Chapter 3

ACTING AND UNDERSTANDING

Evidences supporting a motor theory of language comprehension

3.1- The rationale and the structure of this chapter

Assuming that communication is embodied we state that several language-related processes, instead to be only abstract and disembodied functions, are grounded in the physical features of our body, such as its shape and motor possibilities. The embodied theory of language involves that our conceptual structure is shaped by the peculiarities of our perceptual structures and motor dynamics, so that, our motor activity cannot be considered an autonomous dimension separated from our linguistic abilities.

As any other scientific theory, the embodied theory of language must face the burden of the empirical proof. If language cognition is related with several features of our body, then experimental modification of bodily parameters should produce measurable alterations on the overt behavior concerning language usage and the understanding. This is a condition that cannot be set aside. The aim of this chapter (and the next too) is to review and organize a large – and sometimes "messy" – ensemble of empirical findings concerning the relationships between the body and language understanding.

Within the following paragraphs it will be possible to introduce a fist list of experimental researches evidencing the presence of a surprisingly relationships between language understanding, action observation and execution. This extended review aims at showing that language processing is not grounded in an autonomous module. The existence of functional interconnections between language production and understanding supports the hypothesis according to which our communicative abilities, from concrete to abstract, are linked with other sensory-motor possibilities of our bodies.

Experimental evidences introduced below support the hypothesis that language understanding can influence action preparation and execution, assuming that that the execution of actions involving the use of bodily effectors, such as harms, hands, legs etc., can be influenced by simultaneous execution of an action-related linguistic task. As well as they show that the understanding of action related words should be facilitated by sensory-motor tasks. According to this idea, it will be necessary to introduce some distinctions concerning the specific degree of motor involving during language processing. Therefore, critical will be the distinction between a *communicative* and a *referential* interaction between language and motility, as well as the distinction between the influence of action execution on the *lexical access* and on the *access to meaning*. Following this line, the assumption of a *semantic* involvement of the sensory-motor apparatus during language understanding requires the presentation of evidences concerning the impact of action-words embedded within a sentence. Only if motor resonance is involved after action-word presentation during sentence understanding it is reasonable to assume a role of motor cognition in semantic understanding. This possibility prefigures a "time question" concerning *when* the motor apparatus is functionally involved in tasks concerning language understanding.

3.2- Towards a *motor theory* of language understanding

The concept of *motor cognition* grasps the idea that the human cognitive activity is strictly related to many critical embodied features (Jeannerod, 2006). The motor cognition paradigm takes into account the *preparation* and the *production* of actions, as well as processes involved in *recognizing*, *predicting* and *understanding* the behavior of other people. Effects evidencing a sensory-motor influence on perception are abundant in literature, above all, over the last twenty years, experiments concerning the effect induced by the *perceptual* recognition of *affordances* in object interaction and categorization have assumed an increasingly importance in several fields of discussion concerning human cognition.

Focusing the attention on language, a first distinction between motor understanding of *action* and motor understanding of *language* must be introduced. As noted by Fischer & Zwaan (2008, p. 836), although it may be tempting to consider the understanding of action-sentences as a kind of action-observation, it is important to underline differences existing between a direct observation of an action and the comprehension of a linguistic description. For example, while *directly* observing an action provides *analogue* temporal information about an observed action, this is not true in cases concerning sentences *describing* that action. Since, in hearing and understanding a sentence the speed with which language is processed is determined by speakers' rate of pronunciation, as well as by the natural course of cognitive mechanisms, but it is independent of the real time of action execution.

Another difference between action observation and language understanding is that a great deal of explicit information in the former can be omitted in the latter. A linguistic construction can be correctly defined without any detail concerning the subject or the manner in which the action is performed. So, in sentences describing actions like “He drives a car” no information might occur about the actor of the action (he could be a man, a woman, but also a non-human), as well as it might lack of details concerning what kind of car is driven (the color, its form, if it is a real car or a radio-controlled model) and the way this action is actually performed. Differently, similar kinds of general information are relevant during visual perception[1], since, for example, the perception of an action cannot lack of basic *qualitative details* concerning the presence of a subject, or the way the action is performed.

