Learning Anticipatory Control: A Trace for Intention Recognition

P. Andry, D.Bailly, N. Beausse, A. Blanchard, D. Lewkowicz (*), S. Alfayad (**) ,

Y. Delevoye(*), F. BenOuezdeou (**), P. Gaussier,
ETIS UMR CNRS 8051 ENSEA-Université de Cergy Pontoise. pierre.andry@ensea.fr
(*) URECA, Université de Lille 3
(**) LISV, Université de Versailles St. Quentin

Recent psychological experiments intend to show that social intentions can be read from the recording of motor actions (Becchio, Sartori, and Castiello 2010; Ferri et al. 2011). At the center of the debate is the hypothesis that the motor system is (Blackemore and Decety 2001), or is not (Jacob and Jeannerod 2005) used to recognize social intentions, with a potential openning to a bottom-up understanding of social behavior, agentivity and theory of mind. In (Becchio et al. 2007), the authors proposed to record the arm's trajectories during episodes of a "pick and place" task with a motor *vs* social outcome. The results provided evidence for differences in motor patterning depending on the social context and intention, but where not yet a direct evidence of the involvement of the motor system in recognizing social intention. In (Becchio, Sartori, and Castiello 2010; Ferri et al. 2011), the authors show how social affordances can change the movement parametrization with the hypothesis that a same action linked to a social context may involve an increase of the index of difficulty.

Such experiments raise the issue of understanding anticipatory motor control and how the recognition of social situations affects at a very low level the generation of motor trajectories, and conversely, how trajectories, as a trace of intentions, can affect the social environement.

In this paper, we present a pluridsciplinary[1], study dedicated to understand the link between anticipatory motor control and motor intentions. Our goal is to propose a control architecture for a humanoid robot based on hydraulic technology (Fig. 1), with a potential of high degree of compliance.

We have first conducted psychological experiments (Lewkowicz et al. 2013) designed to record the kinematic of the hand of human subjects during a two player's game (similar to the jungle speed game,Fig. 3) involving an object and 3 condition of play (moving the object 1) to play, 2) for "me", 3) for the other player). In these studies, we have confirmed that typical velocity profiles are affected by the subject's motor intentions according to the final destination of the object. Interestingly, we also developed in this study a simple feedforward NN

[1]This work is part of the project INTERACT (ANR09-COORD014), program CONTINT. (http://interact.ensea.fr)
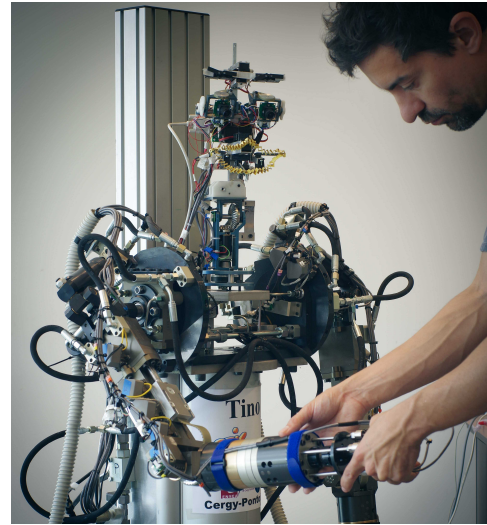

Figure 1: The Tino hydraulic platform. Our motor model is co-designed (both the mechanics and neural network controller) to take advantage of linear hydraulic motors giving a direct access to the oil pressure information, allowing a direct control and sense the effector, and a better size-power compromise.

showing that it is possible to anticipate the motor intention of an agent without the need of high order cognitive imagery processes. The kinematic effects reported in the present study are consistent with the literature and suggest that when planning a sequential action with multiple motor elements, the requirements of the endpoint element are back propagated to constrain the way the very first element of the sequence will be planned and performed. Thus, it is possible to suggest that low-level motor components may contain early indices that reflect the end-point motor intention of an agent.

From this result, we propose a NN brain model for anticipatory motor force control (Fig. 2) inspired by our previous works and (Shadmehr and Krakauer 2008).

