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MIRROR NEURONS, EMPATHY, LANGUAGE A REVIEW ON THE EVOLUTION OF LINGUISTIC FUNCTIONS

Introduction

Since the discovery of the mirror neuron system (MNS), in the ’90s of the last century, a considerable number of studies – not only proliferated within neurosciences, but also in the field of cognitive sciences (philosophy, psychology, linguistics, etc.) – has reinvigorated research and debate on the origins of language. In light of these investigations, we ask to what extent the hypothesis of a possible embodied development process of the verbal language may reach. Or, to what measure the perceptual and motor sensory elements have been crucial to characterize the auditory-vocal synergy from the continuity with earlier forms of gestural communication? Finally, what was the role of the group, that is the emotional, relation and social context of this complex evolution: in particular, can it be considered a connection between empathy and the evolution of linguistic functions?

In this paper we will try to give some answers by referring to the recent scientific literature on the activity of mirror neuron systems. We

will also aim to trace the biological basis, primarily emotional, but also cognitive, of empathy that would be decisive in the stages which, from the evolution of the most archaic forms of gestural communication, led to the development of verbal language.

1. *Aimed motor schemes*

In humans, the most important mirror neuron systems are located in the frontal lobes (particularly Broca's area and premotor cortex) and parietal (inferior and anterior) of left the hemisphere: they, together with Brodmann's area 44, are responsible for motor behaviour and the representation of the hand and mouth movements (Buccino *et al.* 2001; Ferrari *et al.* 2003). The investigation of brain imaging – using functional magnetic resonance (fMRI) and transcranial magnetic stimulation (TMS) – has shown that mirror circuits are responsible for both the representation of mouth movements of the hand and the mimed acts and foot movements (Aziz-Zadeh *et al.* 2004; Buccino *et al.* 2004a; Binkofski, Buccino, 2006).

Several experiments have shown that in men important mirror areas of both hemispheres (especially the inferior frontal gyrus of the left hemisphere) are activated when they observed orofacial motor

behaviours (as chewing) of individuals of their species rather than in other animals (monkeys, dogs, etc.). Similar results occurred when the motor repertoire dealt with oral communication rather than with eating. Watching someone else eating, seeing a man talking or listening to sentences clearly evokes a repertoire of actions greater than that required, for similar behaviour, from other animal species (Buccino *et al.* 2004b). Some researchers (always using fMRI) have investigated the neural function of Broca's area during the execution of a task, which involved the recognition of a movement pattern or required to match the gestural (manual) expression for the production of a verbal predicate. In this case, it has been observed the activation of the mirror circuits of the inferior frontal gyrus, the precentral gyrus, of the lower and upper parietal cortex and the intraparietal sulcus of the left hemisphere which would constitute the related morphological and functional structures of the vocal articulation (Hamzei *et al.* 2003; Skipper *et al.* 2007; Sato *et al.* 2008; Borghi, Scorolli 2009).

The motor skill perceptual properties and wealth of human mirror neurons seem better than in monkeys – or in other animals, where there would be only involuntary repetition phenomena, or facilitation of the response behaviour – which would be functional to the processes of

imitation and learning (Oztop *et al.* 2006). The real imitation behaviours concern the reproduction of a voluntary action aimed at a learning process (Del Giudice *et al.* 2009). This seems confirmed by some studies according to which the observed behaviours are first decomposed into a series of simple actions (recognized as belonging to the vocabulary of acts of the subject) and then reassembled in a new motor way to imitate and learn (Iacoboni *et al.* 2001; Byrne 2003).

The mechanisms of imitation and learning would be allowed by the possibility of exploiting the phenomena of understanding and recognizing the movement patterns, of evaluating the effects of observed actions, but also of the mirror circuit specific modality to encode the sensory-motor information in a common and shared neural format. In these cases complex cognitive processes are also involved– through the intervention of several cortical regions – which relate to functions such as attention or memory and specific control mechanisms that may facilitate or inhibit the activity of mirror neurons. The mirror neuron systems seem so involved in imitation, in encoding mnemonic and therefore in the learning of new motor configurations (Buccino *et al.* 2004c).

