



On the relationship between mouth opening and “broken mirror neurons” in autistic individuals

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ABSTRACT

Electromyographies of the mylohyoid muscle (MH) during the execution of the goal-oriented action “grasping to eat” have been used to determine the time relationship between the opening of the mouth and the beginning of the movement. This has been used to distinguish the behaviour of typical developing (TD) children from that of highly functioning autistic (ASD) individuals. The results of previous studies appeared to provide evidence of a deficit in action chain organization in ASD subjects and prompted the hypothesis of a “broken” mirror neuron system (MNS) for these individuals. Our results show the MH activation timing is not reliable in discriminating between TD and ASD children and the distance between the food and the subject plays a key role on the MH activation timing and cannot be neglected when analysing these type of data. The preliminary investigation on the effects of external perturbations also shows that these might have an effect on the results and further investigations are warranted. It appears that there is not enough evidence to support a link between ASD and a broken mirror network system (MNS), and the experimental results must be carefully interpreted before developing therapeutic or rehabilitative protocols.

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1. Introduction

Observational and behavioural studies performed during the 1980's and 1990's suggested that the main disability causing core autistic symptoms is the lack of imitation (Charman et al., 1997). Further investigations then hypothesized that the ability of imitating could be reduced because autistic individuals are unable to distinguish the goal of an action, prerequisite both for action understanding and conscious emulation (Boria et al., 2009).

Action understanding is a complicated multi-associative task requiring complex interactions between different neural populations and brain areas (Meltzoff and Decety, 2003; Greimel et al., 2010). Nonetheless, a specific neural substrate in the pre-motor area has been advocated by some authors to be central for this process. This occurred after bimodal responses during action execution and presumed action observation were noticed in experiments conducted recording single-cell electrical activity in some neurons located in the pre-motor cortex of monkeys as well as humans (di Pellegrino et al., 1992). The authors named these neurons “mirror neurons” (Rizzolatti et al., 1996) and they thought they represented a “direct matching hypothesis”, that is, what they assumed to be an unequivocal mapping between an action and its cortical motor chain representation (Gallese, 1999). In other words,

Rizzolatti and co-authors considered them a sort of motor dictionary a subject can use to interpret the actions of other individuals.

Notwithstanding the numerous doubts about the simplistic attribution of emerging “cognitive” proprieties to a single cortical cell “embodied representation”, the model of cognition centered on “mirror neurons” has gained large interest in interpreting several aspects of human social activities. This is due to the intuitive explanation of how individuals might interface with others through a “direct match” where, provided that motor patterns are preserved and uniform among individuals, recognizing one own actions' goal permits to establish another's actions goal from the first link of a motor chain. This led to a new perspective in autism patho-physiology, hypothesizing that a deficit in action chain organization might be the key to understanding why individuals affected by autistic spectrum disorder (ASD) lack communicative, imitative and empathic skills (Oberman and Ramachandran, 2008).

The hypothesis regarding the role of mirror neurons in ADS has been investigated by comparing the execution of a goal-oriented action “grasping to eat” between a group of typical developing (TD) children and one consisting of high functioning autistic individuals (Cattaneo et al., 2007). A goal-oriented action consists of a precise sequence of motor acts, the last one of which can be considered the goal (“eating the food”, in this case). In that work, the experimenters used the EMG analysis of the mylohyoid muscle (MH) activity to determine when the opening of the mouth happened with respect to the beginning of the movement. The authors

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reported that ASD subjects appeared incapable of prefiguring the goal of the action proposed since, during action execution, their MH was activated to perform the concluding act (“opening the mouth”) later in time than for TD subjects. Thus, the results appeared to provide evidence of a deficit in action chain organization in ASD subjects. Furthermore, assuming that the ability to prefiguring a goal is implemented by the mirror neuron system (MNS) via an embodied simulation of the complete motor act, it seems logical that any MNS dysfunction would account for the inability of ASD individuals to anticipate the action’s goal.

However, in reading the article reporting the aforementioned experiments (Cattaneo et al., 2007) we realized that there might have been some issues with the methodology used. For instance, the presence of several experimenters during the tests (as illustrated in the supporting additional material available online for the original article) might have affected the results, as could have the distance between the subject and the food, distance that appeared to have been left uncontrolled in their experiments.

Given the important implications of the results of the study of Cattaneo et al. we decided to try and confirm their results by reproducing their experiments although in a more controlled way.

2. Methods

As the goal of this work was to try and confirm the results obtained by Cattaneo et al. we accurately and diligently followed their methodology, and rather than repeating it here we refer to their work (Cattaneo et al., 2007). However, some changes were made, as we suspected that their methodology did not allow a sufficiently controlled experimental setup.

