Internal Models in Interception

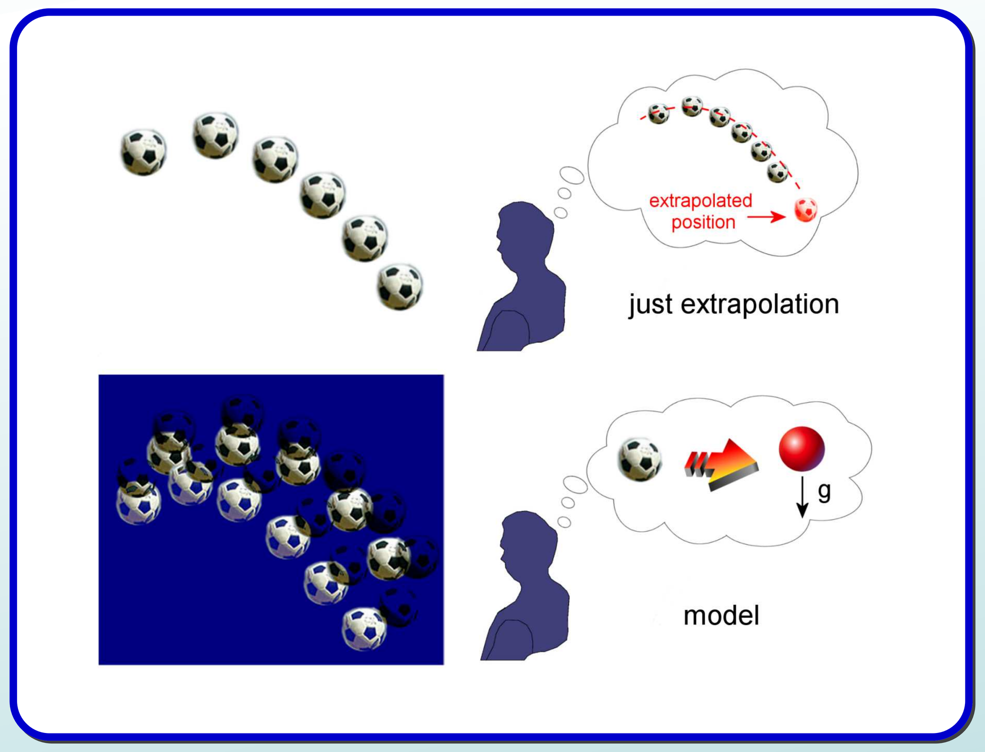
Alessandra Sciutti[1], Francesco Nori[1], Giorgio Metta[1,2] and Giulio Sandini[1]

[1] Robotics Brain and Cognitive Science Department (RBCS Dept.), Italian Institute of Technology (IIT), Genova [2] LIRA-Lab (DIST), University of Genova, Italy

alessandra.sciutti@iit.it , giorgio.metta@iit.it, franscesco.nori@iit.it, giulio.sandini@iit.it

Introduction

The presence of delays in our central nervous system causes a systematic delay between action instantiation and the corresponding motor act. During interceptive or catching tasks, in particular, these delays prevent the instantaneous adjustment of our movements and force us to use a strategy alternative to feedback control. **We have designed an interception experiment with the aim of understanding whether this strategy involves building internal models of the flying object dynamics and whether the motor system plays a role in this modeling phase.**



An illustration of our theory. (Top) When humans see a flying object for the first time, they try to intercept it just extrapolating its trajectory. (Bottom) However, when they have the possibility to see and intercept the same object many times, they model its characteristics. Afterward they will use the model to better intercept the target.

Main questions

- Do humans build internal model of flying objects dynamics to better intercept them?
- Is motor system involved in the modeling phase?