During the first stage of cognitive science, many perspectives assumed that knowledge and understanding rely in a semantic memory system separated from the brain’s modal system for sensory motor activity (Chomsky, 1957; Fodor, 2000). This classical view proposes that concepts are generated by *abstract*, *arbitrary* and *amodal* symbols and that the mind is nothing but a mechanism exploited for syntactically manipulating symbols, such as an information processing device. Accordingly, cognitive functions concerning *perception* and *action* are considered as *low level* and *peripheral* processes, while language usage and understanding is considered a high level and an independent cognitive process. In addition, perception and action are posited as separate spheres, so that it is not possible to imagine that actions have effects on perception, but it is assumed that the perceptual processes take place in the same way independently from the motor responses involved. Recently, however, researches in grounded cognition (Barsalou, 2008) have turned away from a-modal symbols focusing the attention on situated actions and bodily states. This kind of research has rediscovered how *multimodal representation* should be considered central for knowledge and understanding, grounding this assumption on behavioral and neurobiological evidences.

3.3 - Acting and understanding: preliminary evidences

A well known phenomenon supporting the idea that language understanding can be shaped by bodily gestures is represented by the “McGurk effect” (McGurk & MacDonald, 1976). The McGurk effect is a phenomenon based on the interaction between hearing and vision during

[1] It is important to underline that what is relevant here is the comparison between action understanding via perception and action understanding via language description. Questions concerning memory reliability are not considered.

speech perception. It suggests that speech understanding is a *multimodal* process that involves information from more than one sensory modality. Experiments revealing this kind of effect consist in watching a speaker's mouth saying a syllable that conflicts with the heard syllable. A common example of McGurk effect is represented by the experimental setting where participants, while *watching a video,* first declare to *watch* and *hear* a subject pronouncing the syllable "DA", but after, in a different task consisting in *hearing only* the same sound without watching the video, they declare to percept the syllable "BA", while in a final task consisting in *watching only* the same gesture performed by the same subject *without sound*, they declare to percept the pronunciation of the syllable "GA".

This kind of experiments reveals how listeners engaged in language understanding use information not only from the auditory mode, but also from the visual perception of the mouth-related actions, showing in this way a form of *sensory-motor understanding*. In order of generalizing the significance of the MacGurk effect, an influence of action observation on syllable production has been evidenced by Gentilucci (2003), where the author suggests that phonemic representations expressed by mouth articulation gestures correlates with representations of the observed action. The results of the experiments performed by Gentilucci show that the kinematics of lip aperture and the amplitude spectrum of voice when pronouncing the syllables "BA" or "GA" were influenced by the observation of different grasp kinematics, depending on the size of the target objects. Specifically, both lips aperture and voice peak amplitude were greater when the observed hand grasp was directed to the largest object. This evidence, as well as those deriving from other experiments (Gentilucci, Santunione, Roy, & Stefanini, 2004b; Gentilucci, Stefanini, Roy, & Santunione, 2004a), suggest that the execution and the observation of grasping actions activates a mouth articulation posture which selectively influences speech production. They support the idea that the system involved in speech production shares, and may derive from, the activation of the sensory-motor system which is involved in the control of arm–mouth interactions and, in general, of arm actions.

Two opposite and competing views inform the debate concerning the existing relationships between gestures and speech. On the one side, a conception posits that gesture and speech are two separate communication systems and that gestures are an auxiliary support when verbal expression ability is temporally disrupted, or word retrieval is difficult. On the other side a conception posits that gestures and speech form a single system of communication because they are linked to the same thought processes even if the expression modality differs. Following this line, if the latter hypothesis is true, the single system should be involved in the execution and in the interpretation of messages expressed by words, gestures, or both.

According to the second hypothesis, Bernardis & Gentilucci (2006) verified whether gesture execution and 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 the two communication signals simultaneously. Results showed that the voice spectra of the pronunciation task was higher when the word is pronounced together with the corresponding gesture, while no voice modification was observed when executing a meaningless arm movement involving the same joints. Moreover results showed that the pronunciation of meaningless words is not affected by the execution of meaningful arm gestures. Behavioral experiments such as this support the hypothesis that spoken words and symbolic communicative gestures are coded as a *single signal* by a unique communication system involving both linguistic and motor abilities.

