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Language and Embodiment: sensory-motor and linguistic-social experience. Evidence on sentence comprehension.

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INDEX

I part. GENERAL INTRODUCTION

III part. 'THE MEANING OF ABSTRACT WORDS': THE LINGUISTIC EXPERIENCE

Abstract

In this work I address the study of language comprehension in an "embodied" framework. Firstly I show behavioral evidence supporting the idea that language modulates the motor system in a specific way, both at a proximal level (sensibility to the effectors) and at the distal level (sensibility to the goal of the action in which the single motor acts are inserted). I will present two studies in which the method is basically the same: we manipulated the linguistic stimuli (the kind of sentence: hand action vs. foot action vs. mouth action) and the effector by which participants had to respond (hand vs. foot vs. mouth; dominant hand vs. non-dominant hand). Response times analyses showed a specific modulation depending on the kind of sentence: participants were facilitated in the task execution (sentence sensibility judgment) when the effector they had to use to respond was the same to which the sentences referred. Namely, during language comprehension a pre-activation of the motor system seems to take place. This activation is analogous (even if less intense) to the one detectable when we practically execute the action described by the sentence. Beyond this effector specific modulation, we also found an effect of the goal suggested by the sentence. That is, the hand effector was pre-activated not only by hand-action-related sentences, but also by sentences describing mouth actions, consistently with the fact that to execute an action on an object with the mouth we firstly have to bring it to the mouth with the hand.

After reviewing the evidence on simulation specificity directly referring to the body (for instance, the kind of the effector activated by the language), I focus on the specific properties of the object to which the words refer, particularly on the weight. In this case the hypothesis to test was if both lifting movement perception and lifting movement execution are modulated by language comprehension. We used behavioral and kinematics methods, and we manipulated the linguistic stimuli (the kind of

sentence: the lifting of heavy objects vs. the lifting of light objects). To study the movement perception we measured the correlations between the weight of the objects lifted by an actor (heavy objects vs. light objects) and the esteems provided by the participants. To study the movement execution we measured kinematics parameters variance (velocity, acceleration, time to the first peak of velocity) during the actual lifting of objects (heavy objects vs. light objects). Both kinds of measures revealed that language had a specific effect on the motor system, both at a perceptive and at a motoric level.

Finally, I address the issue of the abstract words. Different studies in the "embodied" framework tried to explain the meaning of abstract words The limit of these works is that they account only for subsets of phenomena, so results are difficult to generalize. We tried to circumvent this problem by contrasting transitive verbs (abstract and concrete) and nouns (abstract and concrete) in different combinations. The behavioral study was conducted both with German and Italian participants, as the two languages are syntactically different. We found that response times were faster for both the compatible pairs (concrete verb + concrete noun; abstract verb + abstract noun) than for the mixed ones. Interestingly, for the mixed combinations analyses showed a modulation due to the specific language (German vs. Italian): when the concrete word precedes the abstract one responses were faster, regardless of the word grammatical class. Results are discussed in the framework of current views on abstract words. They highlight the important role of developmental and social aspects of language use, and confirm theories assigning a crucial role to both sensorimotor and linguistic experience for abstract words.

Keywords

concepts, words, sentences, language comprehension, perceptual system, motor system, embodiment, simulation, motor resonance, effectors, dominant hand, intrinsic objects properties, weight, concrete words, abstract words, social-linguistic experience, language-dependence.

Notes

All human studies reported in this thesis have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Some references in the Thesis could appear redundant. This is to allow an autonomous reading of each Chapter.

The studies presented in *Chapters Three, Four* and *Six* are published in international journals. The study presented in *Chapter Seven* is going to be submitted.

I part

GENERAL INTRODUCTION

1 Categories and concepts

In this chapter I first discuss what we intend when we say that concepts are "embodied". Then I briefly explain the notion of simulation, addressing also its neuro-physiological basis.

1.1 Classical view of concepts

The classical propositional view of concepts and meaning proposes that concepts are generated by abstract, arbitrary and amodal symbols (Collins & Loftus, 1975; Newell & Simon, 1976; Landauer & Dumais, 1997, Foltz, Kintsch & Landauer, 1998; Landauer, McNamara, Kintsch & Dennis, 2006). In this framework, the mind is a mechanism for syntactically manipulating symbols, such as an information processing device. Perception and action are considered as "low level" and peripheral processes, and low and high level processes are seen as reciprocally independent. In addition, perception and action are posited as separate spheres (Sternberg, 1969; Pylyshyn, 1999). Therefore it is not possible to envision action as having effects on perception, because the assumption is that the perceptual process takes place in the same way independently from the kind of motor response involved.