Methods

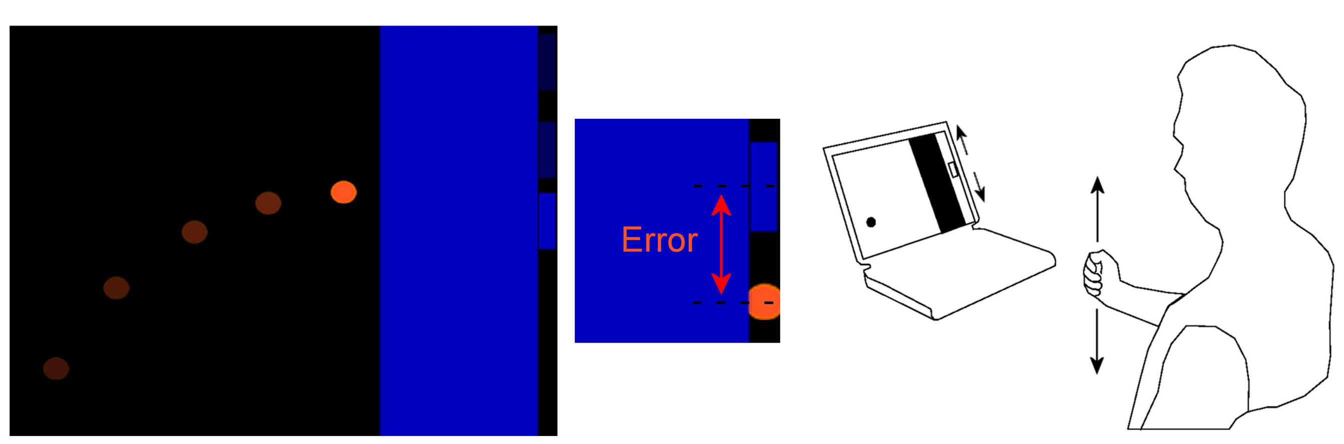


Fig. 1: Experimental setup: (right) a schema of the game played by subjects; (center) error measure; (left) a sketch of an experiment. **28 subjects** participated in the experiment.