Many other evidences show the presence of deeper links between *language understanding* and our *sensory-motor abilities*. One of the most interesting strategies adopted to make explicit this correlation concerns the role of *affordances recognition* during language comprehension. A paradigmatic evidence of the existing correlation between language understanding and sensory-motor cognition is related to an experiment performed by Gentilucci & Cangitano (1998). During this trial the influence of word reading on visuo-motor activity is measured analyzing different kinematic components of actions consisting in reaching and grasping a rod on whose visible face were printed the words "long" or "short" (fig. 1) Results revealed that peak acceleration, peak velocity, and peak deceleration of arm were higher for action performed on rods marked by the word "long", rather than on rods marked by the word "short". This phenomenon is consistent with the hypothesis that during the initial phase of movement subjects spontaneously associate the meaning of the word with the distance to be covered, activating a motor program for farther or nearer objects position. Only in the final phase of the movement subjects modify specific *parameters* in order to tune the action with the physical circumstances[2].

[2] Moreover, results such as these are used to contrast the notion that the analyses executed in the ventral and dorsal cortical visual streams are different and independent.

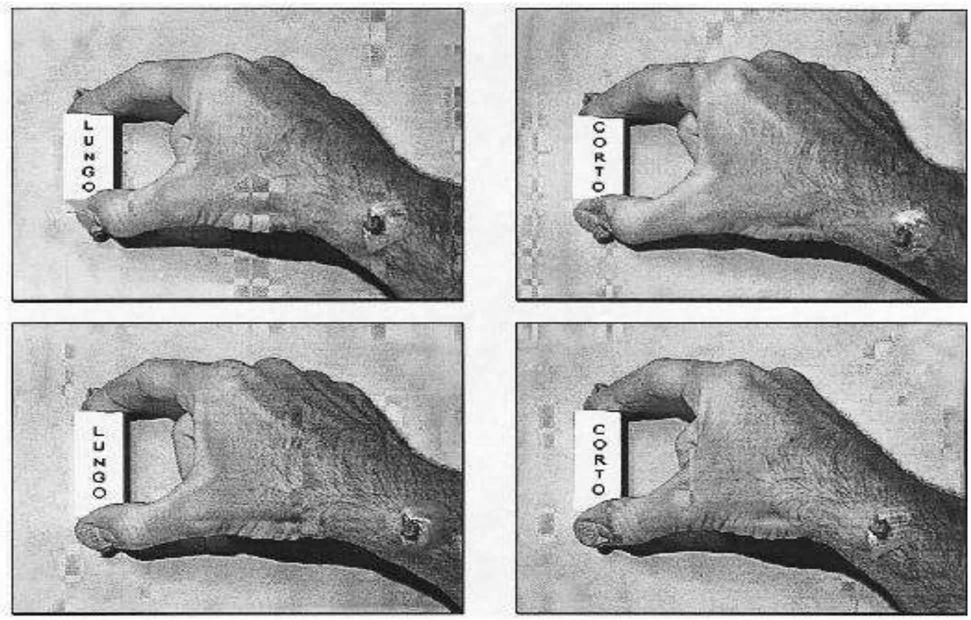


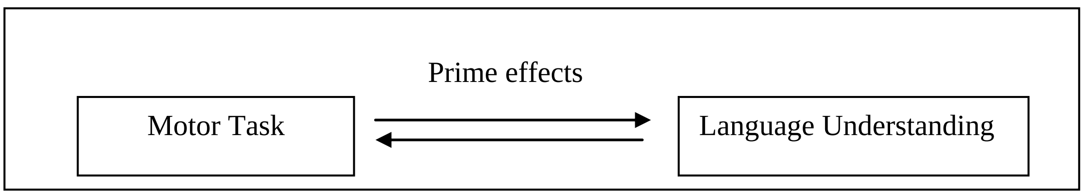
Fig 1. Gentilucci & Cangitano (1998) – p. 573