In this framework concepts are supposed to be "autonomous" from the body. They are represented in our mind in a propositional way, for example through list of properties, statements, frames, semantic networks (Fodor, 1998; Phylysin, 1973). According to this view a transduction process occurs, from the sensorimotor experience in the environment to the mind. The outcomes of this process are frozen representations of the world: in the course of the transduction every link with the body is lost. The ensuing representations are just arbitrarily linked to the world and do not have any modality specific feature: in this sense we could refer to them as *abstract symbols*. For example, the concept "dog" is associated with the amodal, propositional feature "it barks", rather than with the modal acoustic feeling of hearing a dog barking.

Accordingly mind is conceived of as the specific software evolved by humans for manipulating these abstract symbols. These symbols are organized in a stable-linguistic way, and they do not depend on the "hardware", that is on our body with its peculiar sensorimotor functioning.

The consequence of this approach is the elaboration of models, for extracting and representing the meaning of words, based on statistical computations applied to a large corpus of existing texts. The underlying assumptions are that our knowledge is organized in a propositional way, and that the meaning of a concept/word depends on lexical co-occurrence and semantic relatedness. Examples of statistical models of semantic memory are the Hyperspace Analogue to Language (HAL, Burgess & Lund, 1997) and the Latent Semantic Analysis (LSA, Landauer & Dumais, 1997). In both the models word meanings is represented as vectors, detected in matrices (spaces with different dimensions) which describe the co-occurrence of terms in documents. That is: the meaning of a word is derived by its relations to other words and other abstract symbols. In this way it is possible *mathematically* / *spatially* calculating if two or more words/sentences are *equivalent*, namely if people represent them as semantically comparable or not. A low estimated parameter indicates that two words appear in different, *orthogonal,* contexts. The meanings of words are considered as fixed, so the understanding of a sentence would be pretty the same for everyone. LSA models outputs fit various experimental results: they fit human word sorting judgments and word-word lexical priming; they also successfully predict text learnability.

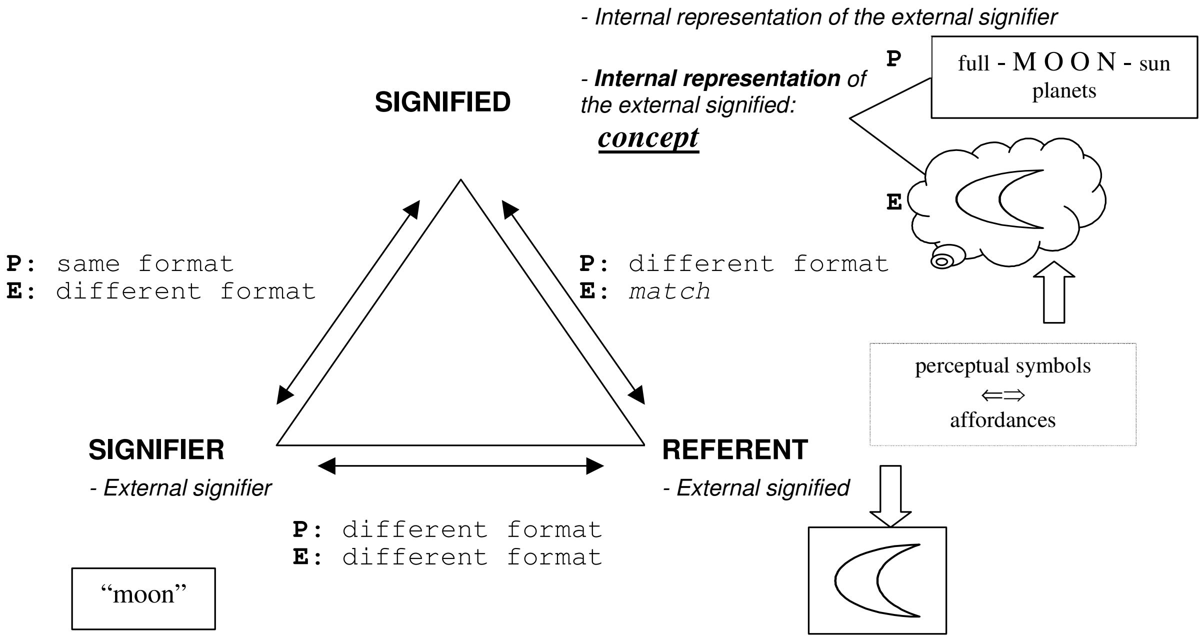
Nevertheless, there is much evidence that the predictions made by these models do not always match people understanding of sentences. For example, Glenberg and Robertson (2000) using LSA equivalent sentences, found that people actually distinguished between them depending on the perceptual characteristics of the objects.

