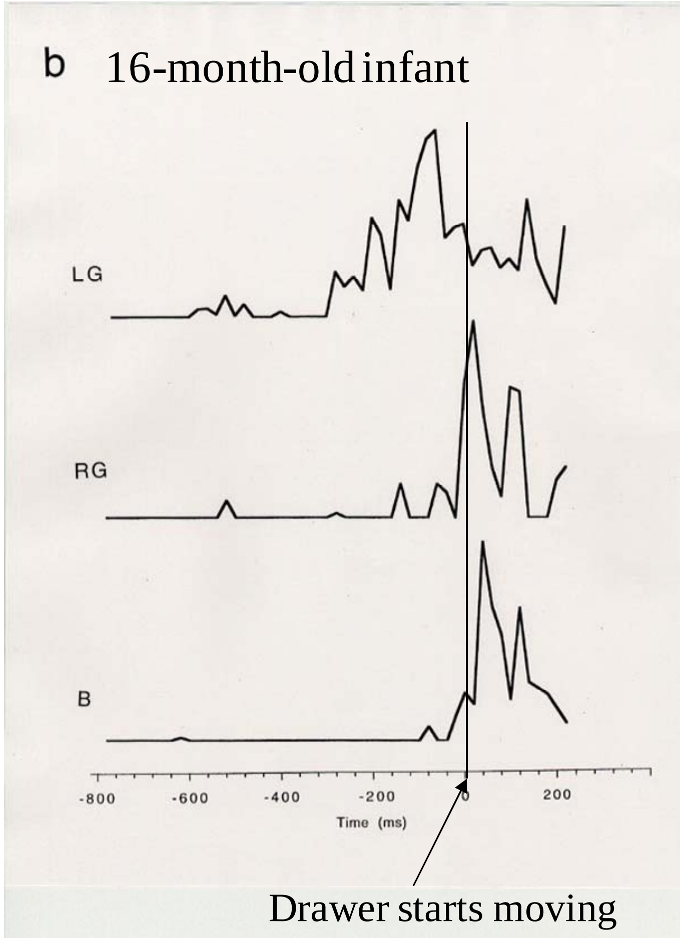
From Claes von Hofsten and Kerstin Rosander

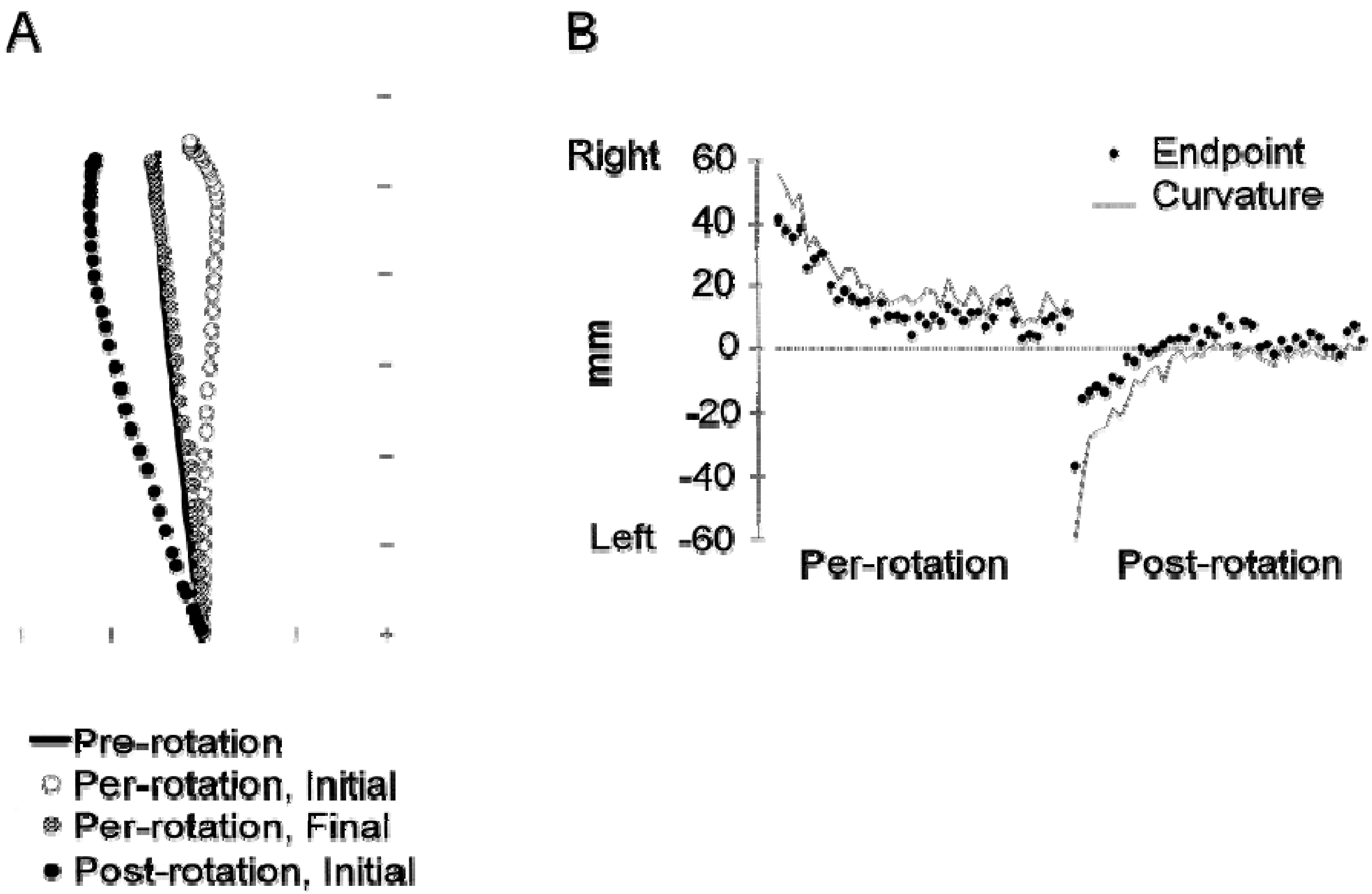
Infants in 10-17m range are very challanged when you put a toy in a drawer and close it. If they can, they will immediately open the drawer and take out the toy. Our drawer resisted opening by a weight attached to it.

Pulling something that resists pulling has to start from the base of support. Adults will start the pull by activating the gastrocnemious muscles 50 ms before the arm starts pulling.