Gentilucci and Cangitano's outcomes find a further confirmation in another célèbre experiment performed by almost the same authors (Gentilucci, Benuzzi, Bertolani, Daprati, & Gangitano, 2000), as well as in the experiments performed by Glover et al. (2004). In the latter, instead of the adjectives used during the previously introduced experience, scholars employed words that only implicitly related to size, and consequently to 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 the experiment scholars observed the interactions between the understanding and the realization of motor activities such as that of grasping. Accordingly, it appears that reading an adjective, or the name of an object, interferes with the planning of a grasping movement. Moreover, it appears that this phenomenon occurs outside the subjects' conscious awareness. In both this cases the results are compatible with the hypothesis that motor affordances influencing action execution are unconsciously elicited during language understanding.

Many experiments show the presence of priming effects between words and motor actions. For example, a series of two experiments performed by Myung et al. (2006) showed how playing the piano and using a typewriter involve similar manual actions, thus corresponding words to these actions were found to prime one another in a lexical-decision experiment. During this test a series of target pairs was presented auditory, after participants were asked to make a lexical decision on a target word. Results show that participants made a significantly faster decision about target words (e.g. ‘typewriter’) following a prime that shared manipulation features with the target (e.g. ‘piano’) than an unrelated prime (e.g. blanket). Final reflections about this finding suggest that manipulation knowledge may constitute a part of the semantic representation of objects and that words related manipulation knowledge may be retrieved without conscious effort.

More accurate behavioral measurement of the interaction between language understanding and action execution are available. An example is represented by the study of Boulanger et al. (2006) where accurate time measurements concerning interferences and prime effects of semantic elaboration and action planning were obtained. In one of these experiments reaching movements were performed concurrently or successively to visual lexical decisions task with action verbs or concrete nouns and pseudo-words. On appearance of a white cross at the center of a monitor for 500 msec (go-signal), participants had to move their arm to reach and grasp a cylindrical object placed in front of them. The onset of the movement triggered the presentation of a new string on the monitor consisting in a word such as a noun, an action verb, or a pseudo-word. If the string was a word, the movement had to be carried on, otherwise it had to be interrupted. 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, longer latency and smaller amplitude suggest that perceiving action verbs interferes with the execution of the movement. Moreover results of this experiment show that interferences between these two tasks occurred as early as 160–180 msec after word onset, whereas priming became evident at about 550–580 msec after word onset. Recently, further findings were showed in an analogous experiment performed by Nazir et al. (2008) where, using the same apparatus of the previous trial, lexical stimuli were introduced with a delay of 50 msec and 200 msec in respect of the arm movement onset.

Experimental evidences introduced above support the hypothesis that language understanding influence action preparation and execution. But, whether we assume that motor resonance is evoked by words, it might be hypothesized that the process can also run in reverse direction. In this hypothesis the understanding of action related words should be facilitated by sensory-motor tasks. A similar conclusion can be reached analyzing a behavioral study performed by Lindemann, et al. (2006). In these experiments, participants made lexical decisions concerning words in a *go/no-go* task paradigm after having prepared for a specific action that they don't execute. During this trial, in order to investigate the effects of action preparation on language understanding, several experiments were conducted in which the preparation of an action provided semantic influence for a subsequently presented word. In all experiments, participants prepared a motor action (e.g., drink from a cup) and delayed its execution until a word appeared on a screen. After, they were asked to answer a question concerning the showed words. Results showed that response latencies were sped up if words presented in a go/no-go decision task were consistent with features of the previously prepared action, revealing in this way that the understanding of action related words is *selectively influenced* in accordance with the co-occurrence of subject's motor intentions.