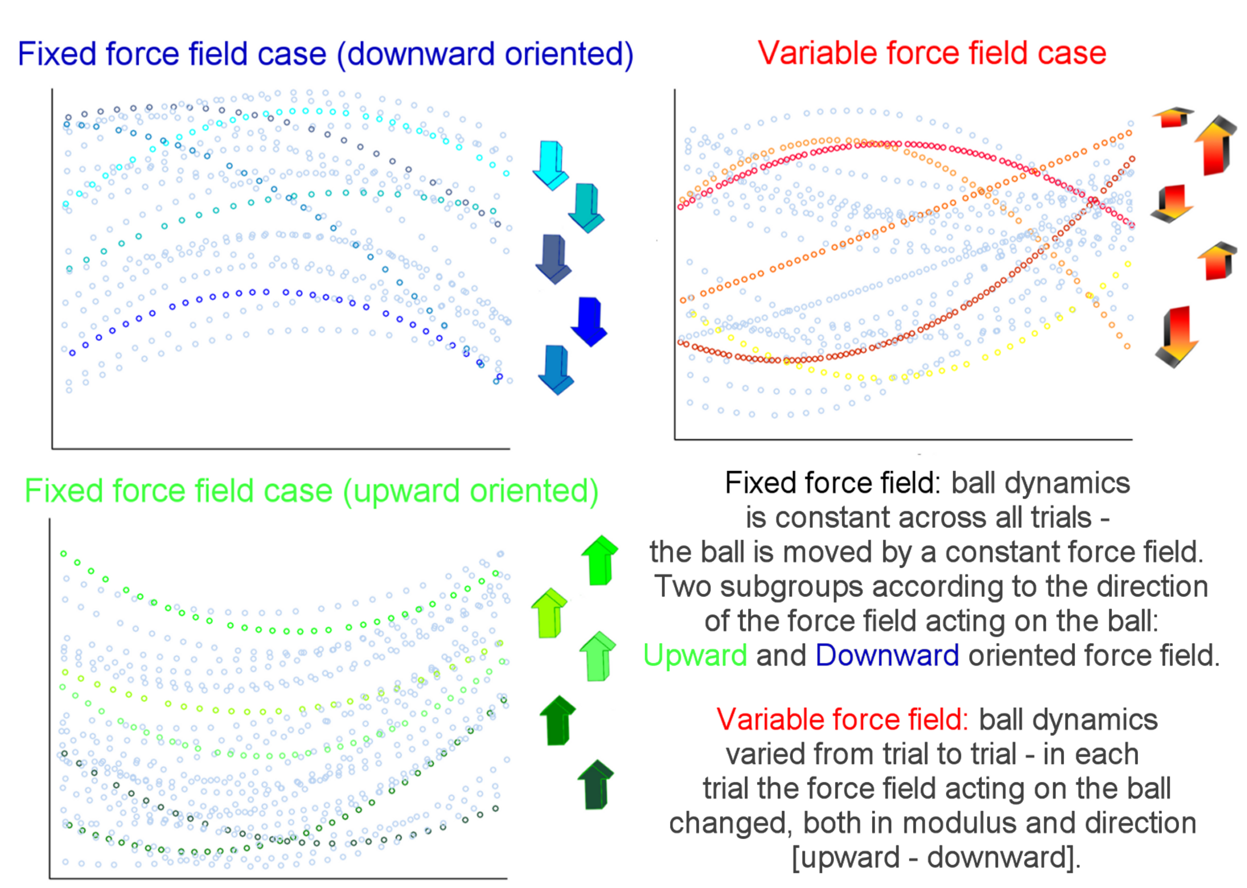


Fig. 2: Examples of ball trajectories and representation of the force fields applied to the ball in the three experimental cases.

Answers

Q: Do humans build internal model of flying objects in interception?
A: Yes, because subjects find easier the case in which the ball dynamics is kept constant and a model can be built.

Q: Is motor system involved in prediction?
A: Yes because a conflict between the environment in which subjects moved (gravity) and the one they saw (upward oriented force field) influenced their performance. If prediction was a purely visual task, this incoherence should not affect results.

Results

Using a model, prediction is easier.

