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MIRROR NEURONS, MEANING AND IMITATION: FACTS AND SPECULATIONS ON LANGUAGE ACQUISITION.

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Abstract:

Recently discovered mirror neurons systems play a major explanatory role in the understanding of human features like imitation, empathy and also language learning. This neural system is at the basis of social, interpersonal and affiliative behaviour. Mirror brain cells circuits are active during imitation activities and may contribute to the ability of learning a language. This article addresses some theoretical implications of the discovery of mirror neurons and will try to evaluate to what extent it can provide a new empirical ground for research in foreign language acquisition.

Parole chiave: *neuroni a specchio, neurolinguistica, acquisizione linguistica, imitazione.*

1. Mirror neurons and meaning

Mirror neurons were first discovered by a team of Italian researchers at the University of Parma (Gallese, Fadiga, Fogassi, Rizzolatti 1996) in the late '90s, who named these groups of brain cells "mirror neurons" for their ability to mirror the actions of others: they respond to both performing an action, to observing it, and to hearing its sound (Théoret, Pascual-Leone 2002; Buccino et al., 2005). These peculiar properties of mirror neurons have brought scientists in the field of neuroscience of language to think that mirror neurons may be critical for communicating, for learning gestures and attuning to others; ultimately, they might play a determinant role in acquiring language. Actually, this population of cells is found in a region of the human frontal lobe -Broca's area- which is close to the motor cortex. Broca's area [Figure 1] is responsible for the production of speech, so, the presence of the mirror neurons' system in this region could be involved in the recognition of actions as well as *phonetic gestures* (Gallese, Fadiga, Fogassi, Rizzolatti 1996).

Both the acts of *performing an action* and the acts of *producing speech* are not single movements, but complex actions that derive from the *intention of doing* or *saying* something: there is an abstract feature common to both motor and speech actions and that is *meaning*. This system works in the recognition of witnessed actions as well as in the performing of the same actions and is, therefore, a matching system that connects what is perceived (sensory areas[1]) to what we want to do (motor areas) passing through *comprehension*.

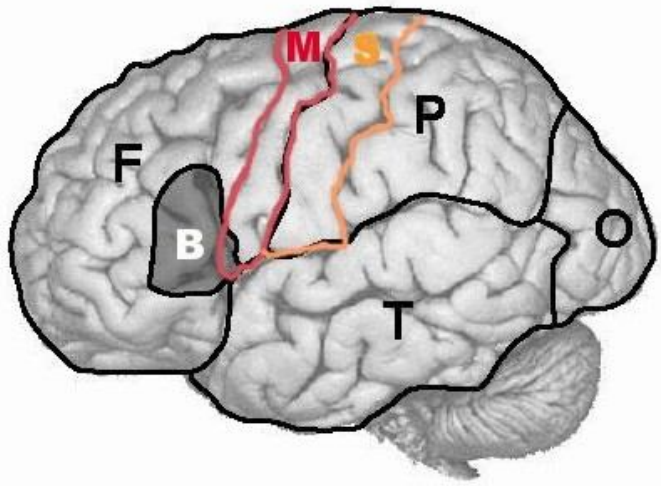

Figure 1: Left Hemisphere showing the Frontal Lobe (F), the Parietal Lobe (P), the Occipital Lobe (O) and the Temporal lobe (T). The area in grey is Broca's Area (B), close to the Motor Cortex (M) (Luppino, Rizzolatti 2000). In the Parietal Lobe is the Sensory Cortex.

Thus, our brain "is not only a brain that *acts*, but it is first of all a brain that *understands*"[2] (Rizzolatti, Sinigaglia 2006): language itself entails, in the word choice, the difference between *simple movements* and *complex actions which are endowed*

[1] As shown in Figure 2, not only an posterior inferior part of the Frontal Lobe is involved in the mirror activation, but also a sector of the Parietal Lobe, which is dedicated to perception.
[2] All translations from Italian are by the author.

with meaning. When we describe actions, we do not say "Extend your arm and open your fingers and reach the apple on the table and close your fingers around the apple and then pull your forearm back towards your body", instead, we say "Grasp the apple on the table", where the word *grasp* entails the chain of movements described above and performed as a single action, an *act with meaning*. When watching an hand performing the initial stage of grasping –such as an arm extending towards an object- our brain already knows the intention of this action, that is, we do not see nor do we understand one movement of the sequence at a time, but we *learn* the whole sequence, store it in our memory as *an act that has meaning*, and retrieve it *anticipating* that meaning when we see it performed by others. To express it with Rizzolatti and Sinigaglia's words (2006):

> "The recognition of others, of their actions and especially of their intentions depends on our motor inheritance. From the most elementary and natural acts, as grasping food with the hand or with the mouth, to the most sophisticated acts which require particular abilities, as the performance of a dance step, a sonata for piano or a play, mirror neurons allow our brain to correlate observed movements to our own movements and thus, to recognize the meaning. Without a system like that we could have a sensory representation, a "pictorial" depiction of the others' behavior, but this would never allow us to know what the others are really doing. […] Our brain is able to understand this immediately without recurring to any kind of reasoning, based on its own motor competence only. The mirror neurons system seems to be critical for the arise of that common ground of experience at the base of our capacity of acting as not only individual subjects , but also and mainly as social beings. Actually, more or less complex forms of imitation, of learning, of sign and even verbal communication find a precise correspondence in the activation of specific mirror circuits. Not only: our very same ability to understand emotional reactions in others is correlated to a particular group of areas characterized by mirror properties. As with actions, emotions are immediately shared too: […]. This shows how deep-rooted the bond that ties us to the others is, or rather, how bizarre it would be to conceive an *I* without a *we*"[3].

Mirror neurons [Figure 2] might be the neurological substrate of social interaction, a mechanism that allows us to understand the others' actions and intentions in order to build that common frame that is social cognition: I know what another person is doing because I share the same knowledge and *knowledge* is based on *meaning*.

[3] Translation from Italian by the author.

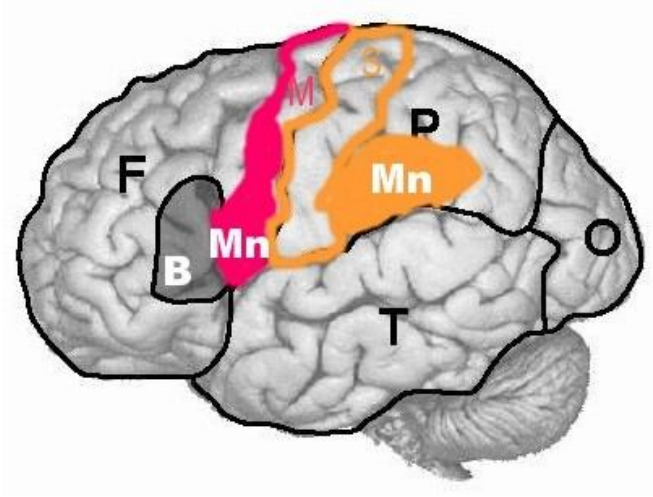

Figure 2: The part in orange represents the region of the Parietal Lobe that is active during the performance of actions and during observation of the same actions performed by others. The part in red is the area of the Frontal Lobe that is active in the same experimental conditions. These regions form the parietal-frontal mirror neurons system (Mn). (Buccino et al., 2001)

This means that we share the same code for meaning[4]: an action , or a gesture, are encoded in the brain in the same way for both participants in the interaction, so that it is possible for both subjects to understand, to reproduce, to imagine, to recognize and to anticipate that action or gesture. In others we see actions and intentions that we also might, respectively, do and have. When we observe another person performing an action, we are *potentially* able to reproduce it because that action has a meaning we know or that we can learn. On the other hand, the same is valid for someone observing us: it is reciprocal that every action we perform takes on meaning immediately in the observer. This builds a space of common action and meaning.