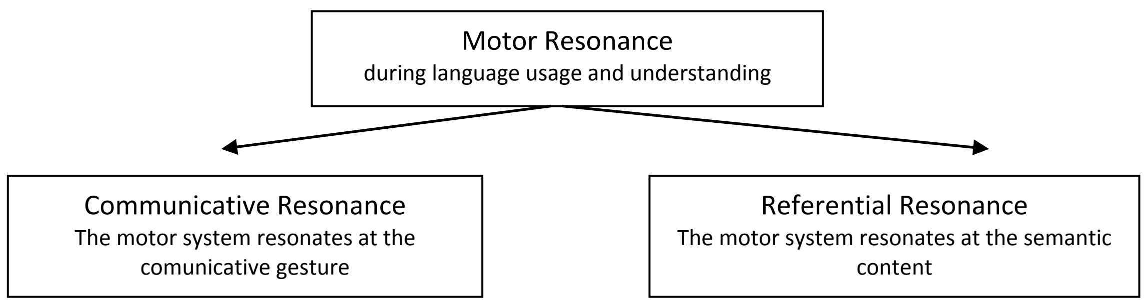


3.4 - The communicative and the referential dimensions of language understanding

Experiments mentioned above evidence the possibility of distinguishing between two different kinds of *motor resonance* occurring in language understanding: a *communicative* and a *referential* (Fischer & Zwaan, 2008). The communicative motor resonance occurs when subject's motor system responds to the *gesture* itself, that is, when the motor system reacts to some components of the articulation required to pronounce a certain linguistic construction. For example, when listener's *speech motor system*, controlling *mouth*, *tongue* and *lips* movements is influenced by hearing the word "kick" (a gesture that is typically accomplished through *feet* and *legs*), we have a case of communicative motor resonance, that is, an interaction between the motor system and the language understanding process limited to the physical *articulation* of an utterance.

A typical experimental confirmation concerning the presence of communicative motor resonance is represented by the previously introduced "McGurk effect". A general theoretical approach is represented by the *motor theory of speech perception* according to which "the objects of speech perception are the intended phonetic gestures of the speaker, represented in the brain as invariant motor commands that call for movements of the articulators through certain linguistically significant configurations” (e.g. ‘tongue backing’ ‘lip rounding’ and ‘jaw raising’, providing the basis for phonetic categories) (Liberman and Mattingly, 1985, p. 2, see also next section). Moreover, recently neurobiological evidences confirm the presence of a specific motor resonance at the level of speech understanding (Gentilucci & Dalla Volta, 2008).

Differently as regard the communicative, the *referential motor resonance* occurs when the motor system responds to the *content* of the communicative act, evidencing how motor cognition is also involved in *semantic* understanding[3]. For example, when hearing the word “kick” subject’s motor system controlling “legs” or “feet” is influenced, we have a referential motor resonance, since in this case the motor system is activated by the content of the heard utterance describing an action involving the movement of specific bodily effectors such as feet and legs. Evidences concerning referential interaction between language understanding and motor cognition are represented by experiments such as that of Boulanger et al. (2006), but also by several neurobiological findings (Buccino et al. (2005), see for a further review next section).



On the basis of this distinction, focusing the attention the referential motor resonance, it’s possible to draw another sub-classification. In order to understand the role of sensory-motor cognitive patterns in language processing it is useful to draw a distinction between the *lexical access* and the *access to meaning* (Nazir, Boulenger, Roy, Silber, Jeannerod, & Paulignan, 2008). Language-induced motor activity that is observed early after word onset (150–200 ms) could reflect processes that are involved in lexical access. This kind of access can be related with a form of association as involved by language acquisition linking an action-word to many phenomenal aspects usually connected with the represented action. For example, hearing repeatedly the verb “kick”, while playing soccer, may produce a link between the word “kick” and specific phenomenal aspects regarding the action of kicking a ball. This involves the

[3] This distinction is analogue to that used by Gallese between *embodied simulation at the vehicle level* and *embodied simulation at the content level* (Gallese, 2008)

activation of motor cognitive processes connecting steadily linguistic modalities and the *perception* of specific sensory-motor features. This kind of *Hebbian* association can't be considered exhaustive of the semantic order, limiting comprehension to the presence of recursive presentations and co-occurrences of linguistic and sensory-motor items.