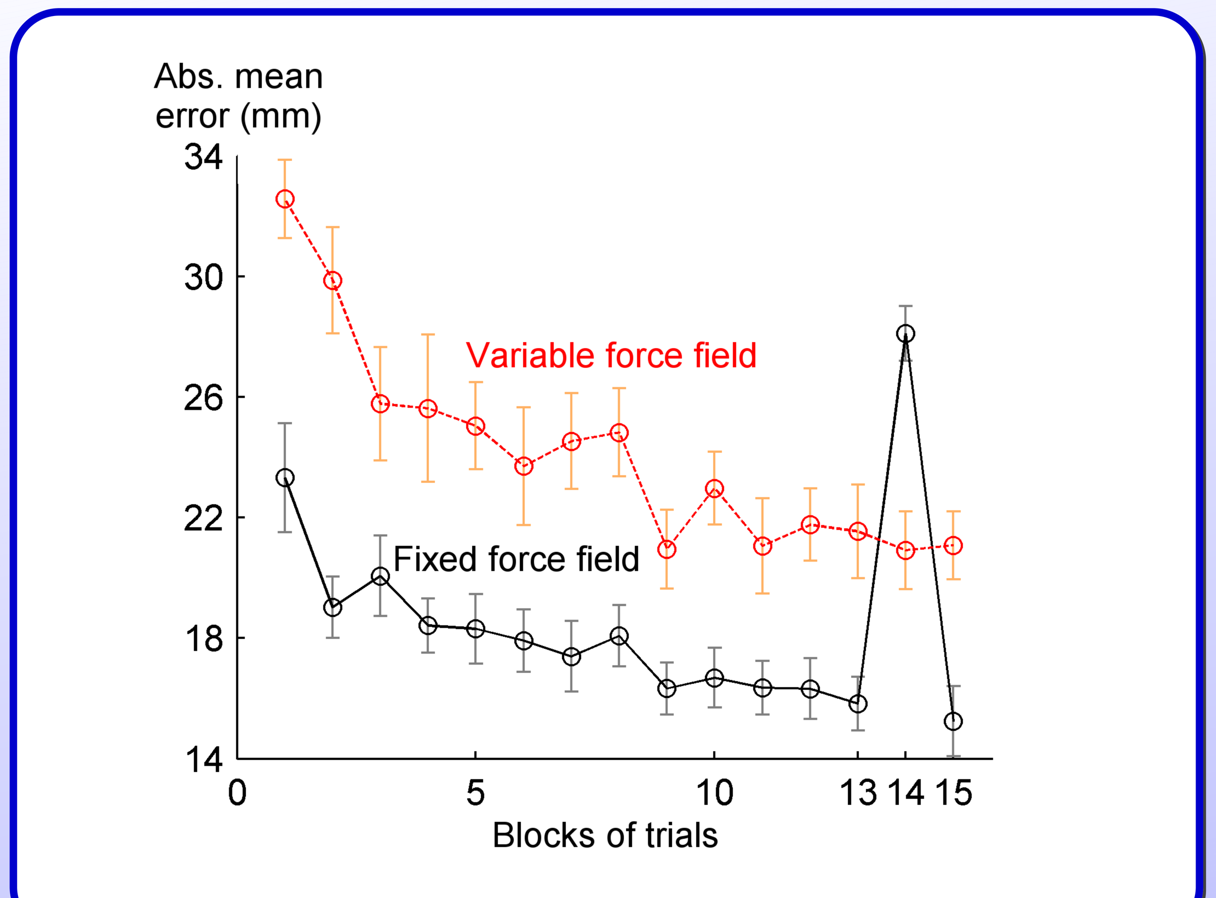


Fig. 3: Absolute mean error (distance between paddle position and real ball arrival point) for the fixed force field and the variable force field cases. Mean and standard error among subjects.

The fixed force field case allows for better performances than the variable force field case. When the fixed force field is suddenly replaced with a vertical force that changes randomly its orientation at each trial (14th set) an error peak appears.

A visuo-motor conflict makes prediction more difficult.