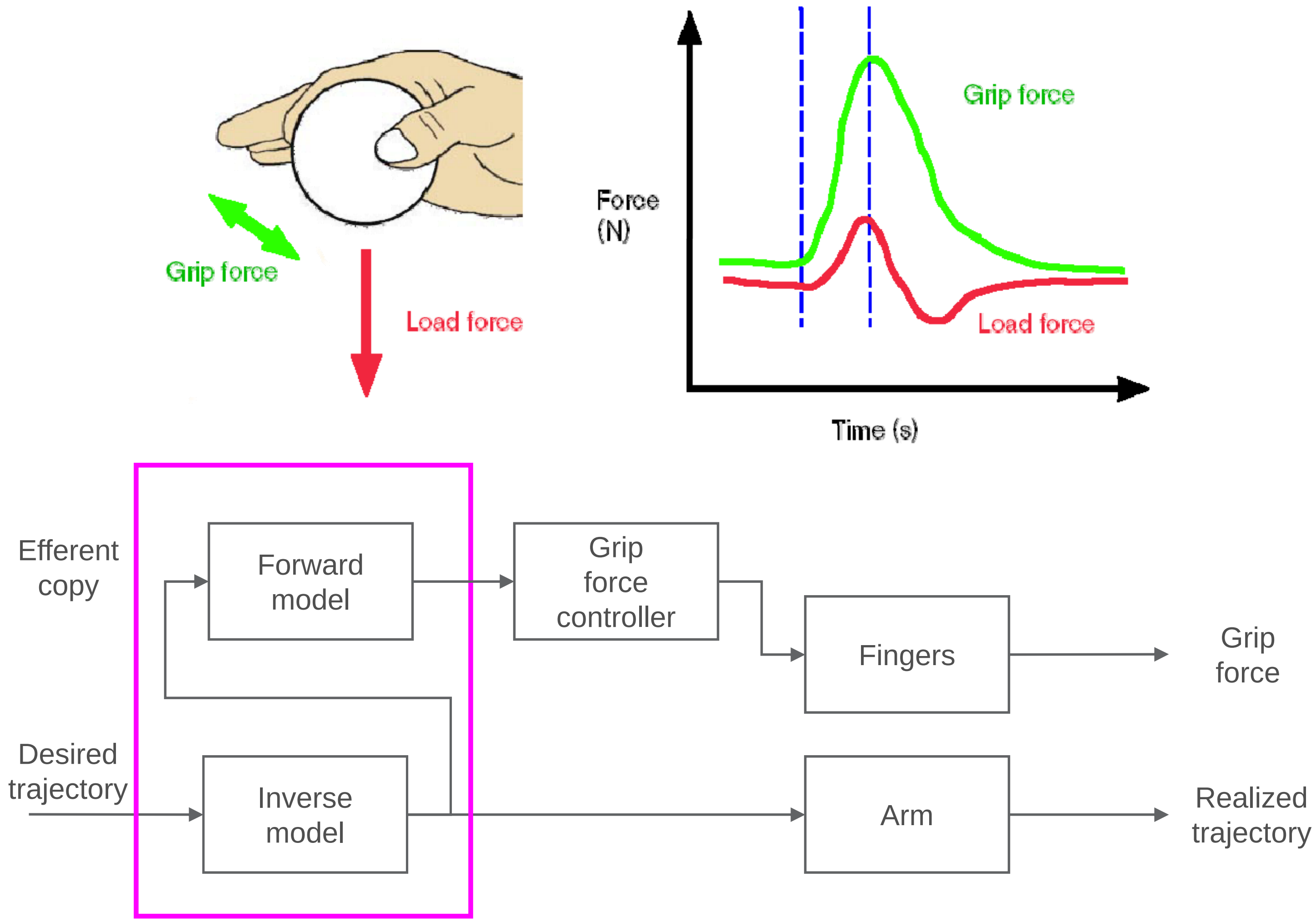
von Hofsten C., Rosander K., et al.


a
10-month-old infant
LG
RG
B
-800
-600
-400
-200
0
200
Time (ms)
Drawer starts moving


b
16-month-old infant
LG
RG
B
-800
-600
-400
-200
0
200
Time (ms)
Drawer starts moving



From: Lackner JR, Dizio P. *Gravitoinertial force background level affects adaptation to Coriolis force perturbations of reaching movements.* Journal of Neurophysiology 1998, 80:546-553.



From: Flanagan JR, Wing AM. *The role of internal models in motion planning and control: evidence from grip force adjustments during movements of hand-held loads.* Journal of Neuroscience 1997, 17:1519-1528.

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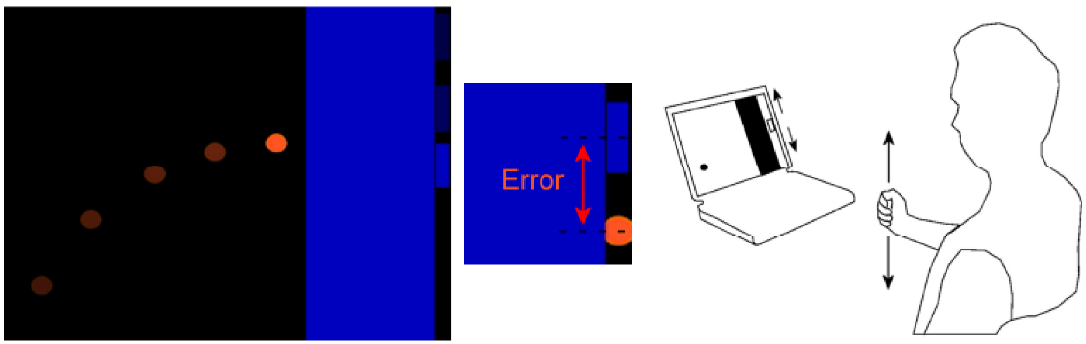


Fig. 1: Experimental setup: (right) a schema of the game played by subjects; (center) error measure; (left) a sketch of an experiment. **28 subjects** participated in the experiment.

Experimental setup

Stimuli (3 conditions)

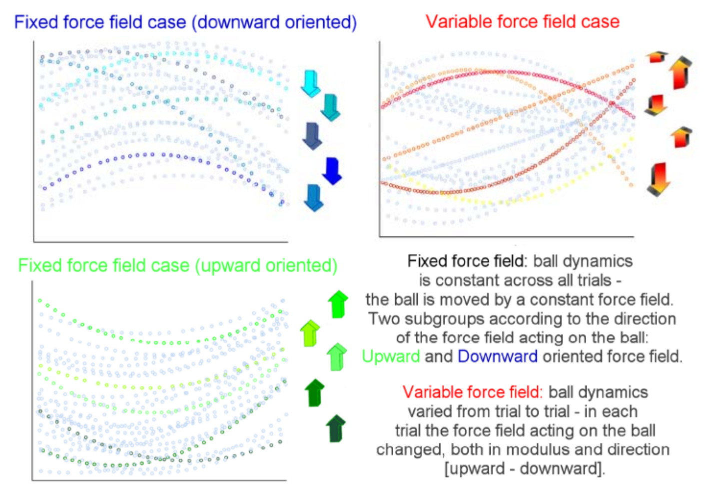


Fig. 2: Examples of ball trajectories and representation of the force fields applied to the ball in the three experimental cases.