Differently as regard the lexical access, motor effects that occur 150-200 ms subsequent to word displays may involve more complex mechanisms than Hebbian association learning. The *access to meaning* can be taken as a representative form of semantic understanding characterized by a more radical and continuative involvement of the sensory-motor apparatus during language comprehension. More than a Hebbian form of association between linguistic constructions and motor-related phenomenal features, a semantic understanding based on motor cognition may show a functional involvement of the motor apparatus during language comprehension. In this case, it could be reasonable to assume that no linguistic representation of action-related constructions may be effectively understood without eliciting the activation of subject's motor apparatus correlated with the execution of the action described by the utterance[4].

Both these theoretical distinctions assume that the interaction between language understanding and motor cognition occurs at different levels. It is reasonable to assume a co-occurrence as for example considering possible the simultaneous presence of a communicative and a referential resonance during language comprehension, as well as the simultaneous presence of lexical and semantic access to meaning during semantic comprehension (Pickering & Garrod, 2007), evidencing in this way the *multimodal* nature of language-understanding.

The main distinction among levels of language understanding is represented by their context dependency. Studies that investigate interactions between language and the sensory-motor apparatus using only behavioral reactions to the presentation of a single word are susceptible of semantic indetermination. However, assuming the presence of a semantic involvement of the sensory-motor apparatus during language understanding requires showing evidences concerning the impact of action-words embedded within a sentence. Only if motor resonance is involved after action-word presentation during sentence understanding it is reasonable to assume an active function of motor cognition in semantic understanding. This possibility prefigures a "time question" concerning *when* the motor apparatus is involved in language understanding tasks.

[4] Many distinctions concerning the involvement of specific motor apparatus during the understanding of action-related words also in cases of physical impairments will be analyzed in section 7 of the present study.

Classical examples evidencing a correlation between semantic understanding and motor cognition are those performed by Glenberg & Kaschak (2002). In these experiments participants were presented with a series of *sensible* and *nonsense* sentences and were asked to determine as quickly as possible whether each sentence made sense. One independent variable, concerning action-direction (e.g. toward/ away), was manipulated for the sensible sentences. Thus, *toward sentences*, such as “Open the drawer” implied action toward the body, while *away sentences*, such as “Close the drawer” implied action away from the body and finally *nonsense sentences*, such as “Boil the air,” were considered to imply no specific bodily-related directions. The responses were manipulated by using a button box with the longest dimension projecting outward from the body. Subjects answered that a showed sentence was sensible by pressing the far button—that is, they moved their hands away from the body to respond *yes*, and responded *no* by pressing the near button – that is moving their hands toward their body. The finding was that *action-compatible* responses characterized by a correspondence between the bodily related direction of the movement described by the sentence and these defined by the direction of the movement required to give the key answer, such in the case of “Close the drawer” and press the “yes” key, were faster than *action-incompatible* responses such as “Open the drawer” and press the “yes” key. In other words, when a sentence implied an action in one direction participants had difficulty making a sensibility judgment requiring a response in the opposite direction (see also Klatzky et al. (1989)

Outcomes of this kind were recently confirmed through another behavioral experiment made by Glenberg et al. (2008) using Italian constructions such as “Andrea ti porta la pizza” (“Andrea carries the pizza to you”), instead of English constructions, but reproducing the same phenomenon of compatibility. Glenberg and Kaschak refer to this phenomenon as the *Action sentence Compatibility Effect* (ACE), following which understanding an action involves the same cognitive mechanisms than making or planning the described action. ACE is compatible with the hypothesis that sentence understanding is grounded in bodily actions, namely, it’s compatible with the idea that the meaning of an action-related linguistic construction is given by a non-propositional understanding regarding how the described action can be accomplished[5].

[5] Similar findings concern the compatibility effect of language understanding and emotional statements. As showed by Glenberg et al. (2005), reading and understanding sentences is facilitated when the suggested mood of the sentence is congruent with the mood induced assumption of a certain facial expression.