Our working hypothesis is that a modulation of the recognition level of sensori-motor information (Y_0, Fig. 2) is enough to produce a change of the shape of the trajectory
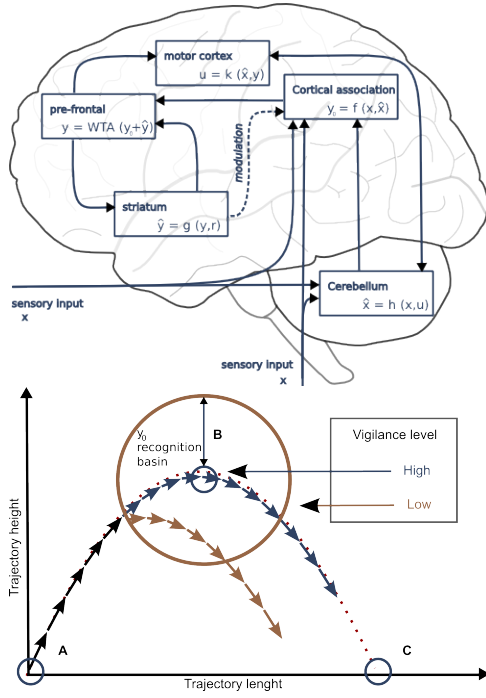
Figure 2: Up : Our architecture for anticipatory motor control. During babbling, the associative area learns multimodal (proprioceptieve and visual) categories (y_0). The cerebellum predicts accurately the next motor information under the form of motor commands ($\hat{u}$) and proprioception ($\hat{x}$). The striatum evaluates all possible trajectories ($\hat{y}$) based on the situation (r, for contextual recognition). Action selection (y) is a simple competition mechanism (WTA) computed by the pre-frontal cortex. Bottom : Our hypothesis for trajectories modulation : context recognition by the Striatum induce a vigilance modulation of changing the recognition level of y_0. In the case of a parabolic trajectory, a high vigilance level correspond to a very selective recognition and a small basins, inducing an accurate movement with a high amplitude.

and especially the amplitude and velocity of the movement. Such modulation originates in the Striatum, which can be seen as the provider of a global evaluation depending on the contextual situation (for example individual *vs* social)

Our assumption is that when the context is recognized as more stressful, it has a direct effect on the parameter accounting for the accuracy of the task. In our model, this parameter is the vigilance value allowing to modulate the recognition level of the via-points y_0. Vigilance factor is used during the learning to define the number of sensorimotor categories and therefore the accuracy of the points describing the working space of the robot, but it can also be used to shrink or dilate the basin of recognition of the via-points. By changing these basins, we can then change shape of the trajectory, and compare our robot's trajectories (Fig 3, bottom right) with psychological experiments (Fig 3,bottom left) refining the social level of the task. These preliminary
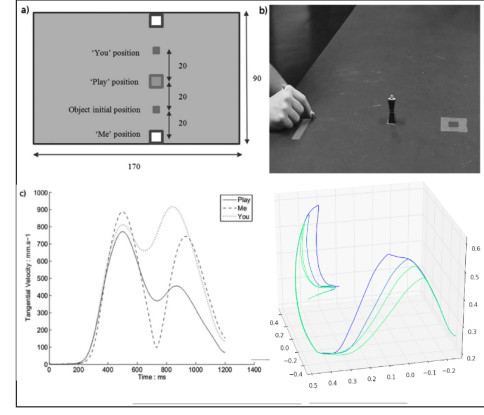
Figure 3: (a)Our experimental set-up showing the "Play", "Me" and "You" final position and their respective distances from the initial object position. The white squared areas are the starting hand position for both the subject (bottom) and the experimenter (top). (b) Example of stimuli. This close view was used for the movie clips to avoid any contextual effect (no body, no head). (c) Typical velocity profiles observed in the "Play", "Me" and "You" conditions are presented with full, dashed and dotted lines, respectively. Note that total movement time, the magnitude and the time to peak velocity of the first element of the sequence are significantly affected by motor intention (i.e., the experimental conditions).We simulated the demonstration of a sequence of two bell shaped trajectory, one for the reach-to-grasp movement and one for the place movement.

results stress the importance of further development of the optimal theories of motor control to include the more cognitive aspects of social context.

References

Becchio, C.; Sartori, L.; Bulgheroni, M.; and Castiello, U. 2007. The case of dr. jekyll and mr. hyde: A kinematic study on social intention. *Consciousness and Cognition* 17:557–5564.

Becchio, C.; Sartori, L.; and Castiello, U. 2010. Towards you: the social side of actions. *Current Directions in Psychological Science* 19:183–188.

Blackemore, S.-J., and Decety, J. 2001. From the perception of action to the understanding of intention. *Nature Reviews Neuroscience* 2:561–567.

Ferri, F.; Campione, G. C.; Dalla Volta, R.; Gianelli, C.; and Gentilucci, M. 2011. Social requests and social affordances: How they affect the kinematics of motor sequences during interactions between conspecifics. *PLoS ONE* 6(1):e15855.

Jacob, P., and Jeannerod, M. 2005. The motor theory of social cognition: a critique. *Trends in cognitive sciences* 9(1):21–25.

Lewkowicz, D.; Delevoye-Turrell, Y.; Bailly, D.; Andry, P.; and Gaussier, P. 2013. Reading motor intention through mental imagery. *Adaptive Behavior* 21:315–327.

Shadmehr, R., and Krakauer, J. 2008. A computational neuroanatomy for motor control. *Experimental Brain Research* 185:359–381.