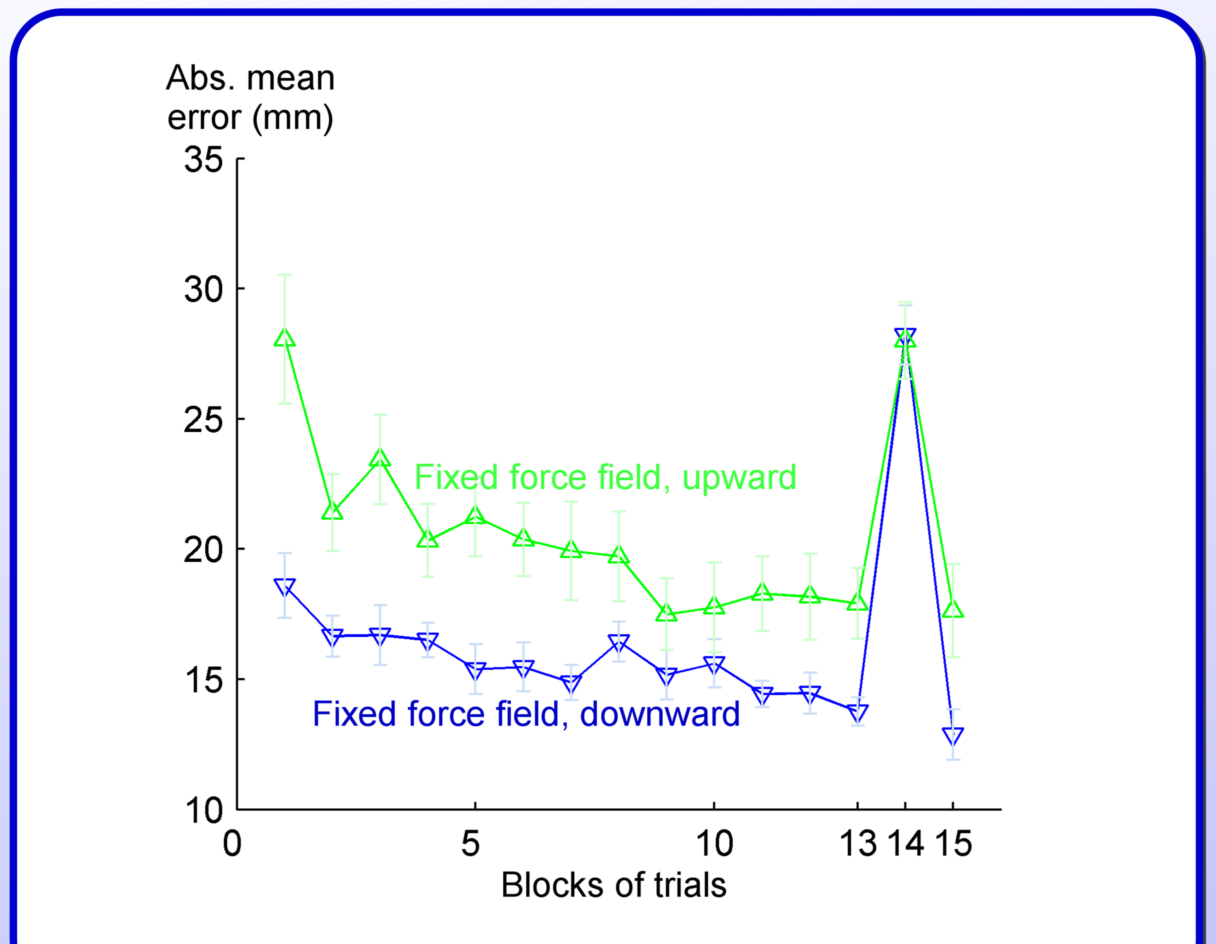


Fig. 4: Absolute mean error for the two fixed force field cases: upward and downward oriented. Mean and standard error among subjects.

Subjects scored a better performance when there was coherence between the force field they saw acting on the ball and the force field they perceived moving their hand (gravity).

Parabolic prediction wins to straight line prediction, when a model can be built.

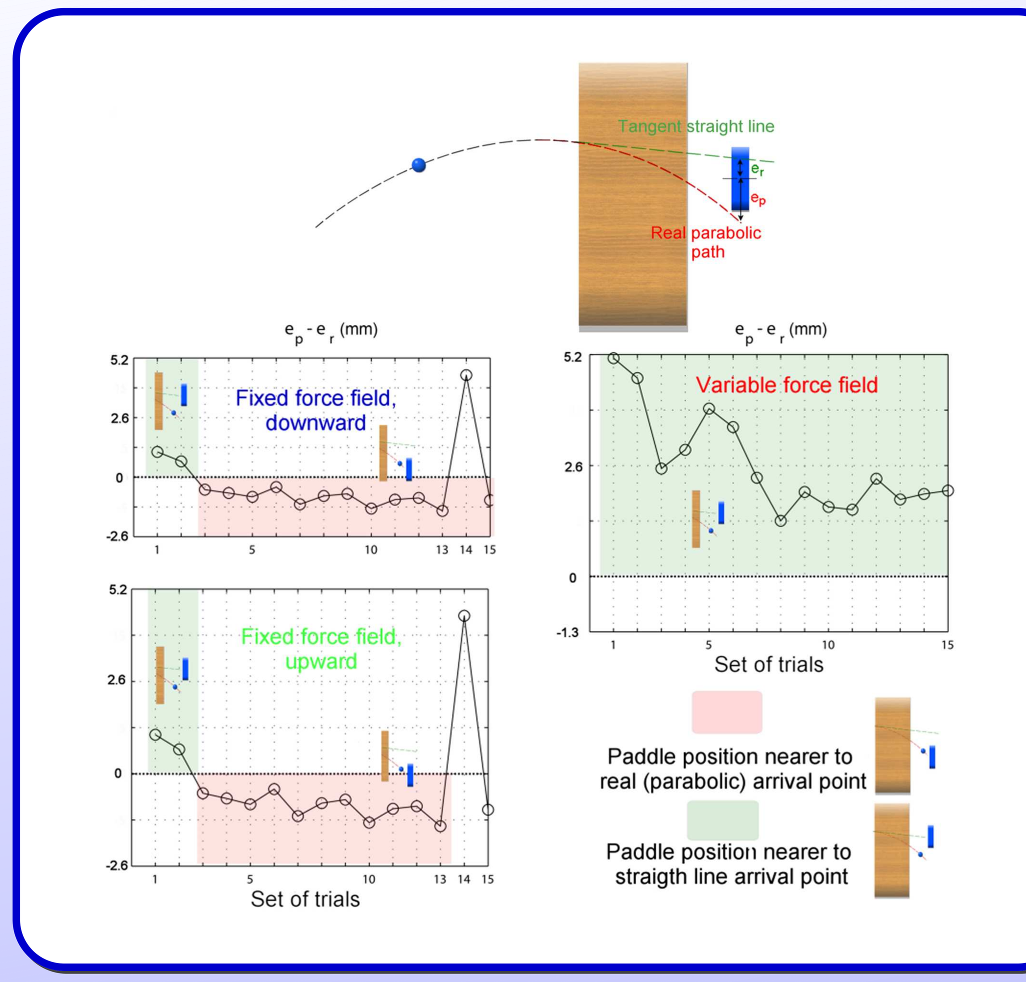


Fig 5: (Top) In red last part of the real trajectory of the ball. In green last part of a false "straight line" trajectory. (Bottom) Difference between the distances of the paddle center from the real ball arrival point e_p and from the false arrival point e_r in the three experimental cases. A negative difference (pink) means that the paddle is nearer to the real ball arrival point.

