

Enacting communication. Evidence supporting an embodied theory of language.

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1. Philosophical background

Embodiment is a recurring theme in several branches of the contemporary philosophical debate. Usually, the term ‘embodiment’ refers to a characterization concerning relations between the mind and the body, suggesting the existence of a *bodily root* for several experiential and cognitive abilities. The idea that experience is embodied implies that specific aspects of our ordinary experience are due to the nature of our bodies and that our construal of reality is mediated in large measure by the character of our flesh-made nature. The concepts we use and the reality we talk about are shaped by the way our bodies interact with the environment, so that essential aspects of the human mind’s activity bear the evidence of our embodied nature. The fact that our experience is embodied, that is, structured by the nature of our own bodies and our own neurological organization, has considerable consequences for the definition of a wide theory of human cognition.

As with other philosophical concepts, the notion of *embodiment* lacks an explicit and shared definition, so one can find the term used differently in different places of the contemporary scientific and philosophical debate. Works concerning embodiment cover many fields of research such as: the nature of *psychological explanation* (WILSON 2004); the idea of *extended mind* (CLARK 2008); the interdependence of *perception and action* (GIBSON 1979); *enactivism* and the *sensorimotor accounts of perception* (NOË 2004; THOMSON 2007).

As an attempt to overcome this obstacle, in the present work the use of the expressions ‘embodiment’ and ‘embodied mind’ will be intended in accordance with

the following properties concerning the relations between *experience*, *cognition* and *corporeity*:

1) *Activity*: conscious experiences and cognitive processes are the result of *specific actions* performed in a given environment; both involve an interaction between an *object* and an *acting subject*, or at least a subject able to imagine his own potential actions.

2) *Dynamicity*: the interaction between the mind and the body is *dynamical* in the sense that any subjective experience, as well as any cognitive ability must be considered a *process* characterized by the property of *duration*. Experience and cognition are not composed of elementary qualities or instantaneous acts, but are the outcome of continuous and motivated bodily dynamics.

3) *Constraints*: the way in which an organism is embodied (i.e., whether it has feet, fins, eyes, a tail, etc., but also its physical shape, spatial orientation and asymmetries) determines how a subject interacts with the environment, thereby influencing sensory-motor experiences, which serve as the basis for the formation of *categories* and *concepts*.

As a kind of embodied theory of mind, the enactive approach to interpersonal understanding supports the idea that cognition is grounded in bodily actions and that the motor system participates in what is considered a mental processing, assuming that both human and non-human primates are characterized by a *direct* and *pre-reflexive* understanding of actions matching their own motor repertoire (SOMMERVILLE & DECETY 2006; JEANNEROD 2006). The nature of this *simulation process* can be interpreted as a *non-reflexive* practice of action representation, according to which bodily mechanisms modulate the understanding of the external social world without undergoing conscious control (GORDON 1996). By way of this motor simulation, a perceived external motor activity is translated into a *potentially executed act*, putting the observer in a position to imitate and learn from the perception of other's action. As Sinigaglia notes, this is in line with the phenomenology associated with understanding another's social action, in that as our

ability to act becomes increasingly sophisticated also our understanding of others' actions develops and becomes increasingly sophisticated (SINIGAGLIA 2009).

In order to show that this condition also matters for a special kind of social action such as *linguistic communication*, the next sections will be dedicated to the analysis of a wide range of behavioral data (section 2) and neurological data (sections 3 and 4), showing the existing interaction between different levels of language processing and the repertoire of motor possibilities pertaining to a body.

2. Acting and understanding

Approaching the issue concerning the correlation between communicative skills and bodily features it is interesting to begin with the introduction of behavioral evidence showing the influence of motor activities on language processing. According to an embodied theory of language usage and understanding, the interactions with the environment and the bodily movements should influence linguistic performances and linguistic comprehension, leading our attention on the analysis of evidence regarding the effect of action execution on different kinds of linguistic tasks. Following this line of thought, a first interesting example of theory involving a role of the motor apparatus in language cognition is represented by Liberman's *Motor Theory of Speech Perception* (MTSP) (LIBERMAN et al. 1967; LIBERMAN & MATTINGLY 1985; LIBERMAN & WAHLEN 2000). According to Liberman and colleagues, the object of speech perception is the intended phonetic gestures of the speakers as represented in the brain of the hearer, so that perceiving an utterance is substantially influenced by the perception and the inner simulation of an intended pattern of gestures involving lips, tongue and other vocal effectors.