Besides, as Rizzolatti and Sinigaglia (2006) point out, we easily understand the *beliefs*, the *expectations*, the more or less overt intentions and *goals* of the people around us. What is fascinating about mirror cells is that they are not only able to recognize an action as a complex series of movements with a meaning (like *grasping*) but they also encode features that may occur in the scene of that performed action (context) and that are not performed yet (anticipation): we can grab a cup *to drink* from it or *to move* it to another place.

Intentions are detected from the very beginning of the action (Fogassi et all, 2005) and determine the specifications of that initial movement we observed. There is an expansion of meaning: only some contexts and only some intentions are correlated to a specific action so that our brain is able to understand and to anticipate the correct chain of events and also the goals we want to reach, even without seeing the conclusion of the action (Umiltà et al. 2001). As in Iacoboni et al.'s experiment (2005), we can grasp a cup to drink from it or to move it: if the context where we see the cup is a table prepared for taking tea, we are prone to think that the cup will be used to drink; but if we see the cup on a table where tea has already been served, we tend to grasp the cup to move it from there and this action of grasping will be

[4] In this case we refer to the meaning of an action or a gesture, not to the broader concept of *knowledge*. Besides, the direct meaning that we are able to grasp through our mirror neuron system is pre-conceptual and pre-linguistic: it has to do with a pragmatic comprehension on which, later, higher cognitive functions are based. (Rizzolatti, Sinigaglia 2006)

different: we apply a different meaning to what initially could be potentially the same act of grasping.

Hence, mirror neurons in the human being have the function of decoding both the chain of single movements as an *act*[5], but also the *aim* of that act. In both cases it is necessary to apply meaning. Mirror neurons' primary role is the *comprehension of the meaning* of conspecifics' actions. Through experience we build a special *lexicon for actions* that regulates the organization and the performance of movements (Rizzolatti, Sinigaglia 2006). The more we expand this repertoire, the more we can *infer* the others' actions: whenever we observe an action, we have a direct experience of it *as if* we were doing it ourselves, thus getting its meaning directly.

The discovery of the mirror neuron matching system sheds light not only on the relationship between sensory and motor functions, which seem not to be separated as previously thought, between sensing and doing, but it also provides valuable insights on how our personal knowledge bridges to implement social understanding. To summarize, mirror neuron systems:

– Integrate perception and action: we learn when we observe and when we act.

– Are able to recognize actions as acts that have a meaning and are goal-directed, thus they can ascribe abstract content (semantic content): they not only know the schemas of how to perform an action, but they link an *idea in terms of goals and intentions* to it.

– According to the context the action is taking place, they anticipate the possible goal of that action.

– Allow us to share a common ground of knowledge: this is at the base of every social interaction.

– Adapt and change their representations of actions according to experience and through interaction. As Catmur et al. (2007) posit: "[…] the mirror properties of the mirror system are neither wholly innate nor fixed once acquired; instead they develop through *sensory-motor learning*. Our findings indicate that the human mirror system is, to some extent, both a product and a process of social interaction."

Another property which has been studied in mirror systems is their imitative ability: the capacity to imitate on the base of solely witnessing.

2. Mirror neurons and imitation

The matching activity of mirror neurons in both the parietal and frontal regions (sensory and motor areas respectively) raises the question of how correspondence between these two regions is possible, and, more specifically, how a transmission of information occurs when it uses different codes, that is:

– How do we translate visual information into action?

– How can we do the same action that we perceived, only on the base of observation?

[5] With the noun *act* we mean "a series of movements", so it is synonymous for *action*. For a different definition see Rizzolatti, Fogassi and Gallese 2001.

– How do we transfer *competences* and *abilities* which are not yet part of our repertoire?

When we repeat an action that we have just seen we *imitate* that action by means of a "resonance mechanism" (Rizzolatti et al. in Meltzoff 2002). To answer the first two questions, Prinz (in Meltzoff 2002) argues that this mechanism (that could be the mirror system) must provide *a neural code common to* both *perception and execution*. This mechanism with a "sensory-motor common representational scheme" is fundamental and at the basis of inter-personal relations including behaviour commonly described as "imitation."[6]

It is relevant to our discussion to distinguish two types of imitation behaviours:

1. Imitation of an action that we already know. This means we can activate a mental image of that action because it is in our repertoire and reproduce it. An action can be imitated with or without understanding the meaning. Simple imitation of an action without a meaning is usually interpreted by healthy adults as strange; actually, it does not happen so often among adults[7] to imitate the others' behaviour without a goal. But we notice it in infants. Few days old infants are able to reproduce buccal gestures, but there is no meaning in those gestures. Though, it could be a way for the infant to establish a link with the adult, which is very important to her survival (Rizzolatti et al. 2001).

2. Imitation of a new action pattern or *complex imitation.* This acceptation of the word *imitation* will be relevant to our later discussion of language insofar as it assumes that there is *learning of new complex input*. In this case, imitation is a complex phenomenon that enables us to transfer competences and abilities, in a word, it is useful to learning. To exemplify it, we can imagine a person learning a guitar chord: she observes her music teacher's hand on the guitar string, she must learn all the fingers positions (set of single movements), then forms the chord, and finally plays it as a whole.

In both cases of imitation there is activation of the mirror neuron system.[8] In the second case however, in the presence of *learning via imitation* (Rizzolatti, Sinigaglia 2006), the mirror system is a necessary condition for imitation, but it is not sufficient: we need a control system above the mirror mechanism able to detect if it is the case that an action we see (a potential action we can repeat) turns into a performance: if there were no control mechanisms on mirror neurons, we would compulsively imitate every potential motor action. The Frontal Lobe seems to be

[6] For a detailed discussion on the theories of imitation see Meltzoff 2002. Here we do not refer to imitation as a replica of someone else's action that we already know, but as a detailed reproduction of a new action pattern learnt by observing a conspecific.

[7] "Response facilitations" without meaning in adults are laughing, yawning, crying and mimicking facial expressions. (Rizzolatti et al.2001)

[8] In infants, a mirror neuron system is present at birth that could be responsible for their capacity to imitate buccal gestures, notwithstanding the fact that their sight is very weak. Their frontal lobe cortex is also not fully developed and its functionality is weak. Infants might have a very weak control system, allowing them to imitate in the form of simple *resonance* (Meltzoff 2002).

involved in this controlling activity: we can *refrain* from imitating, or we can *decide* to imitate an action.

Thus, the capacity to imitate an action involves a more complex system, not only the mirror neurons, but mirror neurons seem to be necessary to activate the process, due to their property of decoding sensory-motor information into a common neural code. Further study must be devoted to *how* mirror systems work, to fulfill the need for a more precise understanding of imitation.