In the first sets of trials of the fixed force field condition and in the whole variable force field condition subjects ended up with their paddle nearer to a false arrival position. This position was obtained extrapolating the ball trajectory with a straight line, tangent to the real parabolic one in the point where the ball vanished behind the occlusion (the green line in figure). This result indicates the progressive building of a model in the fixed force file case in opposition to the continuous extrapolation strategy adopted in the variable force field case.

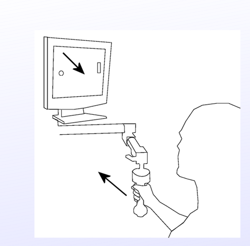
Conclusions

The possibility to model object dynamics has a relevant influence on prediction and interception.

As soon as a fixed force field temporarily varied is restored, errors return in trend with their previous values, as subjects could simply return to a model already learned.

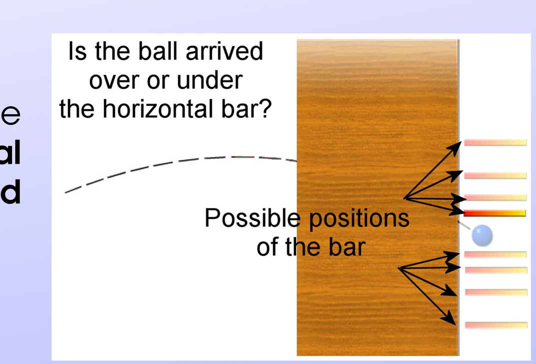
Prediction is not only influenced by what is seen (the behavior of the object and its dynamical feature) but also by the environment in which subjects move their hand (a gravitational world).

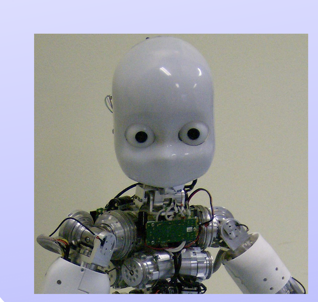
Further developments



Expand research to **different object behaviors** (eg. drifting or rolling) and to **different force fields** (eg. not gravitational force fields).

Analyze if there is a difference in the modeling phase when subjects have to predict **just giving a visual judgement** or when they have to **move their hand** while predicting.





The final aim of my research would be to understand how the ability of predicting future course of actions is developed and used by humans and how it could be applied to the construction of better robotic systems.

Acknowledgments: The work presented in this paper has been supported by the ROBOTCUB project (IST-2004-004370), funded by the European Commission through the Unit E5 "Cognitive System".

References

(1) MM. Hayhoe, N. Mennie, B. Sullivan, and K. Gorgos. The role of internal models and prediction in catching balls. In *From Reactive to Anticipatory Cognitive Embodied Systems.* American Association for Artificial Intelligence (AAAI)., 2005.

(2) J. McIntyre, P. Senot, P. Prevost, M. Zago, F. Lacquaniti, and A. Berthoz. The use of on-line perceptual invariants versus cognitive internal models for the predictive control of movement and action. In *Neural Engineering.*, pages 438–441, 2003. Conference Proceedings. First International IEEE EMBS Conference.

(3) J. McIntyre, M. Zago, A. Berthoz, and F. Lacquaniti. Does the brain model newton's laws? *Nat Neurosci*, 4(7):693–694, Jul 2001.

(4) R. Shadmehr and F. A. Mussa-Ivaldi. Adaptive representation of dynamics during learning of a motor task. *J Neurosci*, 14(5 Pt 2):3208–3224, May 1994.

(5) Myrka Zago and Francesco Lacquaniti. Cognitive, perceptual and action-oriented representations of falling objects. *Neuropsychologia*, 43(2):178–188, 2005.