3. Experimental protocol

The experiments called for the subject to release their right hand from the button, take a piece of food placed on a touch sensitive plate, bring it to his mouth, eat it, and finally press the button again. Furthermore, the subjects had to keep their head fixed and steady, while performing the movement (this was not the case in the work by Cattaneo et al. (see the additional documentation provided with Cattaneo et al.)).

Suspecting that the results could be affected by the geometry of the movement of reaching the food and bringing it to the mouth, three relative distances between the subject and the food were investigated. First, the subject, with the upper extremity partly flexed, was allowed to position himself at a “natural” and comfortable distance from the food. Then, in subsequent trials, the food was moved closer to or further away from the subject forcing him to combine the motor strategy used in the movement of the arm alone with motor acts involving other muscular groups. More in detail, for each subject, the distance in the sagittal plane between the shoulder joint and the tip of the index finger of their upper extremity in their “natural” condition (L_0 , also known as the anti-gravitational condition when all the muscles are in their resting state) was measured from the shoulder joint to the tip of the index finger. This distance allows an optimal movement of the arm, starting from the resting position of the muscle according to the theoretical model of the muscle formulated by Hill (1938). The experiments were therefore conducted with the food positioned at three different distances: L_0 , $0.7 \times L_0$ and $1.3 \times L_0$. Each subject repeated the grasping movement ten times for the L_0 distance, and six times for each of the other two distances, with an inter-trial interval of 30 s.

To verify if external perturbations would influence the results, before proceeding with the experiments reported in this work, we tested one additional TD subject with the food positioned at

the distance L_0 . The subject was tested eight times, six unperturbed and two, randomly inserted in the sequence, during which an external perturbation (knocking on the door) was added during the reaching action. For all the other tests reported in this work, the subjects were alone in a quiet environment, albeit under the remote supervision of the experimenters and a therapist, whereas in Cattaneo et al. several experimenters and other persons were present in the room with the subject while the experiments were conducted (see the additional documentation provided with Cattaneo et al.).

3.1. Participants

Two groups of male subjects were involved in the experiments: the first group included 12 right-handed, typically developed children (TD). The second group included seven right-handed high-functioning children with ASD. They were matched for age (TD children: 7.7 ± 1.28 years old; children with ASD: 7.3 ± 1.76 years old) and with intellectual abilities (I.Q.) in the normal range (70–115) as assessed using the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1995). The children with ASD were diagnosed according to the Autism Diagnostic Observation Scale (ADOS) (Lord et al., 2005), a commonly used diagnostic tool, and followed by the local neuropsychiatric service “Servizio Neuropsichiatria Infantile, Azienda per i Servizi Sanitari n 4 Medio Friuli” for over one year. Their ADOS score was greater than the cutoff for Autism classification (14.85 ± 3.54 versus a cutoff of 7), so there was no doubt about their diagnosis as children with ADS.

3.2. Instrumentation

The custom made experimental setup (Fig. 1) included a start-stop button (to identify the beginning and end of the movement), an infrared photocell gate (to make sure that the trajectory of the approach phase was consistently maintained in the horizontal plane), and a touch sensitive plate (to identify the instant when

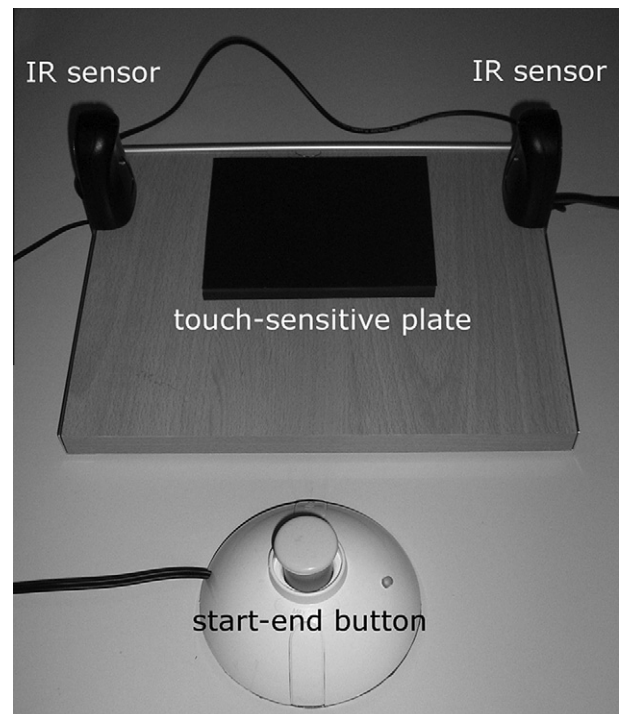


Fig. 1. Custom made instrumentation for the experimental setup.

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