Evidence supporting the hypothesis that speech processing can be shaped by bodily gestures is represented by the interaction between hearing and vision during the

acoustic and visual perception of syllables as showed in the famous *McGurk effect* (MCGURK & MACDONALD 1976). According to this paradigm Fadiga et al. (FADIGA 2002) tested the possibility that passive listening of an inventory of words and pseudo-words might induce the activation of cortical centers specifically involved by gestures for speech production. During the experiment authors recorded the motor evoked potentials (MEPs) from the tongue muscles in subjects instructed to listen to words and pseudo-words characterized by virtually no tongue movements (double 'f'), or by marked tongue movements (double 'r'), while the participants' motor cortex was stimulated with single-pulse TMS (Transcranial Magnetic Stimulation) administered over the area corresponding to the tongue motor representation. Results showed that listening to words containing a double consonant 'r' significantly determines an increase of tongue MEP larger than that induced by listening to pseudo-words and words characterized by non-tongue gestures. Moreover, experimental findings concerning an interaction between different modalities of speech perception (i.e., visual and acoustic) are also represented by the study of Kerzel & Bekkering (KERZEL & BEKKERING 2000), according to which the acoustic perception of a syllable is faster when coupled with the vision of a mouthed face articulating the same syllable, and the study introduced by Fowler et al. (FOWLER 2003), according to which if listeners perceive others' speech gestures visually then speech imitation is speeded up.

Recently, an experiment performed by Gentilucci (GENTILUCCI 2003) has highlighted the influence of action observation on syllable production, suggesting that phonemic representations expressed by mouth articulation correlates with representations of the observed action. This idea, as well as those deriving from Gentilucci et al. (GENTILUCCI 2004a) and Gentilucci et al. (GENTILUCCI 2004b), demonstrates that the execution and the observation of grasping actions activates a mouth articulation posture which selectively influences speech production. Evidence like these supports the hypothesis that the system involved in speech production *shares* the activation of the sensory-motor system which is involved in the control of hands and mouth during actions execution.

According to this line, but emphasizing the possibility that gestures and speech form a *single system* of communication, Bernardis & Gentilucci (BERNARDIS & GENTILUCCI 2006) verified whether the execution of symbolic hand gestures and meaningful word pronunciation influenced each other when simultaneously emitted. During the experiment subjects were required to pronounce words, or execute the corresponding meaning communicative arm gestures (e.g., 'hello'), or emit both communication signals simultaneously. Results show a surprising correlation between arm gesture and speech, in that the voice spectra of the pronunciation task was higher when the word is pronounced simultaneously with the corresponding gesture, while no voice modification was observed when executing a meaningless arm movement.

One of the most interesting strategies adopted to make explicit the correlation between language understanding and sensory-motor cognition concerns the role of *affordances recognition* during language comprehension. Even though in the literature there is not an effective agreement on this notion, an affordance (GIBSON 1979) can be considered an invariant combination of objective features selected on the basis of the subject's *possibilities of action/interaction* in accordance with his physical constitution and intentions. In other words, an affordance can be considered an *opportunity for action* which some object, or state of affairs, presents to an agent characterized by a certain kind of bodily properties (for a discussion see: CHEMERO 2009).