Borghi et al. (2004) also used the concept of affordance to demonstrate that sentence understanding is grounded in situated actions. In one of their experiments, participants read a sentence that mentioned an object such as "car" within the proposition "There is a car in front of you". After participants, using a bodily-oriented button panel (analogous to the panel of the previous experiment), were asked to determine if successively presented nouns such as "roof", "wheel" or "road" were parts of the object named in the sentence (e.g. "yes" for *roof* and *wheel*, but "no" for *road*). Assuming that interacting with the roof of a car normally requires actions directed upwards, whereas interacting with the wheel normally requires actions directed downwards and that these different affordances are part of the basic meanings of car, roof, and wheel, it is reasonable to assume that participants required to move upwards to the top response button to indicate "yes," should respond faster to a target such as *roof* than participants required to move downwards to indicate "yes". A hypothesis effectively confirmed by the outcomes of the experiment.

Moreover, in two experiments conducted by Kaschak et al. (2005) show that understanding phrases concerning movement share the same cognitive roots with the perception of the same movement. During the experiment participants listened to and made judgments on sentences describing motion in a particular direction (e.g. "The car approached you"). They simultaneously viewed dynamic black-and-white stimuli reproducing the perceptual effect of a movement in the same direction as the action specified in the sentence (i.e. towards you) or in the opposite direction (i.e. away from you). Findings show that responses were faster to sentences presented concurrently with a visual stimulus depicting motion in the opposite direction as the action described in the sentence. Result showed the presence of an interference effect so that participants used more time in judging a sentence if the concomitant visual effect showed a movement toward the same direction as described in the phrase. This suggests that the processing mechanisms recruited during language comprehension are also used during visual recognition of bodily related movements, and that these mechanisms can be quite specific.

In two experiments by Chambers et al. (2004) eyes movements were monitored as participants followed instruction sentences containing temporary *syntactic ambiguities* (e.g., "Pour the egg in the bowl over the flour") and watch a display where a possible affordable scenario (where the egg is liquid and can be purred) is placed side by side with an unaffordable scenario (where the egg is solid and can't be purred). Findings suggest that syntactic decisions are guided by affordances evaluation related to contextual situations as described by the utterance.

Other evidences in accordance with the previously introduced results are showed by Zwaan and Taylor (2006), where in a series of five experiments authors demonstrate that manual congruent responses with the action described in a sentence were faster than incongruent responses, suggesting that observing visual rotations and understanding sentences about a manual rotation both engage the same cognitive processes involved in actual manual rotation. Another elegant experiment by Taylor and Zwaan (2008) demonstrates how motor resonance in language understanding is not limited only to the occurrence of a single action-word, but implies the understanding of more complex constructions involving the use of *adverbs*. When a verb is modified by an adverb, such as in the case represented by “He placed his hand on the gas cap, which he opened slowly”, measurements show that compatible motor responses are also facilitated on the adverb only if it primarily modifies the action (e.g., “quickly” and “slowly”) and not when some other element of the referential situation is modified (e.g., in cases such as “He placed his hand on the gas cap, which he opened *happily*/*eagerly*/*nervously*”).

Zwaan, Stanfield and Yaxley (2002) addressed their research questions with the aim of understanding whether the simulation evoked during sentence comprehension is sensitive to subtle differences pertaining an intrinsic property such as the *shape*. In order of verifying their hypothesis, presented participants with sentences describing animals or objects in a different location, implying a different shape (e.g., “He saw the lemon in a bowl” *vs*. “He saw the lemon in the glass”). The shape of the object, or animal, changed as a function of its location (e.g., eagle in the sky, eagle in a nest). After reading a sentence, subjects were presented with a line drawing of the object in question and asked of judging whether the object had been mentioned in the sentence or simply named the object. In both cases, responses were faster when the pictured object’s shape matched the shape implied by the sentence than when there was a mismatch.

More recently, Borghi & Riggio (2009) used a picture recognition task with the aim of investigating the relationship between sentence understanding and affordance recognition. During the experiment, participants were presented with either a observation sentence or an action verb (Look at/Grasp) followed by an object name. Subjects had to decide whether the visual object following the sentence was the same as the one mentioned in the sentence. At the same time, objects graspable with either a precision or a power grip were presented in both a canonical (affordable) and non-canonical (unaffordable) orientation. Results show that action sentences, in combination with object perception, were processed faster than observations sentencex, in addition they found that reaction times were speeded up by canonically oriented objects graspable with a power grip. Authors explain the result assuming that actions rather than observation sentences imply a physical interaction with the object and that this involves facilitation in response.