3. Imitation and language acquisition

Notwithstanding the lack of heuristic data about the processes by which mirror neurons are able to decode information, because of their peculiar decoding properties and relevant role in imitation, mirror neurons are good candidates to the hypothesis of how language is acquired and they can provide clues to how children learn: mirror neuron circuitry is present at birth. Meltzoff (2002) reports that children are hard-wired for imitation, and that their mirror neurons are involved in observing what others do and in practicing doing the same things. Imitation might be indeed a central notion in the language learning process: reflection and observation of children acquiring their native language reveals some striking insights about the role of imitation:

- Imitative behaviours might be extremely important both for learning language and for the development of the other cognitive abilities.
- Imitation has a key role in building a common relational ground that we need to communicate and to relate to others (Nadel 2002; Gallese, Keysers, Rizzolatti 2004). Language, communication and social interaction are tightly interconnected and serve, ultimately, to link us to others. We relate to our conspecifics through our actions and through verbal and non-verbal communication.

Certainly, we do not claim that language acquisition is a result of imitation only, nor are we describing *the mechanism* underlying language acquisition: we are merely describing *behaviours;* however, we assume that the behaviours outlined below might be *functional to* learning language and might be sub-served by the mirror neuron system:

- Ability of infants to imitate conspecifics' movements of the mouth, and vocalizations. As we mentioned above, infants are able to copy movements of the mouth few days after birth, which is crucial both for feeding, for the "shaping" of facial expressions of emotions, and for modulating sounds, linguistic and non-linguistic sounds.. They are also able to repeat vowel sounds or consonant-vowel sounds (ex. "ba", "ma", "ta") very soon (Piaget 1962). At this early stage imitation has probably no linguistic value, but it surely establish an empathic contact between the infant and the caregiver[9] (Nagy, Molnar, 2004).
- Ability of toddlers to imitate adults' actions. Nadel (2002) analyses imitation from a functionalist point of view and posits that "the preverbal child uses imitation to initiate social exchanges and to respond to others' initiations". Young children can imitate adults' actions very early: their imitations will be not as precise and as detailed as the model, but they share many features. Especially during the second year of life, children use imitation in a systematic way, as expressed by Asendorpf (2002): "During the second year of life, children become increasingly able

[9] For a discussion of infants' abilities after birth see Mehler J., Dupoux E. 1990

to communicate with others through *synchronic imitation*, which quickly becomes the most important preverbal form of communication among peers (Baudonnière, 1988; Nadel-Brulfert & Baudonnière, 1982). In synchronic imitation, two children simultaneously play with the same type of objects in a similar, though not always identical, way. They regularly look at the partner and seem to realize and enjoy the reciprocity inherent in their joint play, as indicated by a positive mood, and they often begin and end the object use at the same time or shift to a different activity almost synchronically." Thus employing motoric imitation seems to constitute a means for creating coordinated reciprocal social activity with peer age-mates and with adults, which, therefore, carries an *representational* (Grammont 2004), *intentional* feature:

"In tracing the development of imitation during the first two years, we cannot fail to be struck by its active character. During this period it is in no way "automatic" or "non-intentional." On the contrary, very early we find evidence of intelligent co-ordinations, both in the acquisition of the tools it uses and in its aims" (Piaget 1962). What is noteworthy about Piaget's argument is his consideration of the *intentionality*, the *understanding of aims*, the *co-ordination* and the *dynamism* of this very early form of action imitation: it refers to the second type of imitation process that we described in the previous paragraph, where a new action pattern is learnt, and which would be impossible without a mechanism like the mirror neuron system.

– Toddlers' capacity of vocal and verbal imitation. Usually, we witness an extraordinary ability in young children to imitate not only actions, but also linguistic input beginning from the age of two: "Verbal matching in particular rose dramatically across the second year, a time of rapid language development." (Masur, Rodemaker 1999)

Toddlers begin to imitate the sound of the things and pets around them: for instance, they can imitate the sound of water, the gurgling sound of coffee in the moka, or the animal sounds. At this stage onomatopoeic vocalizations like "Tch-Tch" (referred to the train sound) begin to carry a meaning: they might be conceptual primitives that embody the meaning of a whole sentence ("The train has just passed by", "I have seen a train", "There is the train!") or that might refer to a category since children can utter the same expression when in presence of other means of transportation (or they call "dog" every animal they see) (Piaget 1962): what is crucial to our discussion is that, at this time, *abstract features* begin to be applied to actions and utterances, and that there is a *trans-codification* from an audiovisual perceptual level to the higher cognitive level that characterizes language, and we know that *trans-codification* is a peculiar property of mirror neurons. What can make us assume that the mirror neurons might be fundamental in language acquisition is also the fact that, for example, children say "Tch Tch" not only at the sight of a train, but also when only *hearing* the sound of the train. Actually, Kohler et al. (2002) found that a population of mirror neurons called *audiovisual mirror neurons* are active not only at the *sight* of an action or during its execution, but also when we *hear* the sound of it: mirror neurons have the potential to *evoke*, and, therefore, they can have "*auditory access* to these contents", which is "so characteristic of human language". After two years of age, while they are growing, it is reported that children interact *copying* and r*epeating* utterances (that become more and more complex) right after they have heard them but also *creatively*, after a while they had firstly heard them. It might indeed be that imitation fosters language learning because it provides the child with a measure to test her experience through new trials: the child repeats what she has already heard (experienced) in a new situation and this might give her a sense of what works and what does not in order to obtain the caregiver's attention. During this phase of

experimenting through imitation, she usually receives positive reinforcement by the caretakers[10], which promotes confidence and further learning. Moreover, children are exposed to spoken language which is naturally modified by the caregiver so that it differs from what we usually use with adults: Falk (2004) ascribes to "motherese"[11] - this particular way of talking to infants- the important feature to be a first way of taking turns in conversations, that is, in establishing the social pragmatic pattern of turn taking (Arbib 2002). "Motherese", as a simplified version of the mother tongue, stresses voice pitch and intonation and thus it allows a better discrimination of words in the flux of speech: it makes words more identifiable, and therefore more accessible to a child's capacity to recognize them. Besides, the word repertoire in a conversation between the caregiver and the child is limited to the environment which is essential to the child: Conversations are usually about her bedroom, the kitchen, her toys, her food, and both the child and the caregiver. It is interesting to notice how caregivers talk to infants about their parts of the body, for example, about what the child can do with them; they talk about toys and the child's simple interactions with them: often caregivers refer to the third part they are talking about using the third person singular, for instance, "Sammy has a nice blanket now! Show mom how Sammy goes to bed with his nice new blanket."[12] Using the third person is a way to create a mental link between the self and our own name, it is a way of linking our actions as infants to the action of "this person with my name" (which turns out to be us!): we suggest that it might be a way to let the child represent a mental image of herself, as if she were witnessing from outside her own actions: it functions like a mirror, a mental mirror in which a mental representation of both words heard and images seen are matched.