After a sentence like "Marissa forgot to bring her pillow on her camping trip", people judged more sensible and imaginable the sentence "*As a substitute for her pillow,* she filled up an old sweater with *leaves*" than "she filled up an old sweater with *water*", even though the words *"leaves"* and *"water"* are similarly *far* from *"pillow"* in terms of LSA norms. A pillow made by a sweater filled up with leaves is not usual, but it is afforded, so more sensible and imaginable than a pillow made by a sweater with water. Authors explain the results positing that "the meaning of words in sentences is emergent: meaning emerges from the mesh of affordances, learning history, and goals" (Glenberg & Robertson, 2000, p. 388).

1.2 Embodied view of concepts

Embodied view suggests that concepts are grounded in sensorimotor processes (Barsalou, 1999a; Barsalou, 2008b). They consist in the re-enactment of the same neural activation pattern running when we perceive their *referents* or when we interact with them (Gallese & Lakoff, 2005; Glenberg 1997). With "referent" we bear on the extra-linguistic reality, real or imaginary, to which the linguistic sign refers.

Revisiting Hjelmslev (1975) sign triad – that is an evolution of de Saussure's (1959) concept of sign – we could say that the propositional classical view of concepts assumes that the mental representations of the external signified has the same format and syntactical rules of the external signifier, intended as the linguistic sign. So language is mentally represented in terms of linguistic symbols and the relationship with the external referent is not taken into account.



P: propositional view.
E: embodied view.

Instead the embodied theory states that the format of concepts *matches* the format of their referents, i.e. our experience with/in the extra-linguistic reality to which they refer. In keeping with this view, the Indexical Hypothesis (Glenberg & Robertson, 1999) – that relates the general theory of embodied cognition to language comprehension – claims that language refers to objects and situations, or to the affordances of a situation (Kaschak & Glenberg, 2000) (for a straightforward explanation of "affordance", *see Paragraph 3*).

The link between the mental representation of the signifier and the representation of the signified is arbitrary (for example, a "dog" is called "cane" in Italian). However, the internal representation of the referent is neither arbitrary nor abstract, but is rather grounded. Namely, in this view objects are represented in terms of perceptual symbols that are not arbitrarily linked but are rather analogically related to them (Barsalou, 1999a). Perceptual symbols are multimodal, because they activate different motor and sensorial information tightly linked to the interaction with the world, pertaining vision, audition, taste, touch, motor action etc.

A notion useful to capture how language comprehension is conceived of for the embodied view is that of *simulation* (Gallese & Goldman, 1998). Simulating means that the same neural areas are implicated in perception and interaction with the objects, and in comprehending words that refer to them. For example, the word “glass” should reactivate the experiences of our previous interactions with glasses. So it leads to the activation of auditory, visual, and tactile information, for example the smoothness of a glass of wine, its sound banging into a dish, its shape and size, that surprisingly do affect the smell and the taste of the wine. The same word re-activates also proprioceptive and kinesthetic information, for example hand/arm feedback whereas bringing a glass to our mouth, as well as information on its affordance.

In the present work I do not discuss the embodiment of phonogical aspects of language (in the figure, “Internal representation of the external signifier”). For a critical discussion on this topic I refer to Liberman and Mattingly (1985), and to Fogassi and Ferrari (2007).

1.3 The body, the context, and the current goals

When we claim that cognition is “embodied” we don’t just mean that perception and action generically influence our knowledge, but that our knowledge specifically depends on having a *peculiar, unique body* and sensorimotor system. This implies that concepts cannot be static. The concept of a “chair”, for example, is not the same for a child and for an adult because of the different kinds of interaction a child or an adult could have with the referent, a real chair.

So the concept of a “chair”, conveyed by the object as by the written or listened word, in the case of an adult evokes the action of “sitting down on it”. The same concept evokes a different motor representation in an one-year-old child, such as for example the actions of “leaning on it, standing upright on it”. In Gibson’s terms (Gibson, 1979) we could claim that the affordance of a chair is not the same for an adult and for a child. The notion of affordance refers to the fact that objects in the environment offer to us as stimuli for acting, as if they would “invite” us to act upon them. Affordances are not fixed objects’ properties, but they are variable, as they depend on the interaction between objects’ features, our peculiar body and the surrounding environment. Glenberg (1997) remarks also the role of learning, pointing out that the meaning of a situation depends on affordances tuned on personal experiences of actions and learned cultural norms. The resulting set of available actions in turn depends on each individual’s present goals.

Importantly, according to the embodied view cognition is not only grounded in our body, but also *situated*, as it varies depending on the *context* and on the subject’s *goals*. So, for example, if we need to change a light bulb, the chair will no more afford some rest, but it will afford us a support for reaching the bulb. