The Role of Temporal Variance in Motions for the Emergence of Mirror Neurons Systems

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***Abstract*—The mirror neuron systems (MNS) allow us to project other's motions into our own brain's motor space. However, how the MNS develop remains not fully unraveled. Yet, making robots that acquire a mirroring property is crucial in order to allow them to efficiently cooperate with humans. Inspired by behavioral and computational studies on the MNS, we hypothesize that variances in motions would facilitate their emergence. Experiments showed that human-like motions, which means with variances in motions, lead to stronger connections between robot's motor commands and other's motions (i.e., MNS). It demonstrates the importance of variances in motions for the development of cognitive functions.**

I. Introduction

Found in 1996 inside monkey's brain and then in 2004 in human, experiments showed that some neurons named mirror neurons were discharging both when a monkey was executing an action and observing the same action done by another individual [1], [2]. In other studies [3], [4], it had also been proved that immature perception may leads to the development of cognitive functions in infants. We built our work on the top of an algorithm developed by Nagai et al.[6] and Kawai et al.[7] that emulate visual development through mathematical models to enable the emergence of the MNS. We used the same algorithm that have been previously applied on an electrical robot with low temporal and spatial variances in motions by Nagai et al.[6] and Kawai et al. [7], to show the effect of larger temporal variance in motions for the emergence of the MNS. To generate this variance, we used an infant-like robot named Affetto [5]. It is actuated by pneumatics actuators that allow it to do human-like motions with large temporal variance. To answer the question addressed in this paper, we will first expose the mechanism for emergence of MNS developed by Nagai et al.; then, we will present our experiments, methods and results to finally conclude and talk about the future work that has to be done.

II. Mechanism for emergence of MNS

The algorithm presented in this part that has been developed by Nagai et al. and Kawai et. al (cf I.) and shows the relationship between the emergence of a self-other correspondences and the visual development. In this algorithm, mathematical filters are applied to the optical flows extracted from recorded interactions between a robot and an experimenter to emulate the visual development of an infant. By changing the robot's visual acuity level, aforementioned researchers concluded that the visual development plays a crucial role in the development of self/other correspondence. In our research, this algorithm has been used as groundwork but have been modified a little. Indeed, we change the program to be real time and we extracted robot and experimenter's motion in one image instead of two in order to get more accurate measurements.

III. Experiments and results

A. Experiments setting

The experimenter sit in front of the robot. The robot record other's motions and its own hand movements thanks to a 640*480pixels digital camera placed under its head. The robot's motor commands are send at t = 0.0s. As soon as the robot starts doing its motion, the experimenter have to execute exactly the same motion in front of it. The robot has 6 embedded motions: right, left or right and left hands vertically or horizontally. The algorithm is then used to extract visual information and train the neural network system. 200 sets of data that contain a random number of each possible motion have been recorded in advance for the experiments. The main test intends to prove the role of a bigger temporal variance in the robot's motions for the emergence of self/other correspondence, which is a basic function of MNS.

Fig. 1. This picture shows the extraction of visual information from an interaction between an experimenter and the robot. The visual acuity is here set at the middle stage of development.

B. The effect of a larger temporal variance

Before performing our main experiment, we measured the experimenter's response time to the robot's actions to show the direct effect of the larger temporal variance. As you can see in Fig. 2, a larger variance creates overlaps between the robot and the experimenter's motion. We assume that this overlaps facilitate the self/other correspondence because, in the visual space, it makes the robot and the experimenter's motions more similar.

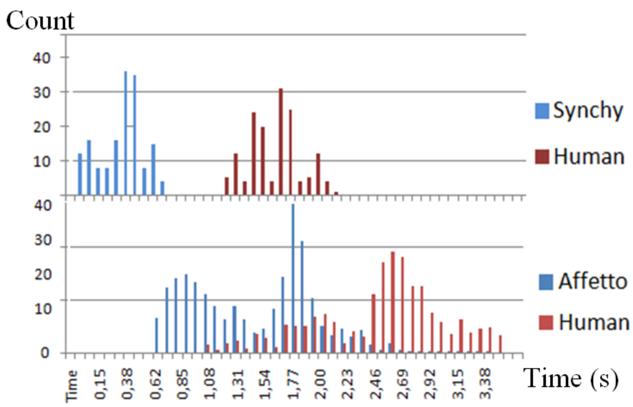

Fig. 2. This figure represents the response time histogram of the experimenter that imitate robot's motions. Upper part represents the results with small temporal variance using an electrical robot names Synchy. Bottom part represents the results with the robot Affetto with larger temporal variance.

C. Result: MNS emergence

In the main experiment, we attended to prove our hypothesis by reproduce Nagai et al.'s experiment with small variances in motions (see [6]) and compare with the result with a larger temporal variance in the robot's motions. For this experiments, we set the vision acuity to $\Psi = 0$ (immature acuity) and then, linearly increment it to $\Psi = 1$ (mature acuity): $\Psi_{t+1} = \Psi + 0.05$. The Fig. 1 shows the extraction of visual information for vision acuity of $\Psi = 0.5$ (middle stage of development). The Fig. 3 represents the sensorimotor mapping acquired through Hebbian learning between the robot (self) and the experimenter's (other) motions information and the robot's motor commands. We call connection the link between a motion information and a motor command. The algorithm has been trained with 100 sets of data and then tested with 100 different sets. In the Fig. 3, we clearly see that in both variance settings, there are good connections between the experimenter's motions and the robot's motor commands. However, the connection strength is stronger if we use a larger temporal variance in the robot's motions.

IV. Conclusion

These data corroborate the results acquired by Nagai et al. with an electrically actuated robot (cf. [7]). However, the connection between the other's motions and the self's motor commands appeared stronger when the temporal variance in motion was larger, which corroborates our hypothesis on the role of the temporal variance in the emergence of MNS. We can then conclude that temporal variance in motion facilitate the emergence of self/other correspondence (cf. Fig. 3). However, human motions also have a larger spatial variance than electrical robots. Further works will attend to show the effect of both temporal and spatial variances to show the effect of human-like motions for the emergence of MNS.

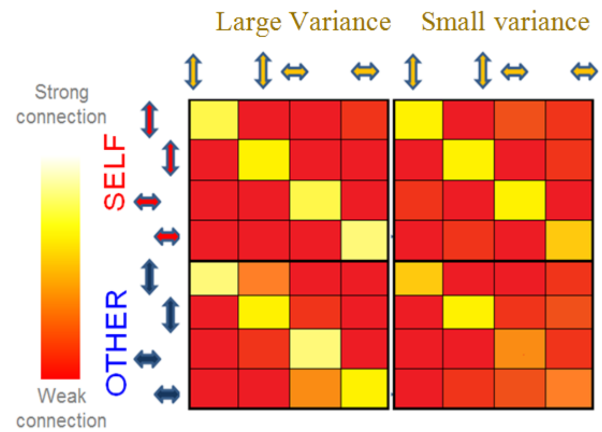

Fig. 3. Sensorimotor mapping acquired through Hebbian learning. Each colored area corresponds to the activation strength of the output (motor command) for a specific input (Self or Other's motion). SELF (Red): robot's motions. OTHER (Blue): Experimenter's motion. (Orange): Robot's motor commands

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