- Awareness of the imitation and "somatic empathy" (Rand 2002). Asendorpf (2002) hypothesizes that "the development of self-awareness and certain forms of social imitation may be closely linked because both the ability for self-awareness and the ability for sustained immediate imitation as a form of early nonverbal communication depend on a common cognitive capacity, the capacity for secondary representation." As we mentioned before, imitation is a means of conveying meaning at many levels: it might be that children do not always know the complex meaning of utterances they repeat, but they know that their imitative performance will be noticed and will create a contact; it is like showing the other person the willingness to establish a relationship because we are repeating what we have seen: doing or saying the same things that another person did is usually a sign of liking because we repeat things that we liked and we tend not to repeat what had negative results or we did not like. Imitating creates the common ground between child and caregivers. It is interesting to notice how both adults and children know when they are imitating a facial expression, an action or a verbal expression[13]. This might be functional to the implementing of the common experiential ground mentioned above. When imitations turn to laughing, smiling is a pleasant way of confirming a common experience; it is an exchange of emotions and a way to recognize a mutual *knowing-each-other.*

[10] It is reported that adults usually respond more to conceptually correct utterances during interaction: they reinforce sentences where the meaning is important or they correct utterances which do not make sense. This means that more relevance is given to *meaning* , not to the form of conveying it (grammar accuracy) (Dabrowska 2004)

[11] For information about "motherese" see also Trevarthen (2001).

[12] Transcription from a case study of an infant that we carried out in 2004-2005. Interactions between Sammy and his mother were transcribed. The study lasted for one year.

[13] We do not refer to infants, but to children from one year of age.

Imitation thus serves to define the boundaries between the "I" and the other conspecifics, it arises the self-awareness and it develops the "other-awareness", which is essential to empathic behaviours. But, on the other hand, mirror systems "dissolve the barrier between self and others" (Iacoboni et al. 2005): mirror neurons seem to be the common neural basis for empathy: they are active when observing or executing the same action, but they are also active when we see emotions in other people. Mirror neurons are active when we feel an emotion as well as when we see it in the others: it allows us to feel empathy, that is, to understand emotions directly. We know from research in the field[14], that the role of emotions and empathy is essential in language acquisition and communication. The fact that mirror neurons are at the basis of empathic behaviours -thus at the basis of a very important constitutional element of language- reinforces our assumption that they might be the neural key to language learning.

Other behaviours observed in children learning their mother tongue that might be ascribed to mirror circuits in the nervous system are the *use of gestures* and the *ability to parse the context*.

4. The use of gestures in language acquisition

So far we have analysed the properties of mirror neurons and inferred that imitative behaviours might be functional to learning in general, but also very important for language acquisition. Besides, mirror neurons are not only important for the humans' capacity to learn through imitation and feel empathy: they seem to have a key role in the use of semantics. Their network is active not only when watching a transitive action[15], but also when reading literal phrases such as "biting the peach" or "grasping a pen" which suggests that mirror neurons enable "the mental *re-enactment* of actions when linguistic descriptions of those actions are conceptually processed"[16]. This is summarized in Bownds[17]:

> "Classic language areas -Broca's and Wernicke's (yellow) overlap (orange) with areas critical for imitation (red) [Figure 3]. So, there is the idea that mirror neurons could facilitate the imitation of skilled movements like the hand and mouth movements used for communication. Learning by imitation is a key feature of language acquisition in infants and is widely considered a prerequisite for language evolution. It turns out that listening to speech cues up activity in regions of the frontal cortex that are active during speech production. This fits well with the old "motor theory of speech perception," ...when children imitate their first words, they seem to be guided by the "gestural" features of the sound -that is, by the actions of the mouth rather than by a sound's acoustic features. Apparently there is a well-known trick to demonstrate this, […] the McGurk effect: If you watch someone pronounce the syllable "ga" while listening to a recording of someone saying "ba," you will likely hear "da," a sound anatomically between the other two. The idea is that we perceive speech by referring the sounds we hear to our own production mechanism. […] because of an intuitive sense of how our body parts correspond with those of others. Like a small child knows how to raise its hand in response to a parental wave."

[14] See Schumann 1997, 2004; Gallo 2003; Morosin 2006; Titone 1987.
[15] By *transitive action* we mean an action that involves an agent and an object. *Grasping, biting* are transitive actions.
[16] See the interview to Iacoboni at www.physorg.com (21/09/2006)
[17] See Bownds' lectures, writings and blog on mirror neurons at his web site www.dericbownds.net

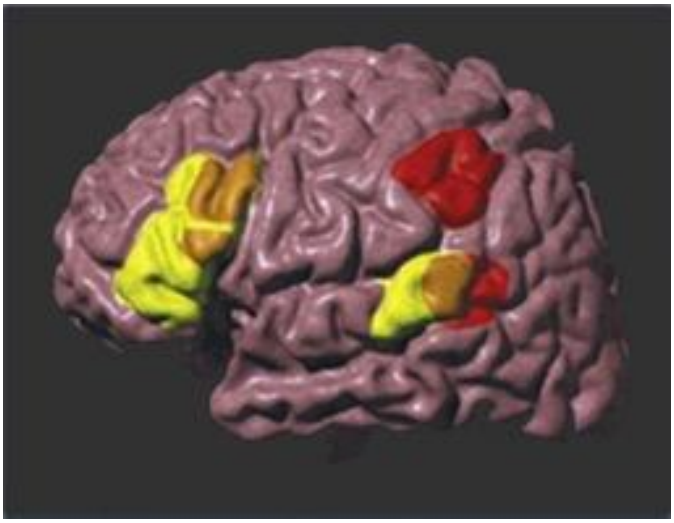

Figure 3: The overlapping (orange) of imitation areas (red) and language areas (yellow) (www.dericbownds.net).

This brings us to the question of the role of gestures in acquiring language. Recent studies about mirror neurons' role in language (Arbib, Rizzolatti 1997, 1998; Arbib 2002, 2005, 2006; Stamenov, Gallese 2002; Gilissen 2005) shed light on the matter proposing that:

1. The mirror neuron system in the inferior frontal lobe contains overlapping networks for *spoken* language and *sign* language.
2. Complex *hand gestures* and the complex *tongue and lip movements* that we use in uttering sentences share the same neural system.
3. We use mirror neurons not only to understand *the actions* of other people but also to understand *the meaning of sentences describing the same actions* (Iacoboni 2006[18], Tettamanti et al. 2005)

Thus, these recent data give us the first empirical evidence in support of the hypothesis that language comes from action and, therefore, that manual gesticulations are extremely important precursors of language communication. Arbib (2002) sums up the path from action to language[19] in the following way:

"Step 1: Grasping.

[18] See http://www.physorg.com/news78073175.html

[19] We will not focus on the *evolutionary* tenets of the theory in the present discussion; instead, we will focus on the considerations interesting to our discussion of gestures in language acquisition. In Arbib's argumentation, the steps outlined above describe an evolutionary path that took place in thousands of year, and that distinguished the human beings' ability to imitate and use gestures for communication, from the apes', that can only reach up to stage 3. Complex imitation, instead, is a prerogative of the human kind.

Step 2: A mirror system for grasping shared with the other conspecifics.

Step 3: A *simple imitation system* for object-directed grasping[20] through much repeated exposure. […]

Step 4: A *complex imitation system* for grasping. This is the ability for *complex action analysis*: "recognizing another's performance as combining actions which can be approximated by variants of actions already in the repertoire […] and then repeat them. *Complex imitation then rests on the ability to exploit that analysis* to ground imitation of the observed action.

Step 5: *Protosign*, a manual-based communication system.

Step 6: *Proto-speech*, resulting from the ability of control mechanisms evolved for proto-sign coming to control the vocal apparatus with increasing flexibility.

[…]

Step 7: *Language*: the change from action-object frames to verb-argument structures to syntax and semantics; the co-evolution of cognitive and linguistic complexity.

The Mirror System Hypothesis is simply the assertion that the mechanisms which get us to the role of Broca's area in language depend in a crucial way on the mechanisms established in Stage 2. The above seven stages provide just one set of hypotheses on how this dependence [between action and speech] may have arisen."[21]

With this argument in mind, consider the observations about language acquisition in children learning their first languages, which seem to follow the main steps outlined above and which seem to support the view that gestures implement language acquisition and have a key role in helping determine semantics (McNeil 2005):

Step 1. through 3. Grasping, Simple imitation system. This first stage reminds us of the simple imitation processes described in paragraph 2, where we reported the description of infants reciprocating facial expressions. Moreover, we observe children grasping objects, letting them fall on the ground, repeating the same procedure over and over, and even imitating the caregiver's head movements while she says "don't through the spoon on the floor". It might be that at this stage, children begin to make a simple analysis of the components of actions and begin also to apply meaning from what they repetitively hear. It can be inferred that "social reciprocity in neonatal imitation may be a necessary precursor for complex imitation, establishing that "I am like the other" (Zukow-Goldring, 2005). This suggests an innate basis for "conversation" that precedes its pragmatic function[22]; it is a first way of exploiting movements to communicate and it suggests that language develops from these early inter-subjective "conversations" (Trevarthen, 2001).

Step 4 and 5. Complex action analysis and Complex imitation system. At this stage, children acquiring language can do complex analysis of actions and imitate

[20] Transitive actions: an agent grasps an object.
[21] The text has been adapted by the author. The text in brackets is ours. See http://www.interdisciplines.org/coevolution/papers/11
[22] See Arbib at http://www.interdisciplines.org/coevolution/papers/11

complex actions applying intentions to their imitative performances and gestures. At this stage of "proto-signing", children go from transitive actions (like grasping a cup that is at sight and at hand) to intransitive actions (like extending their arms towards a cup which is not at hand). Vygotskij (1934) suggested how these intransitive actions come from transitive actions: when the objects are at hand and can be grasped, children grasp them; but when the objects are far from the children, they extend their arm as if they wanted to reach them: when the caregiver intervenes and gives the object to the child, the child will later repeat the same action (extending the arm) *to indicate* that she *wants* to grasp the object. Thus, the child's *gesture conveys a meaning* and *has intentionality*; it is not a reflex, nor a simple imitation, but a complex meaningful *sign* common to the child and the caregiver. To say it with Arbib's words:

> "The whole process of complex imitation comes into play as the child acquires phonology and lexicon, and learns which "sentential actions" may be deployed to achieve its goals. However, when adults talk to each other, it is only the *complex action analysis* (recognizing what the other said) that comes into explicit play. Bickerton (2005) is quite right to observe that when someone addresses you, you do not just imitate what they said. The human mirror system creates a representation that can be used for *feedback control*, *imitation*, or *generating some appropriate response*[23] while inhibiting mimicking."

Step 6 and 7. Protolanguage and Language. We observe that the developing child uses her hands to indicate things, describe things and events imitating with her body the situation. This substantial use of the body, (beside language), to communicate, seems to be extremely important for learning (Hostetter, Alibali, in press; Esposito et al., in press): thinking is expressed not only with words, but also with signs , chains of movements that represent real objects and people in the environment, but also concepts. Especially, in illustrating concepts and new studied material with one's own hands, gestures have demonstrated to make learning last longer, that is, new memory is retained longer when concepts are learnt through multimodal perceptual channels (Broaders et al.; Cook, Mitchell, Goldin-Medow in press; Goldin-Meadow, Wagner 2005), like through linguistic input, but also through vision and gestures.

Notwithstanding the linguistic development that children go through, spontaneous gestures accompany speech with synchrony as if they were an inseparable unit during our all life and are present in every culture. They reflect "different semiotic aspects of the cognitive structure that underlies them both; […] In addition, gesture may be an indicator of transitional periods with respect to the acquisition of new concepts." [24] Current research by McNeill on the role of gesture in language acquisition underlines the property of gesture being used to access information about language. In other words, "gesture is a visual manifestation of the imagistic aspects of cognition; it can inform our understanding of the structure underlying the linguistic aspects of cognition."

5. Parsing the context in search for meaning

When we describe our experience of life in the world we mainly describe actions and objects or subjects participating to the action; actions that we perform with

[23] Passages in italics are ours. See note 22.
[24] For more details on the work by the McNeill's Gesture and Speech Lab, visit http://mcneilllab.uchicago.edu/topics/topics.html

objects (like *drinking water, grasping*) or without objects, that is, abstract actions (like *thinking)*.

We describe emotions and intentions, which are expressed through actions anyway (He *was happy*.) Our whole knowledge is, ultimately, knowing about actions, about acting subjects involved, but also about the context these actions where performed. Through language we express relations between meanings. We collocate these meanings in context, and the context itself is meaningful to understand situations, intentions and goal-directed actions. As a matter of fact, we cannot separate language from its context: we do not have language without a person speaking; we do not have communication without a message from a speaker to a listener who understands, we usually speak surrounded by a context which is determined through spatial and temporal categories. Even when we read a book to ourselves we create a mental image of the context where actions take place: we see things in a context, not in isolation. Mirror neurons too, are able to predict the intentions of others and they are able to understand what another person is doing, both because they have a representation of the action in their repertoire, but also because they are able to extrapolate features of the objects, details of the context that suggest that only one action is likely to occur.

In Iacoboni's experiment (Iacoboni et al. 2005), *the context* –either a table prepared "before tea", or a table "after tea" (this scene was called intention)- *added information about the intention action that was being performed*: actions embedded in contexts, compared with the other two conditions (in the first, there was no context at all but only the view of an hand grasping a cup, so only *the action*; in the second condition there was only *the context*, that is objects on the table, but no hand performing actions) yielded a significant signal increase in activation of the mirror system:

The "before tea" context promoted the idea that the action of grasping was "to drink tea", while the context "after tea" suggested that the next action would be "grasp the cup for cleaning". This means that mirror neurons are not only sensitive to the presence of objects in a context, but are able to ascribe abstract features –actually "what-you-can-do-with-that-object"[25] features, or "affordances"[26], that go beyond the mere recognition of the action observed. They suggest that "*coding the intention* associated with the actions of others is based on the activation of a neuronal chain formed by mirror neurons *coding the observed motor act* and by "logically related" mirror neurons *coding the motor acts that are most likely to follow* the observed one, *in a given context*. To ascribe an intention is to infer a *forthcoming new goal*, and this is an operation that the motor system does automatically." (Iacoboni et al. 2005).

In the process of language acquisition the context must have a significant role: on one hand, we have seen the preceding paragraph that children rely on imitation and repeat what they hear as a form of experimentation; on the other hand, as suggested by Dabrowska (2004), the other way that children can exploit to determine what a new utterance means is to observe "competent speakers use it and note as much as possible about the context." The context offers clues and hints to understand the action possible in a given situation; human beings too offer an "emotional context" that children can read to understand our actions and intentions: body movements, facial expressions, the tone of our voice -to sum up- all the supra-segmental features

[25] For example, a tea cup has a handle so that one can grasp it by the handle: that is a features that is probably stored with the representation of the cup: " an object with a handle, you can drink from"
[26] See Arbib in note 22.

of speech and our movements in the context. As we posited before, the context is made up of objects that offer *affordances* to the child exposed to language: she must learn that the cup has a handle that can be grasped by her hand; that the feeding bottle can be sucked as well as the pacifier; at the same time combination of objects in the context will predict what it is likely to happen:

> "The developing child must learn both affordances (opportunities for action as presented in the sensory stream) and *effectivities* (what the body can do; Shaw & Turvey, 1981) as two sides of the mirror system. By directing the child's attention to its own effectivities in relation to affordances, the caregiver narrows the search space for learning, and thus enhances that learning (Zukow-Goldring, 1996). These practices may pave the way to early word learning (Zukow-Goldring, Rader, & Cain, 2001). The prolonged period of infant dependency in humans combines with caregiving to provide conditions for complex social learning."[27]

As we mentioned before, the types of conversations directed to a child are exclusively related to the child's environment, so, there is indeed a restriction of space, or *context*, in which to locate actions and meanings. Not only the spatial context offer the same scene (think about the kitchen, for instance) but also the objects are the same (milk, favourite toy) and the people around the caregivers): It turns out that the interactions are most of the time redundant, in their content and in their form, so that the child might predict what can be said in certain circumstances: she can develop anticipations strategies. So, as the child might be able to get the affordances of objects, and the clues from the spatial context, on a higher level (but we think with the same underlying dynamics[28]), the child might as well be able to learn language because speech itself gives her important clues (*language affordances*) about what to retain: the notion is that, language, being an artefact and a prerogative of the human kind, must present features that are learnable, accessible, which in fact is the case. In addition, we not only are able to predict the others' actions, but we are also able to anticipate what they are going to say: predictable situations allow us to understand another person's talk long before she is finished talking, or, for example, we know what constituent of a sentence is going to be pronounced next. This capacity of anticipation in language comprehension, or *expectancy grammar* (Oller 1979), might be present or it might begin to develop at this early age: as a matter of fact, observation of interactions between mother and child show how a child can, for example, anticipate the final words of the line in a song, or completing a sentence pronounced by the mother[29] like in the following example:

Mom: "Where is daddy's …?"

Child: "Car."

In this case the context is the linguistic context itself: the child had heard that question repetitively, every time he was on the way to his father's car where he would play. The sentence first, and then the mom's action (pointing at the car in the distance while walking in its direction) might have activated the mirror neurons system at many

[27] See Arbib in note 22

[28] See Morosin 2008

[29] In our case study, we reported an interaction between Sammy and his mother: Mom singing "Twinkle, twinkle little …" Sammy: "star", Mom: " how I wonder who you …" Sammy: "are". Notice the phonetic similarity of the two final words of the lines.

levels: action recognition, intention understanding at a motor level, but also at a linguistic level through language comprehension.

Certainly, this might be only an aspect of language acquisition, but we assume that the context, in which actions take place, and language finds its communicative sense, might contribute to our understanding of meanings since it provides us with hints and clues about the meaning of things, but also about their additional abstract qualities: it really seems to be made especially for us human beings, endowed with brains, and especially, with mirror systems able to "parse" the world around us.

6. Speculations on mirror neurons and second language acquisition

On the basis of the recent discoveries of mirror neurons' involvement in the acquisition of language, and observing the data collected so far about learning behaviours that might be due to the activation of the mirror systems in the brain, we propose that this neural network might be also functional to the learning of a second language.[30] Firstly, in this paragraph, we refer to learning a second language in a formal environment, like at school, so we exclude the cases of bilingualism from birth: in that case, we think that the conditions analysed for first language acquisition would still be valid. Secondly, we refer to foreign language learning, so learning a language that is not spoken by the community we live in. Finally, we make our considerations thinking at adult foreign language learning. With this premise in mind, let's look at the properties peculiar to mirror neurons that we think are fundamental in foreign language learning:

a. The ability to observe an action and to keep a mental representation of it.

b. The ability to understand the others' actions.

c. The ability to correlate an action we observed to a specific context of performing

(parsing the context).

d. The ability of comparing that observed action with our own previous experience of

the same action

e. The ability to anticipate the others' intentions

f. The ability to make suppositions about the others' emotional state and to feel

empathy.

Learning a new language is indeed an act of social interaction where our beliefs, our certainties must be reorganized on the basis of completely, or at least apparently, new patterns: sounds are arranged in a different way; some sounds are new, intonation is not the same, and gestures that we knew were polite in our country assume a new meaning in the target language environment; there is another problem: we don't know the meaning of words.

[30] In the present discussion, second language is synonymous for foreign language, or, any language learnt after the native language (or languages)

In this scenario, what helps us overcome the initial shock of learning a foreign language is the search for a common ground, that is, we simply do what our mirror systems do, or what young children naturally do: we go back to the value of *action*, the importance of *gesture* and we rely on the *context* in search of all the hints to understand the person talking to us so that we can try to communicate:

a. We observe and pay attention to what our foreign language speaking interlocutor does

and try to link the words she utters to her actions.

b. We try to understand, finding clues from the context, analyzing it in search for what

is familiar to us and can help us get the meaning of either speech or written texts.

c. We often make comparisons between our language and the new one: we outline

similarities and differences.

d. We try to anticipate the interlocutor's actions, or words.

e. We understand the emotional state of a message by "reading" the tone of voice, the

facial expressions and imitating (or showing a similar disposition to) the person we

are interacting with.

f. We imitate our interlocutor: we try to copy her pronunciation, the way she

"embodies" her native language[31].

g. We rely on gesture, especially in the first times.

In addition, it seems that when we learn a foreign language we make use of both forms of imitation: the *simple imitation process* –when we just recognize patterns in the foreign language which are similar to ours- and the second form of imitation – the *complex imitation system* that allows us to learn complex input on the base of an analysis of the parts and a re-elaboration of the same into a new performance. In the case of language learning the parts of the whole are the many aspects of language itself: vocabulary, syntactic and morpho-syntactic structures, prosody, pronunciation, pragmatic rules, etc... which constitute the components of the complex act to imitate. The more we are able to incorporate all these features in our "language performance", the more we sound like native speakers; yet, especially in the adult population, not all performances are successful: we still do not know exactly why some learners get stuck at one level, while other learners can reach very high standards of proficiency (Skehan 1998).

[31] See Rinvolucri 2007.

Another form of imitation in foreign language speakers that might be due to the presence of the mirror neuron system is the so called *lexical alignment* phenomenon (Ivanova et al. 2007). Speakers of different languages copy each other at many different levels, because they *align* their linguistic representations (Pickering, Garrod, 2004); Ivanova found evidence that this form of imitation occurs to speakers of the native language (L1 speakers) interacting with speakers learning their language (L2 speakers): when the L1 speakers receive feedback from the L2 speakers indicating comprehension, L1 speakers do not align with L2 speakers more than they do with other L1 speakers; this means that they do not change the choice of words they would choose if talking to another native speaker of their language. But if the L2 speaker gives sign of not having understood, of poor comprehension, L2 speakers tend to aid their L2 interlocutors with their lexical choice because they are unsure of their degree of comprehension.

Finally, we would like to underline the role of gestures in learning a foreign language: when used by adults, interacting in the L2, the use of gestures has the same value of meaning vector that it had in the development of language in children, but it success can now be compromised by the fact that the target language (L2) may use a different set of gestures to convey a given meaning, while, in the child's experience, instead, gestures were precursors of the first language, and thus, attuning to it. However, all languages share basic gestures to indicate the spatial context, and this facilitate the communication with an L2 speaker.

7. Teaching with the mirror neurons in mind

We would like to conclude our discussion of the mirror neurons and their importance in the processes of language acquisition, with some general considerations about language teaching. The teaching environment is surely the best of the situations in which to remember, as instructors of foreign language, that nature has provided us with a system that *fosters* the acquisition of a language, for a very important reason: communication. Simple tough it is, it might be insightful to stress and promote a learning environment that takes advantage of the "mirror" properties of our brains:

1. Disposition to social interaction: a mirroring system serves to construct a common ground. As teachers we can welcome our language students showing first of all the similarities that unite us, notwithstanding the differences in language and cultural background. It is always a way to break the ice in a beginners' class when we explain about us, and talk about basic things that are understandable through our actions, that are not ambiguous, that our students can immediately understand and relate to.

2. Let the students parse the context. It is crucial to provide the students with a context they can refer to for meaningful clues. The context might be the spatial dimension of the classroom, but also the page of the textbook: a visual context helps communication, but, especially with children, realia and objects to manipulate help memorize semantics better (Goldin-Meadow, Wagner 2005). Instruments, like audio-visual material, also help and serve a double purpose: they create the background, or the context, while bringing into class a piece of the target culture. This also helps to build of not only a common ground of linguistic comprehension, but also a window towards the new culture.

3. Use of gestures and kinaesthetic. Gestures foster comprehension when the teacher uses them in accordance with the meaning of the speech: in human interaction, non-verbal communication has a very important role for communicating content meaning, but also emotional content. Gestures and speech must match. Another way to reinforce the use of gesture is through teaching techniques based on total physical response, because the whole body participates in the *action of learning*: playing activities and games work best with little learners, while adults usually need encouragement. McNeill (2005) suggests using gestures when teaching new concepts to children: the connection between gesture and speech had shown to have pedagogical value, since it would reinforce memory duration.

4. Introduction of "expectancy techniques" We do not refer here only to the teaching activities, but also to the organisation of time: when the teacher promotes a division of time in sections with different activities that is recurrent (for instance, on Tuesdays there is always a certain activity), the learner learns to expect that activity and thus he establishes a routine that fosters another type of mental common ground between her and the instructor. Teaching to expect pleasant activities is the first step to achieve better levels of attentions and, hence, better results. Students could also exploit their mirror neurons system capacity to understand and read the others' actions and intentions, by inferring, deducing, supposing, referring, finding implications by themselves as an alternative to other kind of structured exercises.

8. Conclusions

The recent discovery of the properties of the mirror neurons system has brought us to think that such a system might be active and sub-serve language acquisition: there is evidence that the mirroring mechanism accounts for our unique ability to imitate complex behaviours and learn complex patterns of actions, like language. We have gone through the facts in language development that let us think that mirror neurons play an important role not only in the acquisition of the L1, but also in the learning of L2. However, these assumptions must be corroborated by further future research in the field.

References

Arbib M.A., 2006, *Action to Language via the Mirror Neuron System*. NY, Cambridge University Press.

Arbib M.A., 2005, "From Monkey-like Action Recognition to Human Language: an Evolutionary Framework for Neurolinguistics", in *Behavioural and Brain Sciences*, 28, pp. 105-167.

Arbib M.A., 2002, "The mirror system, imitation, and the evolution of language", in Nehaniv C., Dautenhahn K., (Eds.). *Imitation in Animals and Artefacts.* Cambridge, MA, MIT Press, pp. 229-280.

Arbib M.A., Rizzolatti, G., 1997, "Neural Expectations: a Possible Evolutionary Path from Manual Skills to Language", in *Communication and Cognition*, 29, pp. 393-423.

Asendorpf, J.B., 2002, "Self-awareness, Other-Awareness and Secondary Representations." in Meltzoff A. N. Prinz W., *The imitative mind: Development, Evolution, and Brain Bases*. Cambridge, England, Cambridge University Press.

Baudonnière P. M., 1988. *L'évolution des compétences à communiquer chez l'enfant de 2 à 4 ans*. Paris, PUF.

Bickerton D., 2005, "Beyond the Mirror Neuron – The Smoke Neuron?", in *Behavioral and Brain Sciences,* 27.

Buccino G., Riggio L., Melli G., Binkofski F., Gallese V., Rizzolatti G., 2005, "Listening to action-related sentences modulates the activities of the motor system: A combined TMS and behavioural study" in *Cognitive Brain Research*, 24, pp. 355-363.

Buccino G., Binkofski F., Fink G.R., Fadiga L., Fogassi L., Gallese V., Seitz R.J., Zilles K., Rizzolatti G., Freund H.-J., 2001, "Action observation activates Premotor and Parietal Areas in a somatotopic manner: an fMRI study", in *European Journal of Neuroscience*, 13, pp. 400-404.

Broaders S. C., Cook S. W., Mitchell Z., Goldin-Meadow S., *Making children gesture brings out implicit knowledge and leads to learning.* Under review.

Cacioppo J. T., Berntson G.G., 2005, *Social Neuroscience: Key Readings,* New York,

Psychology Press.

Catmur C., Walsh V., Heyes C., 2007, "Sensorimotor Learning Configures the Human Mirror System", in *Current Biology*, 17, pp. 1527-1531.

Cook, S. W., Mitchell, Z., & Goldin-Meadow, S. *Gesture makes learning last.* Under review.

Dabrowska E., 2004, *Language, Mind and Brain. Some Psychological and Neurological Constraints on Theories of Grammar,* Washington D.C., Georgetown University Press.

Esposito E., Keller M., Marinaro Bratanic M. (eds), *The fundamentals of Verbal and Non-verbal Communication and the Biometrical Issues*, A. Amsterdam, IOS Press BV. In Press.

Falk D., 2004. "Prelinguistic Evolution In Early Hominins: Whence Motherese", in *Behavioral and Brain Sciences*

Fogassi L., Ferrari P.L., Gesierich B., Rozzi S., Chersi F., Rizzolatti G., 2005, "Parietal Lobe: from Action Organization to Intention Organization", in *Science*, 308, pp. 662-667.

Gallese V., Fadiga L., Fogassi L., Rizzolatti G., 1996, "Action Recognition in the Premotor Cortex" in *Brain*, 119, pp. 593-609.

Gallese V., Keysers C., Rizzolatti G., 2004, "A Unifying View of the Basis of Social Cognition", in *Trends in Cognitive Sciences*, 8, pp. 396-403

Gallo B., 2003, *Neuroscienze e apprendimento.* Napoli, Esselibri.

Gilissen E., 2005, "Imitation Systems, Monkey Vocalization, And The Human Language", in *Behavioral and Brain Sciences*, 28, 133-134.

Givón T., Bertram F. Malle, 2002, *The Evolution of Language Out of Pre-language*, Amsterdam, The Netherlands, John Benjamins Publishing Company

Goldin-Meadow S.,Wagner S. M., 2005, "How our hands help us learn", in *Trends in Cognitive Science*, 9, pp. 234-241.