Considering the whole production and perception aspects, human language has a significant motor component, which is evident in the vocal articulation, in the non-verbal gestures, in the structure of sign languages and in writing. The linguistic behaviour concerns mainly the cortical functions of the left hemisphere in same parts where the mirror neuron systems seem to be more widespread and in synergy with the motor areas (Corballis 2009).

The recent hypothesis about a progressive and parallel evolution of both mirror systems and gestural and verbal communicative functions are based on the extraordinary cognitive and linguistic importance of Broca's 'motor' area which is responsible for laryngeal, oral-facial, arm-manual movements (as well as for syntactic and semantic associations) and which is the seat of the most important structures of mirror neurons (Rizzolatti, Arbib 1998; Iacoboni, Wilson 2006). Probably, the evolution of the vocal over laryngeal tract of the species *Homo sapiens-sapiens* has taken full advantage, along with other cognitive functions, of the ability of mirror cortical structures and allowed the development of the faculty of speech and of the related linguistic function (Corballis 2009; Bucca 2012a).

Therefore, it seems that language evolution has gone through a series of stages in which the importance of mirror neural systems involved in the processes of immediate understanding-recognition of specific motor acts, imitation, learning (as well as the reproduction and the intentional use of linguistic behaviours) are necessary and crucial. They would not only constitute the (preconceptual and prelinguistic) neural and motor prerequisite of gestural articulation and human language, but, as other studies seem to demonstrate, they would have an important role also in the recognition of emotional states that are the basis of subjective and social experiences (Rizzolatti, Arbib 1998).

2. *Emotional communication and linguistic (cognitive) use*

According to some studies, the species *Homo* has gradually developed several communication patterns starting from the imitative and learning behaviour allowed by the functional characteristics of mirror neurons and by their cognitive control (Molnar-Szakacs *et al.* 2006; Bucca 2010). Such forms of communication would be first gestural, or arm-manual, from which, however gradually, during the phylogenetic evolution, the articulation of verbal language would originate (Gentilucci, Corballis 2006). In this case, however, despite the

hypotheses that would ascribe the origin of language as deriving from animal vocalizations, the focus is the gradual transition from manual gestures to oral gestures (Corballis 2009; Zlatev 2008).

Apparently, the animal calls may seem 'closer' to human vocalizations, however there are significant differences in both their structural and functional nature. According to brain morphology, primates' vocalizations involve mainly the subcortical areas including the cingulate gyrus, the diencephalon and brainstem. Moreover, in primates it is not possible to detect morphological structures similar (especially from a functional point of view) to those of the vocal over laryngeal tract, which allow the articulation of speech sounds (Lieberman *et al.* 1972). As we know, human vocal articulation is permitted by the involvement of cortical areas, especially those of the left hemisphere, particularly of the frontal and temporal lobes (Jürgens 2002; Bucca 2003).

On the other hand, from a communicative point of view animal vocal 'production' is linked exclusively to emotional purposes related to survival: reporting danger (fear), indicating the presence of their fellows (joy), or of food (surprise), ritual coupling etc. Naturally, besides emotional-communicative needs of this type, human vocal articulation

also implies much more complex cognitive and linguistic behaviours: for instance, the (subjective and inter-subjective) computational, referential, relational use of verbal symbols (graphemes and phonemes) (Hauser *et al.* 2002).

About two million years ago, the hominid species *Homo habilis* probably began to communicate through a rudimentary form of gestural proto-language, whereas the species *Homo erectus* was probably capable of producing motor actions mimic-gestural. While, as shown by the cast of the skull obtained from the fossil, the species *Homo sapiens* had already brain structures (especially as to the areas of the left hemisphere and possibly as to the mirror neuron systems) that would allow the development of both the gestural communication mode and the first vocal articulation (Corballis 2009).