With Alessandra Sciutti, Francesco Nori, Thierry Pozzo

Results

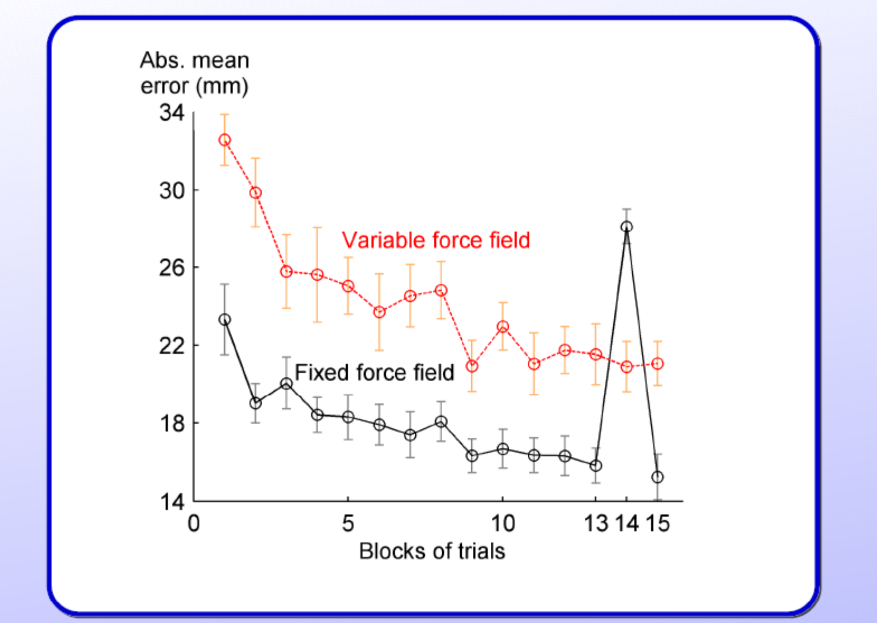


Fig. 3: Absolute mean error (distance between paddle position and real ball arrival point) for the fixed force field and the variable force field cases. Mean and standard error among subjects.

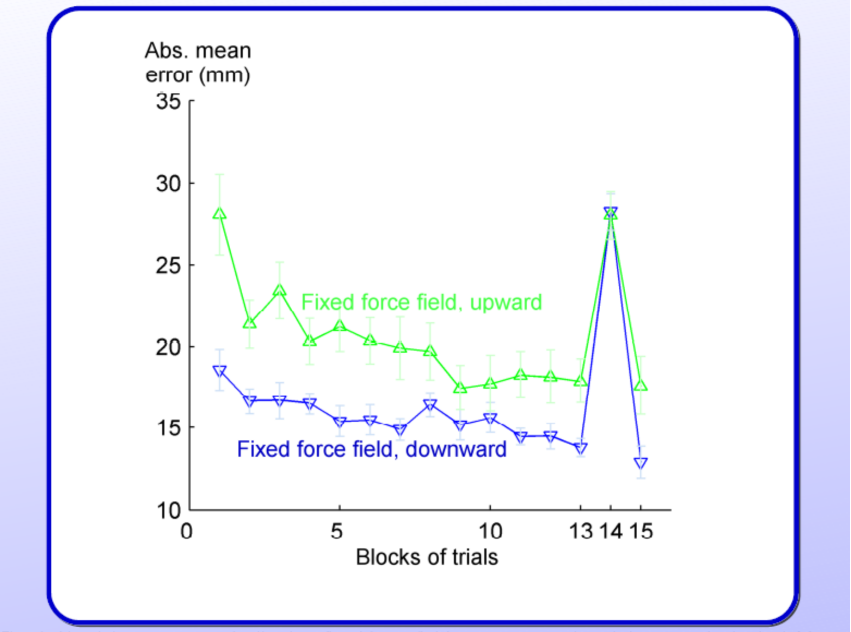
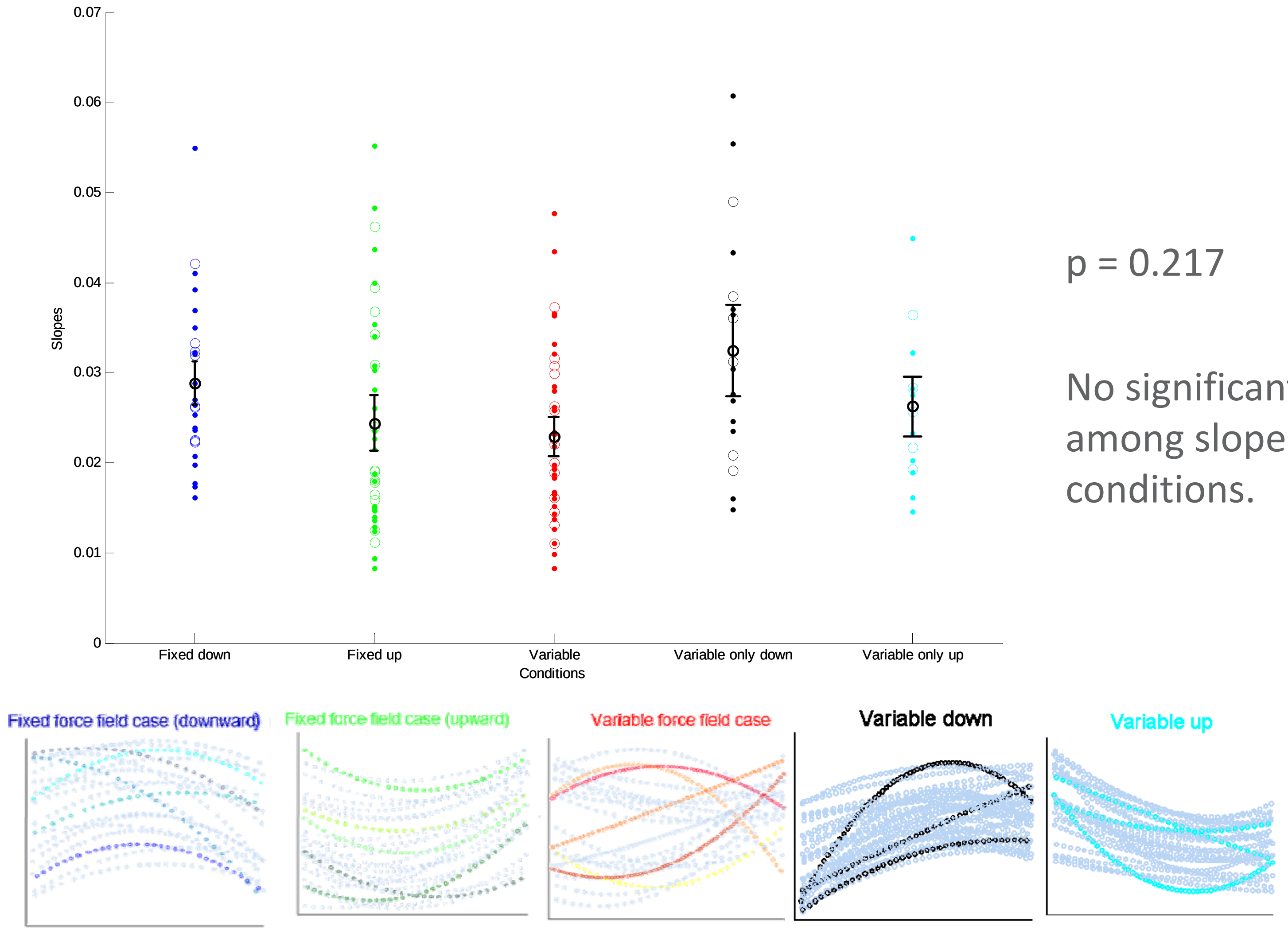


Fig. 4: Absolute mean error for the two fixed force field cases: upward and downward oriented. Mean and standard error among subjects.

Results (vision only)

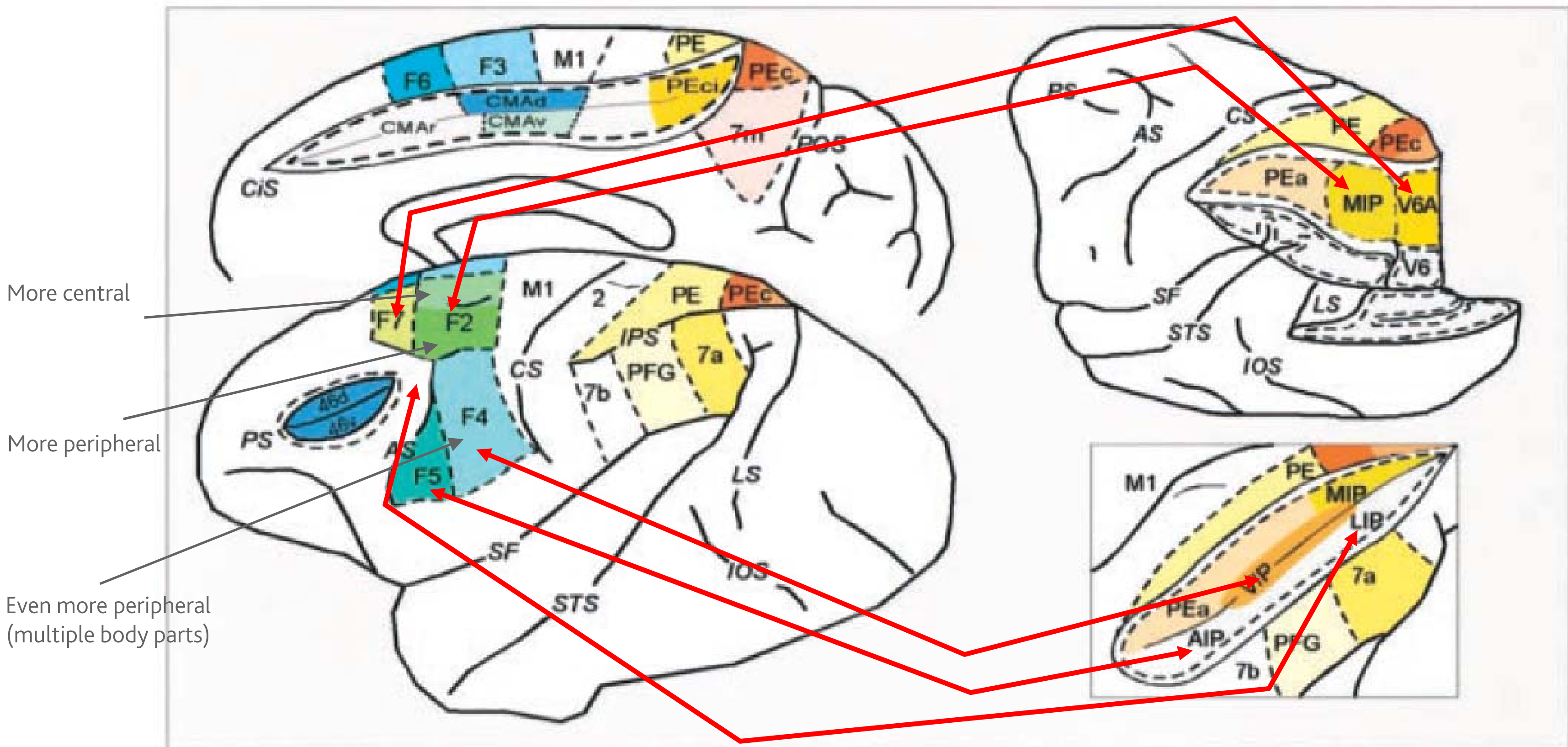


p = 0.217

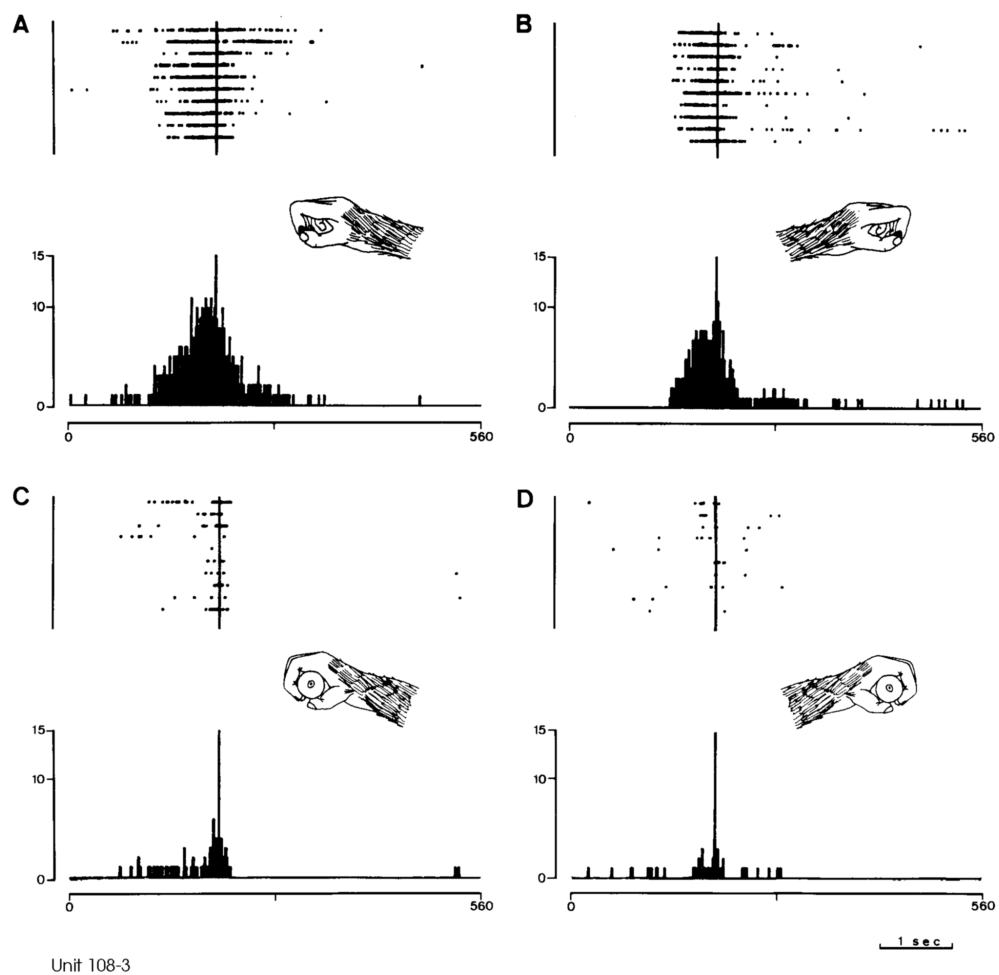
No significant difference among slopes in all conditions.

Conclusions

- In a predictive purely visual task, we **don't** find the same results as in the motor task.
- In a purely visual task prediction doesn't require the use of a dynamical model. In contrast to what happened in the motor task, performances aren't significantly better when a model of ball behavior can be built.
- Neither modulus nor orientation of the force field acting on the ball seems to have a predominant role in affecting predictive performances.

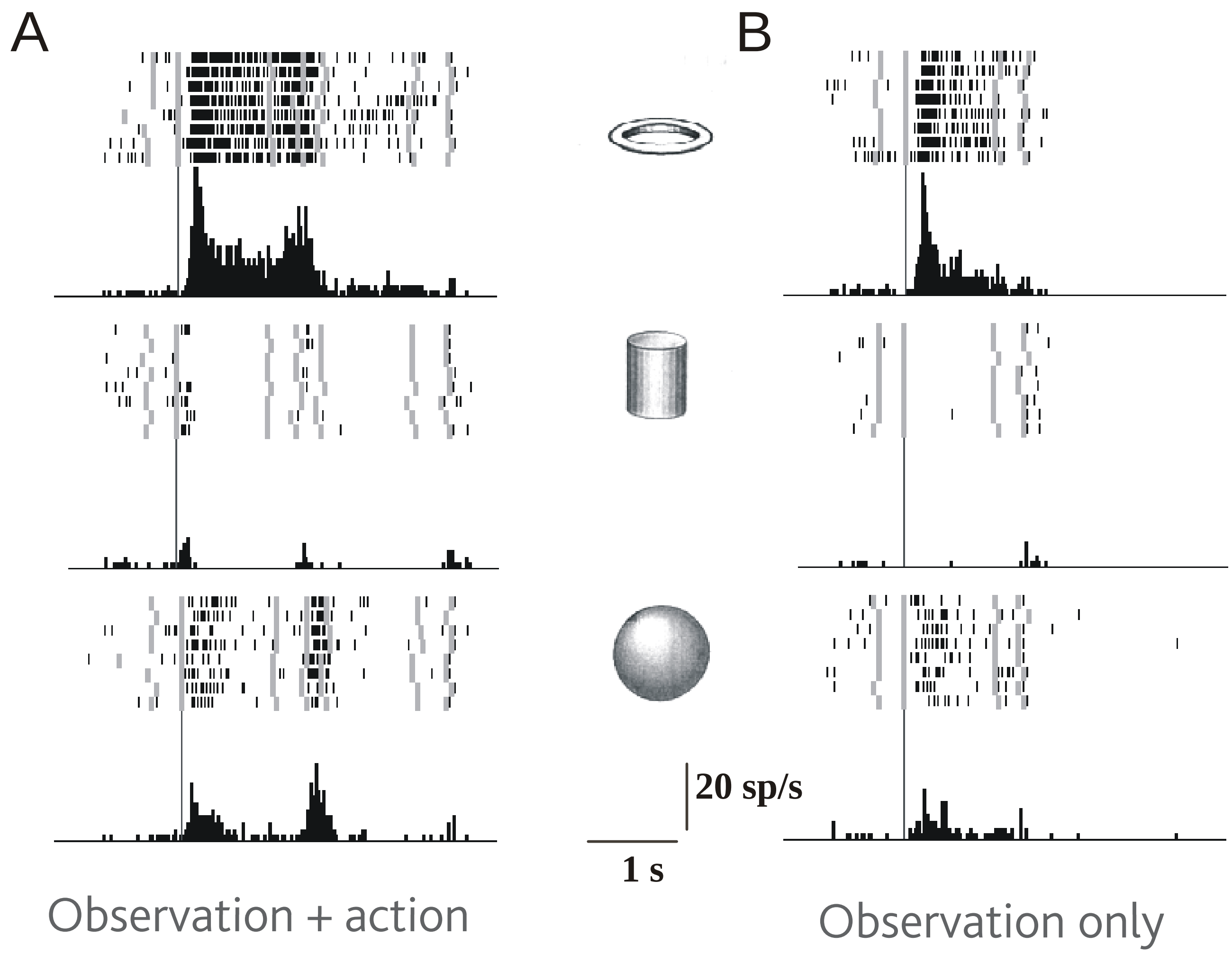

More central
More peripheral
Even more peripheral
(multiple body parts)
F6
F3
M1
PE
PEc
PEci
CMAd
CMAv
CMAr
7m
POS
CiS
F7
F2
M1
2
PE
PEc
CS
IPS
7a
PFG
7b
F4
F5
AS
PS
SF
STS
LS
IOS
PS
AS
CS
PE
PEc
PEa
MIP
V6A
V6
LS
SF
STS
IOS
M1
PE
MIP
LIP
PEa
AIP
PFG
7a
7b

Grasping neurons



F5 canonical neurons

looking at objects

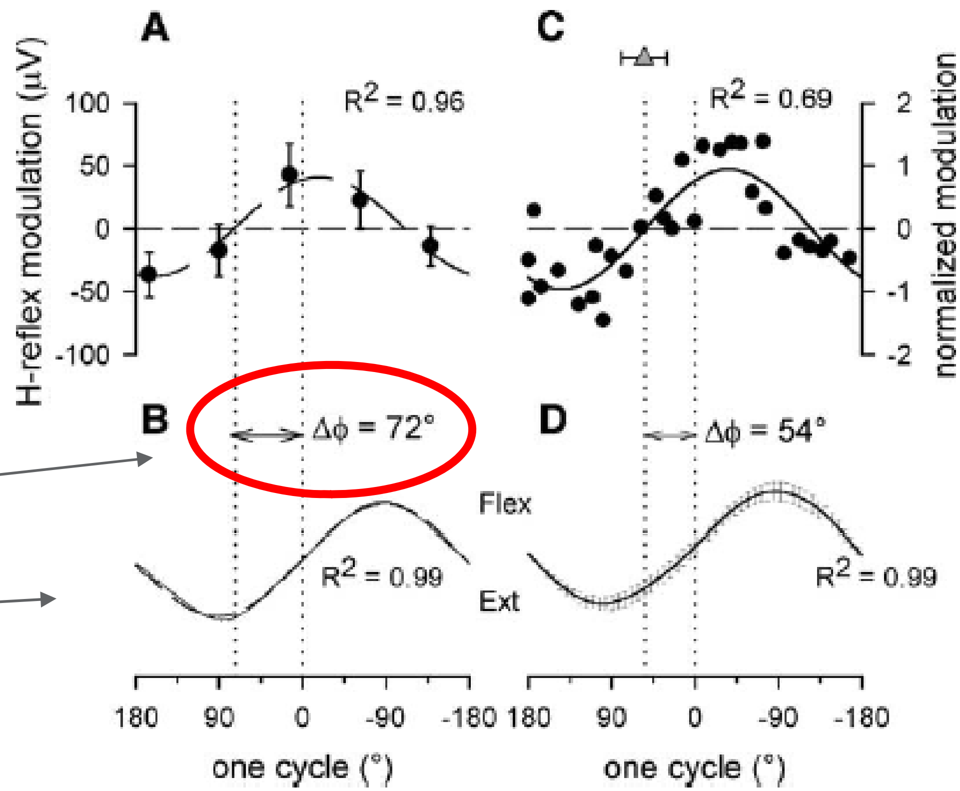


Looking at others

H-reflex deviation from the mean
(conductance of the spinal-muscle nerves)

Muscle anticipate the kinematics

kinematics



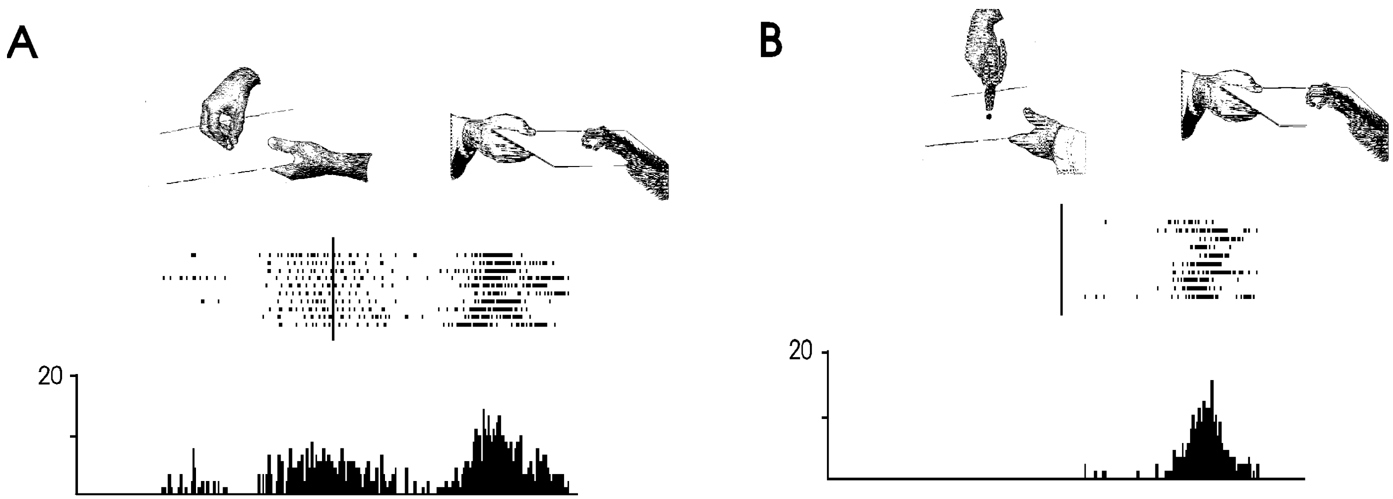
Prone position, wrist ext/flexion (ECR, FCR muscles)

Borroni, P., Montagna, M., Cerri, G., & Baldissera, F. (2005). Cyclic time course of motor excitability modulation during the observation of a cyclic hand movement. *Brain Research, 1065*, 115-124.

Mirror Neurons

looking at others

The neuron is activated by “seeing” someone else’s hand performing a manipulative action **and** while the monkey is performing the same action



The type of action seen is relevant

From: Fadiga, L., L. Fogassi, V. Gallese, and G. Rizzolatti, *Visuomotor Neurons: ambiguity of the discharge or "motor" Perception?* Internation Journal of Psychophysiology, 2000. **35**: p. 165-177.

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Speech listening…

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SHORT COMMUNICATION
Speech listening specifically modulates the excitability of tongue muscles: a TMS study

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Keywords: mirror neurons, motor-evoked potentials, motor system, motor theory of speech perception

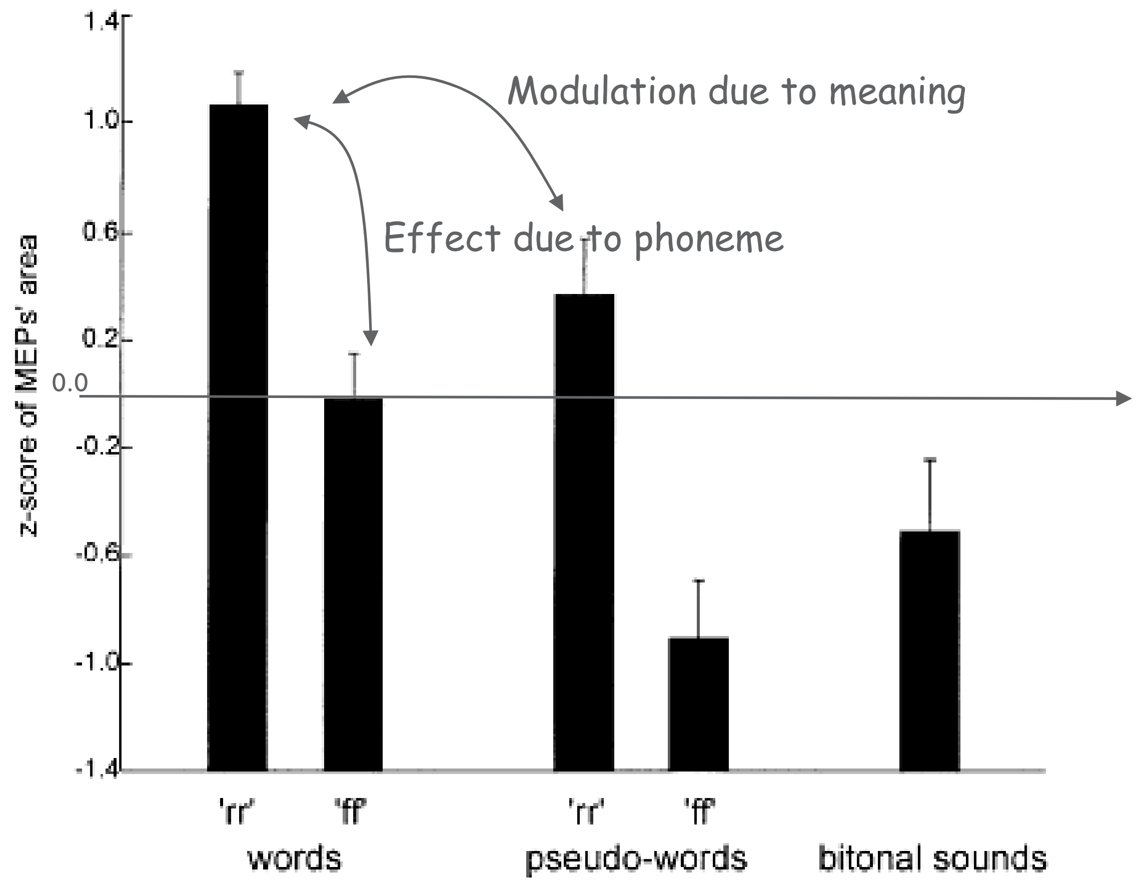
The experiment

- Listening: three categories of stimuli (words, pseudo-words, bi-tonal sounds).
- Two phonemes ‘rr’ requires strong tongue tip movement, ‘ff’ requires slight tongue tip movement.
- TMS of the under-threshold motor cortex.
- Recording of the MEP (motor-evoked potential) from the tongue muscles.

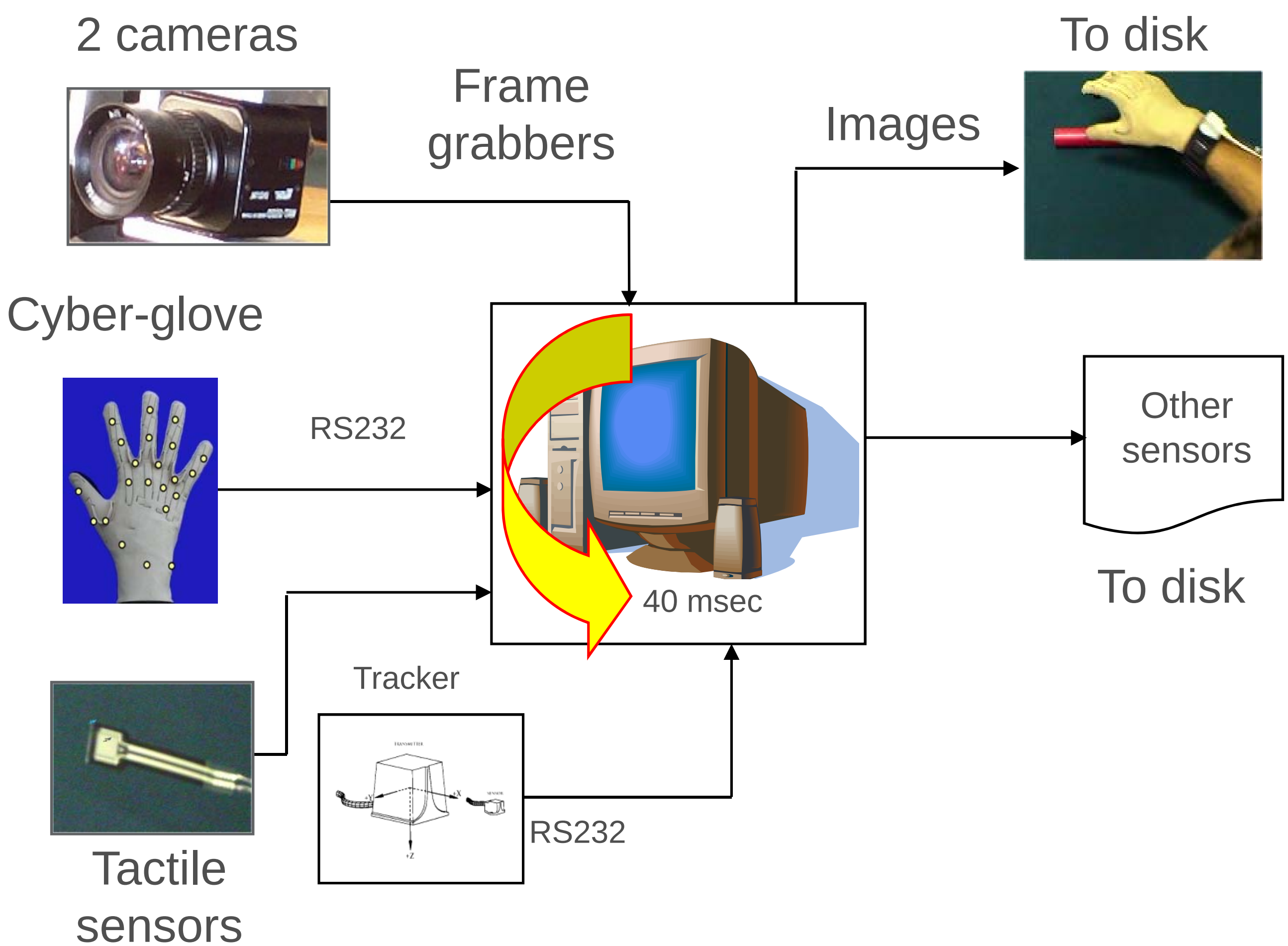
Examples of word/pseudo-words

Labiodental fricative consonant, 'rr'		Lingua-palatal fricative consonant, 'ff'	
Words	Pseudo-words	Words	Pseudo-words
birra (bier)	berro	baffo (moustache)	biffo
carro (cart)	firra	beffa (hoax)	ciffo
cirro (cirrus)	forro	buffo (funny)	leffa
farro (spelt)	furra	ceffo (snout)	meffa
ferro (iron)	marro	coffa (crow's nest)	paffo
mirra (myrrh)	merro	goffo (clumsy)	peffa
morra (morra)	parro	muffa (mold)	poffa
porro (leek)	perro	puffo (smurf)	seffa
serra (greenhouse)	vorro	tuffo (dive)	viffa
terra (ground)	vurro	zaffo (plug)	voffo

Results (in short)



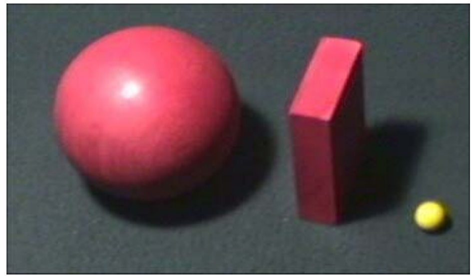
Data from human grasping

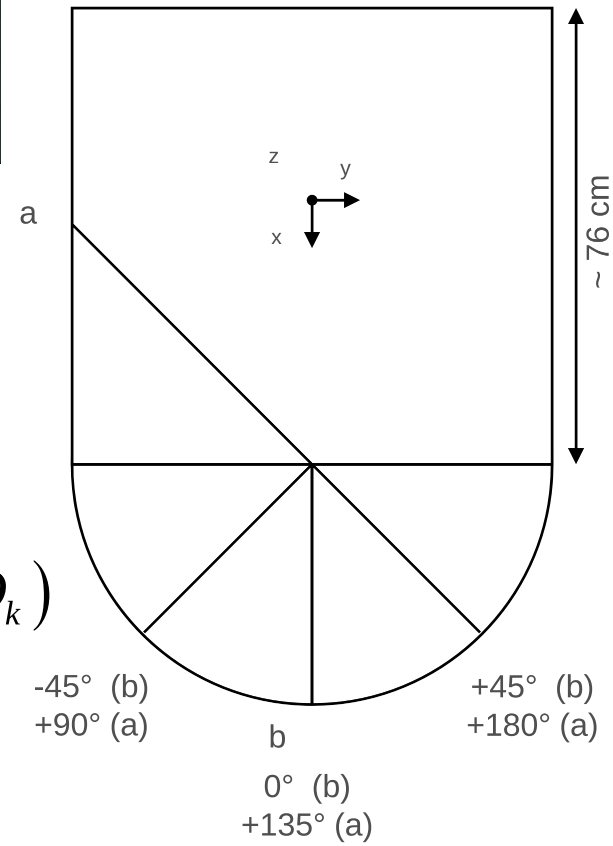


Bayesian classifier

168 sequences per subject
10 subjects
6 complete sets

{G_i}: set of gestures
F: observed features
{O_k}: set of objects



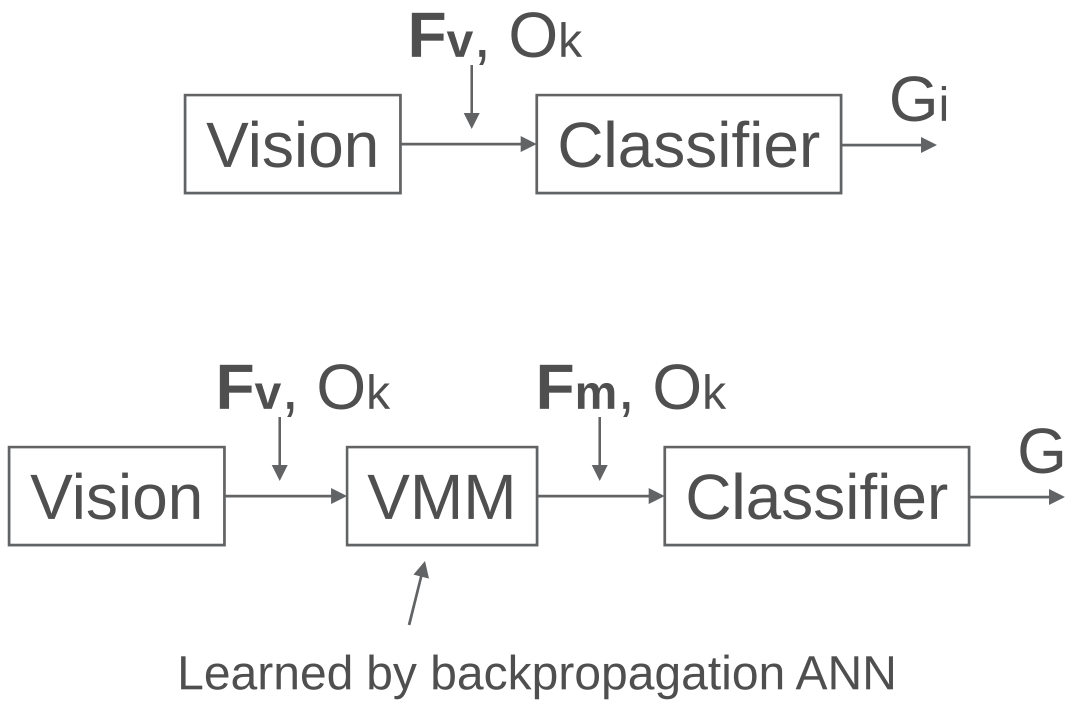


$p(G_i|O_k)$: priors (affordances)
$p(\mathbf{F}|G_i,O_k)$: likelihood to observe **F**

$$p(G_i \mid \mathbf{F}, O_k) = p(\mathbf{F} \mid G_i, O_k)\, p(G_i \mid O_k) / p(\mathbf{F} \mid O_k)$$

$$\hat{G}_{MAP} = \arg\max_{G_i} (G_i \mid \mathbf{F}, O_k)$$

Two types of experiments



Role of motor information in action understanding