Paradigmatic of this field is an experiment performed by Gentilucci & Gangitano (GENTILUCCI & GANGITANO 1998). During this trial the influence of word reading on visuo-motor activity was measured by analyzing different kinematic components of actions consisting in reaching and grasping rods of the same measure on whose visible faces were printed the words 'long' or 'short'. Results reveal that peaks of acceleration, velocity, and deceleration of arm were higher for action performed on rods marked by the word 'long', rather than on rods marked by the word 'short' even if the action afforded by the identical physical dimension of the rods was in both cases the same. This phenomenon is consistent with the hypothesis that during the initial phase of movement subjects associate the meaning of the word with the distance to be covered in the task and activate a different motor program for

farther or *nearer* objects position, accordingly it is arguable that affordance effects concerning the influence of perception on action can be induced not only by means of visual stimuli (TUCKER & ELLIS 1998; 2001; 2004; ELLIS & TUCKER 2000), but through linguistic stimuli with specific semantic values as well. Accordingly, Glover et al. (GLOVER 2004) employed words that only implicitly related to size, and consequently to different kinds of affordance characterized by different measures of hand overture during a directed reaching gesture (e.g., 'apple' as a prototypically large object, versus 'grape' as a prototypically small object). In this experiment scholars observed the interactions between the understanding and the realization of grasping activities, showing that reading an adjective, or the name of an object, interferes with the planning and the execution of grasping movements.

More accurate behavioral measurements revealing the presence of a priming effect between language understanding and action execution are present in the literature. In one experiment performed by Boulenger et al. (BOULENGER 2006) subjects were asked to perform reaching movements concurrently or successively to visual lexical decisions tasks with action verbs or concrete nouns and pseudo-words. The analyses of movement parameters revealed that individual wrist acceleration peaks appeared later and were smaller during displays of action verbs than during displays of concrete nouns. Thus, assuming that a wrist acceleration peak is indicative of initial muscular contractions, the measurement of longer latency and smaller amplitude suggests that perceiving *action verbs* interferes with the execution of the movement itself (see also: NAZIR et al. 2008)

Evidence introduced above supports the hypothesis that language understanding influences action preparation and execution, but it might be hypothesized that the priming process can also reveal the presence of different kinds of interactions. Accordingly, the time required to process action related words could be speeded up by sensory-motor tasks, so that action preparation might show an influence on a consequent semantic assignment. A similar conclusion can be reached analyzing a series of behavioral studies performed by Lindemann, et al. (LINDEMANN et al. 2006). In the first of these experiments, in accordance with the hypothesis that action semantics can be influenced by the subjects' intentions to act, participants were asked

to make lexical decisions concerning words in a *go/no-go* task paradigm (e.g., valid word 'go', pseudo-word 'no-go') after having prepared for a specific action that they execute only after word presentation. Results show that the differences of time between word onset and movement onset (response latencies) were reduced if words were consistent with the previously prepared action. This facilitation in making lexical decisions allows one to hypothesize the presence of a priming effect relating the subject's motor *intentions* and the subsequent semantic process.

According to this evidence, before proceeding any further it is necessary to distinguish between two different kinds of *motor resonance* occurring during language processing: *lexical* and *referential* (FISCHER & ZWAAN 2008; GALLESE 2008). The lexical motor resonance occurs when the subject's motor system responds to the *communicative gesture* itself, that is, when the listener's *speech motor system*, controlling effectors such as *tongue*, *lips* and *oro-facial* muscles, is influenced by hearing the sound of a word independently of its semantic value. Unlike the lexical one, the *referential motor resonance* occurs when the motor system responds to the *semantic content* of the communicative act, highlighting how motor cognition is also involved in *semantic* understanding, as in the case in which on hearing the word 'kick' the subject's motor system controlling 'legs' or 'feet' is influenced. Cases of lexical motor resonance, showing the involvement of the motor apparatus in lexical recognition, are for example represented by experiments such as those introduced by McGurk & MacDonald, (MCGURK & MACDONALD 1976) and Gentilucci (GENTILUCCI 2003), while cases of referential motor resonance, concerning the involvement of the motor apparatus in semantic comprehension, are represented by results such as those introduced by Gentilucci & Gangitano (GENTILUCCI & GANGITANO 1998), Bernardis & Gentilucci, (BERNARDIS & GENTILUCCI 2006) Boulanger, (BOULANGER 2006) and Lindemann (LINDEMANN 2006). Following this line of thought, another paradigmatic example of referential understanding is represented by Scorolli & Borghi (SCOROLLI & BORGHI 2007) according to which the presentation of nouns and verbs pairs concerning foot and hand actions involves a facilitation effect in hand and foot responses; moreover recently Borghi and Scorolli (BORGHI AND SCOROLLI 2009) have shown a

similar advantage in reaction times related not only to the effectors compatibility, but also to the goal involved by the meaning of a presented sentence.