Grammont F., 2004, "L'action dans le miroir", in *Annales Fyssen*, 18, pp.11-17

Hostetter A. B., M. W. Alibali., "Handing it to Perception and Action: Gestures reflect embodied Thinking. Manuscript.

Iacoboni M., Molnar-Szakacs I., Gallese V., Buccino G., Mazziotta J.C., Rizzolatti G., 2005, "Grasping the intentions of others with one's own mirror neuron system", in *PLoS Biology*, 3, pp.529-535.

Ivanova I., Costa A., Pickering M., Branigan H., 2007, *Lexical alignment of L1 speakers with L2 speakers.* Poster

Kohler E., Keysers C., Umiltà M.A., Fogassi L., Gallese V., Rizzolatti G., 2002, "Hearing sounds, understanding actions: action representation in mirror neurons", in *Science*, 297, pp. 846-848.

Luppino G., Rizzolatti G., 2000, "The Organization of the Frontal Motor Cortex", in News Physiol.Sci., 15, pp. 219-224

Masur E. F., Rodemaker J. E., 1999, "Mothers' and Infants' Spontaneous Vocal, Verbal and Action Imitation During The Second Year." in *Merrill Palmer Quarterly*, 45, p. 392

McNeil D., 2005, *Gesture and thought.* Chicago, University of Chicago Press.

Mehler J., Dupoux E., 1990, *Naître humain*, Paris, Editions Odile Jacob.

Meltzoff A. N. Prinz W., 2002, *The imitative mind: Development, Evolution, and Brain Bases.* Cambridge, England, Cambridge University Press.

Morosin M.S., 2008, *Repetition: in Language, Learning and Teaching*, Doctoral Thesis. Department of Language Sciences, University Ca' Foscari, Venice, Italy.

Morosin M.S., 2006, "Emozioni e Apprendimento: il Cervello che Sente e Impara." in In.It, 19, Perugina, Guerra Edizioni, pp.6-10

Nadel, J., 2002, "Imitation and Imitation Recognition: Functional Use in Preverbal Infants and Nonverbal Children with Autism." in Meltzoff A. N. Prinz W., *The imitative mind: Development, Evolution, and Brain Bases.* Cambridge, England, Cambridge University Press.

Nadel-Brulfert J., Baudonnière P. M., 1982. "The Social Function of Reciprocal Imitation In 2-Year-Old Peers." in *International Journal of Behavioral Development, 5*, pp. 95–109.

Nagy E., Molnar P., 2004, "Homo imitans or homo provocans? The phenomenon of neonatal initiation", in *Infant Behavior and Development*, 27, pp. 57-63.

Oller J.W., 1979, *Language tests at school: A pragmatic approach.* London, Longman.

Piaget J., Gattegno C., Hodgson F.M., 1962, *Play, Dreams and Imitation in Childhood*. NY, W.W. Norton

Pickering M. J., Garrod S., 2004, "Towards a mechanistic psychology of dialogue", in Behavioural and Brain Sciences, 27, pp. 169-226.

Rand M.L., 2002, "Mirror neurons: Somatic Empathy and Counter-transference.", in *Annals of the American Psychotherapy Association*, 5, p. 32.

Rinvolucri M., 2007, *Belief Systems in Language Learning, in Training and in Culture studies*, manuscript.

Rizzolatti G., Sinigaglia C., 2006, *So quel che fai. Il cervello che agisce e i*

neuroni specchio, Milano. R. Cortina Ed.

Rizzolatti G., Fogassi L., Gallese V., 2001, "Neurophysiological Mechanisms Underlying the Understanding and Imitation of Action", in *Nature Reviews Neuroscience*, 2, pp. 661-670.

Rizzolatti G., Arbib M.A., 1998, "Language Within our Grasp", in *Trends in Neuroscience*, 21, pp. 188-194

Schumann J.H., 1997, *The Neurobiology of Affect in Language*. Malden, Oxford, Blackwell.

Schumann J.H., Crowell S.E., Jones N.E., Lee N., Schuchert S.A., Wood L.A., 2004, *The Neurobiology of Learning*, Mahwah, New Jersey, Lawrence Erlbaum Associates Publishers

Skehan P., 1998, *A cognitive approach to Language Learning*, Oxford, Oxford University Press.

Stamenov M.I., Gallese V., 2002, *Mirror Neurons and the Evolution of Brain and Language*, Amstredam, The Netherlands, John Benjamins Publishing Company.

Tettamanti M., Buccino G., Saccuman M.C., Gallese V., Danna M., scifo P., Fazio F., Rizzolatti G., Cappa S.F., Perani D., 2005, "Listening to Action-related Sentences activates Fronto-parietal Motor circuits", in *Journal of Cognitive Neuroscience*, 17, pp. 273-281

Théoret H., Pascual-Leone A., 2002, "Language Acquisition: Do as You Hear", in *Current Biology*, 21, pp. 736-737.

Titone R., 1987, "La Dimensione Affettiva" , in Freddi G., 1987, *Lingue Straniere per la Scuola Elementare*, Padova, Liviana.

Trevarthen C., 2001, "The neurobiology of early communication: Intersubjective regulations in human brain development", in. Kalverboer A. F., Gramsbergen A., (Eds), *Handbook on Brain and Behavior in Human Development*, Dodrecht, The Netherlands, Kluwer, pp. 841-882.

Umiltà M.A., Kohler E, Gallese V, Fogassi L, Fadiga L, Keysers C., Rizzolatti G., 2001, "I know what you are doing. A Neurophysiological Study", in *Neuron*, 32, pp. 91-101.

Vygotskij L.S., 1962, Thought and Language, Chicago, The MIT Press.

Zukow-Goldring P., 2006, "Assisted Imitation: Affordances, Effectivities, and the Mirror System in Early Language Development", in Arbib M.A., (Eds.), *Action To Language via the Mirror Neuron System*, Cambridge University Press

Zukow-Goldring P., Rader N., Cain, T., *Dynamic gestures and early word learning: A test of a perceptually based theory*. Under review.

Zukow-Goldring P., 1996, "Sensitive caregivers foster the comprehension of speech: When gestures speak louder than words", in *Early Development and Parenting*, 5, pp. 195-211.

Web sites references

Arbib M.A., *The Mirror System Hypothesis. Linking Language to Theory of Mind.* http://www.interdisciplines.org/coevolution/papers/11

Azar B., "How mimicry begat culture**.** Researchers from varied disciplines look to mirror neurons to explain many aspects of human evolution", in *Monitor on Psychology*, APA on line, 36, *http://www.apa.org/monitor/oct05/neurons.html* , published 5 October 2005.

Blakeslee S., *Cells that read minds*, http://www.nytimes.com/2006/01/10/science/10mirr.html,

published 10 January 2006.

Bownds D., *Mirroring Minds: Are Mirror Neuron Systems the DNA of Psychology or a Red Herring?*, in http://dericbownds.net

Ramachabdran V.S., *Mirror neurons and imitation learning as the driving force behind "the great leap forward" in human evolution*, www.edge.org/documents/archive/edgeedge69.html

First Evidence Found of Mirror Neuron's Role in Language, http://www.physorg.com/news78073175.html, published 21 September 2006