The human evolution of subsequent to *Homo sapiens-sapiens*, will be characterized by a cognitive and intentional use of the gestural and vocal communication skills. At the base of the language phylogenetic development, it seems conceivable to hypothesize a shared communicative act instinctive mechanism, which would allow first to approach and then to associate the gestural meaning to those of words (Arbib 2005). The word roots of historical-natural very different

languages (Polynesian, Chinese, Indo-European, etc.) would evoke, in fact, the relationship between the original manual movement and the vocal articulation: there would be some sort of relationship between gestures and linguistic sounds that would reproduce respectively large or narrow movements (Paget 1930; Gentilucci, Corballis 2006).

The attention to the linguistic function of the six articulators of the vocal over laryngeal tract, which allows the production of sound gestures, is at the basis of the so-called *speech perception motor theory* (Corballis 2009). This assumption would have the advantage of adding to the original manual gesture the perceptual component and, together with it, the hearing-voice synergy (Lotto *et al.* 2008; Corballis 2009). Together with the role of auditory perception, it must also be considered the importance of memory processes and of language recursive characteristics (Aboitiz *et al.* 2006).

To sum up, a simple reference to the manual configuration of sign languages (SL), that is the primordial form (or rather, 'natural', for the deaf) of 'gestural communication' is enough: the function of the frontal and parietal lobes for the understanding and production of sign languages, as well as that of the mirror neuron systems is well known (Corina, Knapp 2006). During the phylogenetic evolution, then, the

verbal language seems to have exploited the perceptual-motor possibilities allowed by the Broca's area and mirror neuron circuits (especially the so-called *echo*-mirror neuron systems) both for the recognition of phonetic motor patterns, and for those typical of vocal articulation (Rizzolatti *et al.* 2006).

3. *Empathy and social sharing*

Practically, the activity of mirror neuron systems allows a purpose-oriented 'resonance' action, the same which would be at the basis of motor perceptual mechanisms, especially the linguistic ones which are detected in an «embodied simulation»: therefore, the activity of these neurons would also be the source of the shared inter-subjective space. The act of understanding reflects the act of simulating, with the difference that understanding others' 'objective' actions constitutes an automatic simulation process, while imagination would be the will to raise the simulation. Even before being considered a symbolic-cognitive faculty, representation – at a brain physiological level – would consist of an elementary «pre-concettuale» and «pre-linguistico» process of «controllo dell'azione» that only later would be re-adapted for «interscambi con il mondo *esterno*» (Gallese 2006, p. 299-305).

Thus, mirror neurons would play a role also in the «sistema della molteplicità condivisa», in the «relazioni d'identità» at the bottom of empathy and intersubjectivity. Some areas of the somatosensory cortex would constitute the empathic resonance sensory substratum, which seems to distinguish itself primarily because of its body experience feature, that is its «percezione di una relazione di *somiglianza* con l'altro [che] risiede nella comune esperienza dell'azione» (*ibidem*, p. 308-20).

The emotional root of empathy would rise out of the *emotional contamination* or even in the manifestations of *suffering*, which are evident in several animal species, while the more evolved feelings of *compassion* would belong to primates and humans, but only in that the latter (and empathy) are the essential foundation of cognitive and moral behaviours. Among the forms of animal emotional contamination and human empathy feelings, there would exist a *trait d'union*: but only humans are aware of the difference between the perception of one's emotional condition and that of the other, or the recognition of the difference between his experience and that of the other. Some experiments on consolation or assistance behaviour, as well as studies in mirror image self-recognition on anthropomorphic monkeys would show, however, that these primates would be able to represent the point

of view of the other, and probably to feel empathy (Preston, de Waal 2002).

According to the theory of the *matryoshka model*, hypothesized on the basis of the *perception-action mechanism*, the phenomenon of empathy would be the result of complex processes of primarily emotional stratification. It would have its origin from the (animal) emotional contamination and then it would take the connotations of cognitive empathy at the time of the (first emotional) assimilation and identification in a different experience: this form of empathy would be characterized, mainly, by the other's feeling recognition as well as of his views and his personal experiences (de Waal 2008, p. 62-3).

Besides the emotional sphere, empathy also involves the reflexive and cognitive abilities, the same which allow the understanding of someone else's different experience, and the recognition of a different subject. This implies the need to represent concretely desires, intentions, personal and interpersonal expectations of the other even before entering into a relationship (Bucca 2011). Hence, the need to make inferences, predictions and to attribute beliefs. Through a *theory of mind* (ToM), empathy calls into question the recognition of states of mind (as well as emotions) and the experience of the other. Apart from the emotional

component, which embodies the essential biological basis of empathy being a subjective experience as well as somebody's else, it keeps a very close connection with mind reading, that is with a typical cognitive ability (Stueber 2010; Bucca 2012c).

Empathy starts from the disposition to identify oneself with the other, sharing desires, feelings, intentions and beliefs. It is an experience, which deals with the subjective and inter-subjective experience, relating in various ways to body, emotions, mind state and will. This phenomenon of deep closeness and participation to the experiences of the other begins with the act of *realizing*, namely with the *discovery* and recognition of the other's experience as a different experience from the self: in this sense, it embodies the otherness, another's actions (subject-object-subject) and the relationship to the other (Stein 1998). However, being a specific way to *feel the other*, empathy allows at the same time to recognize the diversity of others and to recognize the self, to individualize: it is, therefore, a peculiar kind of experience in which subjective experiences open to inter-subjectivity, integrating different ways of being within a common feeling (Boella, 2006).

Considering the genetic substratum, the morphological neural correlates, and the evolutionary continuity in part shared, at least, by in

part the animal world, the emotions on which empathy is based would represent the phylogenetic «punto di partenza» of progressive processes of social and cultural development. «La forma originale, prelinguistica, del rapporto interindividuale che solo in un secondo tempo ha subito l'influenza del linguaggio e della cultura» (de Waal 2008, p. 45-6) would derive from theemotional nature of empathy. Probably this is reason why, during phylogenetic evolution, this state would be useful also to strengthen the relational ties which are necessary for the survival of the individual and especially of the group.

It seems, therefore, that during the phylogenetic evolution mirror neuron systems have carried out really important perceptual, cognitive and motor functions. In particular, in the *sapiens-sapiens* hominids, they would allow to develop first the communication gestural mode and then the first forms of vocal articulation (Bucca 2012b).

In addition to emotional communication needs – common to the rest of the animal world to which they are linked only for reproductive purpose or for survival – the human vocal production implied much more complex cognitive and linguistic behaviour. The evolution of human language, in fact, has been characterized by the cognitive-

intentional-relational use of the abilities offered mainly by forms of vocal production.

To do so, the activity of mirror neurons would have also contributed through the so-called *multiplicity shared system* which would represent the cerebral basis of empathic phenomenon and, therefore, of the inter-subjectivity. Permitting to assimilate one's experience to the other, empathy during evolution of hominids proved to be very useful to strengthen the bonds of solidarity within the group and, with them, probably it also encouraged the development of verbal language naturally together naturally with the rest of emotional, cognitive, social and moral behaviours.

Conclusions

In light of its emotional, cognitive and social characteristics, empathy seems particularly linked to the activity of mirror neuron systems. Since the discovery of these neural circuits in macaques and humans, a large number of studies seem to have indicated in cortical functions, in auditory sensory morphological correlates, and vocal over laryngeal tract – together with the role of inter-subjective bonds played by empathy – the key elements of the phylogenetic evolution of language.

From an evolutionary and natural perspective, the discovery of mirror neuron systems (beyond the explanation of sensory, perceptual and motor cortex functions) has helped to redefine a number of concepts crucial not only in neurosciences, but also of great interest for philosophical and linguistic research areas. Some of these, as we have tried to show, directly concerning the origin of language: especially for what concerns the nature of perception, understanding, (subjective and intersubjective) representations and the phenomenon of empathy.

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