In order of supporting a simulation theory of language understanding some studies have shown that listening phrases concerning actions directly activate a motor system of the subject. Evidence supporting this theory is provided by Spivey & Geng (2001) who have demonstrated that when we understand a phrase we are only apparently at rest, while our eyes are actually moving and follow the line of imagined objects. During the experiment ocular movements were registered in subjects listening a story suggesting directionality. For example people were leaded to imagine being on the middle of a canyon following the movements of a person going down from the top to the bottom. Results showed that participants move the eyes following the direction of the imagined actions. Results such as this support the hypothesis that ocular movements are not only the way we retrieve information from the environment, but they represent also the link between the understanding of an action and the understanding of a related sentence.

The experiments illustrated above evidence that sentence understanding is influenced by natural affordance sensibility, that is, by the ability to identify potential actions within *situated* contexts described by an utterance. Moreover, these findings are consistent with the hypothesis that interactions between linguistic cognition and motor ability are captured by patterns of congruence such as those represented by the case in which certain directed action facilitates the understanding of a sentence describing a congruent action.

The importance of the evidences illustrated above is that they show the limits of a radical modular theory of meaning, that is, a conception considering language a symbolic system processed by dedicated and independent cognitive mechanisms. As noted by Barsalou (1999, p. 578), it's essential to see that this kind of symbolic system is *a-modal* and *arbitrary*. It is a-modal because conceived without presuming any correlation with other cognitive processes such as those concerning perception or motility. In force of their a-modal character symbols of a representative system are linked arbitrarily to whatever perceptual state.

A modular theory of meaning faces many unresolved problems. Between them, it is dramatic the absence of direct empirical evidences that a-modal symbols exist and are processed by a strictly dedicated region of the nervous system. Moreover, in addition to a large number of behavioral evidences confirming the interaction between different cognitive channels during language understanding, several findings from neuroscience challenge the a-modal symbol theory establishing that categorical knowledge is grounded in sensory-motor regions of the brain (see for example Damasio, 1994: for a further review see next section).

Contrasting the idea that language understanding is grounded in a mere symbolic dimension and that abstract categorization is made possible by an abstract and disembodied comprehension, several experimental findings converge into assuming that linguistic symbols become meaningful only when mapped to non-linguistic experiences such as action and perception. Instead of considering the meaning as an abstract symbol, it is reasonable to assume that the meaning is *embodied*, that is, strictly connected with the bio-mechanical nature of bodies and perceptual systems (Glenberg, Havas, Becker, & Rinck, 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* (see section 5 for furthers details concerning simulation).

According to a *simulation theory of language understanding*, meaning arises from simulating the sensory motor conditions described by a linguistic construction. In this context, a simulation consists in the 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 that a certain circumstances and goals elicit.

Notwithstanding the numerous behavioral evidences introduced above supporting a simulation theory of meaning, some open questions persist. Despite a great deal of evidence supports the idea that actions are more than collateral facts as regard cognitive processes, the role of motor processes in cognition is still not well defined. First of all, it is not clear if the activation of sensory-motor processes co-occur systematically with the performance of any cognitive task. Further researches should clarify if the activation of sensory-motor representations must be considered necessary for any action-related language comprehension and what kinds of linguistic items admit to be understood through simulative procedures. Finally, the discovery of simulative procedures for language understanding doesn’t show by itself whether or not the activation of sensory motor representations is sufficient for the comprehension at less of action-related words and action-related sentences, nor it shows how motor cognitive functions relates with other cognitive processes during language understanding.

In order to give an answer to these questions, a more detailed account concerning the understanding of the social dimension of language requires a change of perspective, moving from a phenomenological and behavioral point of view, to a neurobiological one. With an examination of the nature and the functioning of several biological aspects related to the possession of linguistic abilities it will be possible clarifying the previously introduced questions. This is the aim of the next section.

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