3. Embodied semantics

According to the distinction between lexical and referential resonance, in order to introduce evidence supporting an embodied theory of communication, a critical issue is represented by the actual involvement of the motor system during semantic processing. Even if there are many revealing behavioral experiments focusing on the existence of correlations between *meaning understanding* and *action planning* (ZWAAN, et al. 2002; BORGHI, et al. 2004; BORGHI & RIGGIO 2009), or *action execution* (GLENBERG & KASCHAK 2002; KASCHAK, et al. 2005; GLENBERG et al. 2008), in order to support the idea that semantic understanding is correlated with motor cognition it is necessary to change the level of enquiry and focus our attention on the neural mechanisms underlying linguistic practice. This hypothesis, generally known as the *Embodied Semantic Theory* (EST), is now the object of several experimental researches carried out with the aim to understand how the comprehension of motor related words and sentences is somatotopically mapped on the motor areas of the human brain.

EST states that concepts related with action perception and execution are grounded within the same sensory-motor areas in which the enactment of that concept relays (GLENBERG & KASCHAK 2002; AZIZ-ZADEH & DAMASIO 2008). As in the case of a *referential resonance*, the concept of 'kicking' would be represented by the same sensory-motor areas of the brain that control kicking actions, as well as the concept of 'grasping' would be represented in sensory-motor areas involved in planning and executing grasping actions. Moreover, EST predicts that pre-motor regions involved in action planning should be activated both when acting as well as when understanding *motor-related* linguistic constructions. Accordingly, recent

studies concerning correspondences between bodily effectors and cerebral cortical areas support the idea that many semantic mechanisms are grounded in action-perception systems of the brain. As a result, several brain activation patterns derived from imaging studies reveal the existence of specific differences between categories such as those concerning the use and the perception of diverse objects (MARTIN et al. 1996; MARTIN & CHAO 2001; BEAUCHAMP & MARTIN 2007).

To the understanding of the neural mechanism underlying *single word comprehension* is dedicated a dual task PET experiment performed by Damasio et al. (DAMASIO 2001). In this study ten subjects were scanned when retrieving single words denoting actions performed both with and without an implement, while other ten different subjects were scanned when retrieving words denoting spatial relations between objects. Results were finally subtracted to control tasks involving respectively objects name retrieval and faces recognition. Finally, in both cases significant activations were revealed in frontal and parietal association cortex including motor and pre-motor regions (DAMASIO et al. 2001). A more accurate result is shown in an fMRI experiment performed by Hauk et al. (HAUK et al. 2004) where authors tested the hypothesis that the understanding of single action words (verbs) activates the motor cortex in a *somatotopic* fashion. In this experiment subjects were asked to read fifty words of three semantic categories concerning face, arm and leg actions while hemodynamic activity was monitored. Final results confirm the initial hypothesis showing increasing activity in effectors specific primary motor areas for arm and leg related words, while the pre-motor area was somatotopically activated by arm and face related stimuli (HAUK et al. 2004).

Experiments such as those performed by Damasio and Hauk show that action-words perception activates the same areas involved in actions execution related to their contents. Although this phenomenon introduces a first differentiation between lexical resonance and referential resonance at the neural level, involving a specific activation of motor areas related to the *content* of a term instead of motor areas involved in speech effectors control, it is not enough to show that a *functional* relationship between somatotopical reactions and semantic understanding exists.

In order to clarify whether the activation of specific motor areas may reasonably reflect word comprehension, or instead only a secondary process, Pulvermüller et al. (PULVERMÜLLER 2005) tried to specify the time point of cortical activations during single verb understanding tasks. In this experiment using magneto-encephalography (MEG) subjects were asked to listen to spoken action words and pseudo-words while the brain magnetic field was recorded. Also in this case, data analysis shows that face and leg related verbs elicit different patterns of activity within the motor area, moreover it shows that word specific activations arise early within 200 msec after the stimuli presentation. As noted by Boulenger et al. (BOULENGER 2008a) a critical argument against the assumption that cortical motor regions are involved in action word semantic processing is that, even though the activity in motor regions is observed within 200 ms after stimuli onset, it could nonetheless result from mental imagery that occurs after that the word has been identified. To exclude the hypothesis that hearing an action verb activates the motor system because the subject conjures up the image of an action *after* having just semantically processed the verb, Boulenger et al. (BOULENGER 2008b) investigated single action-words understanding and cortical motor processing using visual words presented too fast to be consciously perceived by the subject (50 ms), so that they should not trigger any mental imagery activity. Authors predicted that subliminal displays of action verbs during motor preparation will interfere with motor processes and thus delay or diminish the amplitude of the *readiness potential* of motor cortex if compared to concrete nouns. Accordingly, both kinematic parameters and readiness potential reveal that subliminal displays of action verbs during movement preparation have a stronger impact on ongoing motor processes than the subliminal display of generic concrete nouns. This shows that action words do not only interfere with movement execution but also with movement preparation. Since subjects don't perceive consciously the word stimulus, their action-imagination cannot be involved in the task. Moreover it must be noted that motor imagery activates the pre-motor cortex *bilaterally* (EHRSSON, GEYER, & NAITO 2003), while congruent maps for action observation and language are observed with more frequency only in the left hemisphere of the brain.

In addition to the single *words comprehension*, EST asserts that *sentence* understanding is also grounded within the same sensory-motor areas in which the enactment of action and motor concepts relay. This supposition appears to be of crucial value within the definition of a theory concerning linguistic practice. Thus, if language processing of action-related sentences relies on sensorimotor representations and not on abstract and a-modal units, then activations should be observed in areas coding for action execution as well. According to this hypothesis, a two task experiment performed by Buccino et al. (BUCCINO et al. 2005) was used to assess whether listening to action-related sentences *somatotopically* modulates the activity of the motor system. During the first experimental section authors recorded motor evoked potentials (MEPs) from hand and foot muscles while participants were asked to attentively listen to different acoustic stimuli consisting of hand or foot action-related sentences. During the acoustic presentation, a single-pulse TMS was automatically triggered in concomitance with the end of the last syllable of the verb. Results show that listening to hand action-related sentences induces a decrease of MEP amplitude recorded from hand muscles, as well as listening to foot-action-related sentences induces a decrease of MEP amplitude recorded from foot muscles. Because in the TMS study participants were not *explicitly* required to semantically process the listened sentences, a second behavioral test was proposed. In this trial, participants were asked to make a judgment on sentence content, giving a motor response (either with the hand, or with the foot) when the listened sentence expressed a concrete action (hand and foot action-related sentences), and to refrain from responding when the sentence expressed an abstract content. According to the finding of the first experiment, also the behavioral data showed that reaction times were slower when participants responded with the same effector that was involved in the listening task.

Results such as these are also confirmed by two fMRI experiments performed by Aziz-Zadeh et al. (AZIZ-ZADEH et al. 2006) and Tettamanti et al. (TETTAMANTI et al. 2005), In the latter, a group of native Italian speakers was scanned while passively listening to sentences describing actions performed with the mouth (e.g., 'I bite an apple'), with the hand (e.g., 'I grasp a knife'), and with the leg (e.g. 'I kick the

ball’), In addition, as a control condition, participants listened to sentences with an abstract content (e.g., ‘I appreciate sincerity’). As in the previous experiment, results show that listening to action-related sentences activates a left-lateralized fronto-parieto-temporal system which is activated also by action execution and action observation, while the activations associated with abstract sentences, when compared to action-related sentences, were only found bilaterally in the posterior cingulate gyrus, a brain region without any significant relation with action representation.

4. Functional evidence

However, even though the results of these studies clearly demonstrate that motor regions are recruited during the processing of an action-related language, they do not clarify the problem about the *functional role* of these areas for semantic understanding, so that the crucial question ‘are cortical motor regions critical to word understanding?’ is left unsolved. A crucial test concerning the role of motor regions in language comprehension might come from studies of subjects that show selective deficits in action-related language processing because of the presence of circumscribed lesions in motor regions of the brain.

While cases of traumatic damage are frequently characterized by lesions not limited within the motor system, subjects with pathological impairment specific of the motor areas can represent interesting cases of study. Along this line, Bak et al. (BAK, et al. 2001) investigate the nature of the aphasia in a group of patients with MND (motor neurone disease) showing that action-verb production and comprehension are both selectively vulnerable in association with a *bilateral* motor system impairment. The finding of a selective deficit in verb action processing in association with MND suggests that the neural substrate underlying motor verbs representation is connected with the cortical motor system. This result is also confirmed by a study conducted on two members of the same family affected by a progressive movement disorder and dementia associated with a selective verb use and understanding deficit (BAK, et al. 2006).

Recently, Boulenger et al. (BOULENGER et al. 2008c) examined the impact of Parkinson’s disease on lexical decision for action words. According to the experimental hypothesis, if premotor and motor regions that are involved in movement preparation and execution play also a role in action word understanding, than Parkinson patients that are usually characterized by an impairment of the motor system, when deprived of dopaminergic treatment (levodopa), should show selective deficits in processing action related words but not in processing other classes of words, such as concrete nouns. According to this hypothesis, results show that

processing of action words can be selectively disrupted following a pathology that affects the motor system. Parkinson disease patients, without dopaminergic treatment, that is when the motor disability is strongest, don't show prime effects during tasks involving action verbs and words, while they show prime effect on non-action words. Moreover, according to the hypothesis, the experiment shows that levodopa treatment, increasing functionality of the motor system, also restores the possibility to induce prime effects for action words.

The hypothesis that naming of actions depends from structures located within the *left* premotor areas of the brain is supported by some experiments performed by Tranel et al. (TRANEL, et al. 2001), and Tranel et al. (TRANEL, et al. 2003). Both experiments support the assumption that there is a functional segregation of the distinctive neural systems subserving naming of actions and naming of concrete objects and that the left pre-motor cortex is related to the retrieval of specific visuomotor aspects of action concepts. Thus, while lesions in the left inferotemporal region is statistically associated with defective naming of concrete entities, but not with normal naming of actions, lesions in the left motor and pre-motor cortex are associated with defective naming of actions. Accordingly, an elegant rTMS experiment performed by Aziz-Zadeh et al. (AZIZ-ZADEH, et al. 2005) shows that the temporary functional disruption of the *right* motor areas functioning doesn't influence semantic processing but only speech production, whereas multiple TMS on the *left* motor areas produces both difficulties concerning the *articulation* and the *use* of the words. The authors started from a result of Stewart et al. (STEWART, et al 2001) concerning the distinction of two different types of overt (aloud) speech impairment induced by repetitive TMS over two different left hemisphere sites. The first type, called 'motor' was determined by stimulation of a *posterior* site located in the motor area of the frontal lobe, and was associated with EMG (electromyography) activity evoked in lower facial muscles, while the second one, called a 'non-motor', was caused by the stimulation of an *anterior* part coinciding with the Broca's area and was not associated with EMG activity in oro-facial muscles.

Experiments confirm that also covert speech production activates the motor system. McGuigan & Dollins (McGUIGAN & DOLLINS 1989) showed with EMG that

tongue and lip muscles are activated in covert speech in the same way as during overt speech. Following this line, an fMRI study by Wildgruber, et al. (WILDGRUBER, et al. 1996) showed primary motor cortex activation during covert speech, whereas Aziz-Zadeh et al. (AZIZ-ZADEH et al. 2005) measured times of latencies in a syllable counting task while a repetitive TMS was addressed on the areas individuated by Stewart et al. (STEWART et al. 2001), not only within the left hemisphere but on the symmetric regions within the right hemisphere as well. Authors measured the impact of temporary disruption of selected motor areas on both the production of *overt* speech and for the production of *covert* speech, assuming that silent speech should not involve the use of oro-facial articulators but only a semantic processing. Results show that overt and covert speech impairment are induced with similar patterns by repetitive TMS in the left hemisphere, accordingly both the Broca's site and the posterior motor site of the left hemisphere can be considered involved in covert speech as they are in overt speech. By contrast, the results show that the right hemisphere posterior motor site elicits overt speech impairment, but it does not interfere with covert speech. Authors hypothesize that the overt speech impairment in this case can be considered due exclusively to a motor interference with the activation of the oro-facial muscles.

5. Conclusion: From modularity to embodied simulation

The importance of the evidence illustrated above consists chiefly in contrasting a *radical* modular approach to language processing considering linguistic communication as an exploitation of abstract symbolic systems processed by dedicated cognitive mechanisms. As noted by Barsalou (BARSALOU 1999), it's essential to see that traditional cognitive linguistics assumes language as an *a-modal* and *arbitrary* symbolic process grounded in the functional role of restricted circuits of the brain (see for example: PINKER 1995). According to this view, language usage

and understanding should be assumed as independent from action perception and execution, as well as only dedicated modular sections of the brain should be identified as having an *exclusive* functional role in language processing. Notwithstanding its popularity, a radical modular theory has to face many unresolved problems such as the absence of crucial evidence that a-modal symbols exist and are processed by *strictly* dedicated regions of the nervous system, and the fact that several findings from neuroscience establish that categorical knowledge is grounded in the *multimodal* functioning of sensory-motor regions instead of functionally dedicated areas.

Contrasting the idea that language understanding is grounded in a symbolic dimension and that abstract categorization is made possible by abstract and disembodied comprehension, numerous experimental findings converge into assuming that linguistic symbols become meaningful only when mapped to non-linguistic experiences such as action and perception. Even if the development of an exhaustive embodied theory of language requires a wide ensemble of evidence in order capture the extraordinary variety that characterize the actual communication practice, this hypothesis is at least confirmed for words and sentences whose content is related to the description of actions and movements that are part of the subject's motor repertoire. Accordingly, instead of considering the meaning as an abstract symbol, it is reasonable to hypothesize that semantic understanding is *embodied*, that is, connected with the bio-mechanical nature of bodies and perceptual systems (GLENBERG, et al. 2005). In this view, comprehension does not involve the activation of abstract and a-modal mental representations; instead it involves the activation of sensory-motor cognitive routines configuring a *multimodal* dimension of semantic understanding based on the instantiation of *simulative processes*.

According to a *simulation theory of language understanding*, it is possible to hypothesize that meaning arises from simulating the sensory motor conditions associated with the content of a linguistic construction. In this view, a simulation consists in the *functional* activation of the same cognitive processes during both language understanding and action execution. These simulations are determined by the properties of both the object and the action, that is, by the affordances elicited by certain circumstances and goals. This makes it possible to associate language usage

and understanding with action execution and comprehension using a framework of the kind adopted to study the relation between perception and action, for example by Alva Noë (NOË 2004) and Evan Thomson (THOMSON 2007).

Indeed communication is an embodied activity and is part of our *repertoire of actions*. If we accept that by means of our communicative skills we are engaged in a kind of *intentional action*, then it is possible to recognize that also several aspects of language use and understanding are linked with specific features of our body. Accordingly, *using* language requires the ability to control the body, to move it in a way to produce communicative gestures and sounds, while *understanding* language requires that the sender and the receiver of a message share common cognitive patterns as it is guaranteed by the exploitation of common simulation processes based on the presence of corresponding interpersonal neural codes.

Finally, since communication involves the recruitment of our motor skills, it is also arguable that our linguistic and communicative capacities derive from a more primitive ability consisting into understand the intentions underlying others motor actions (RIZZOLATTI & ARBIB 1998, TOMASELLO 2008).

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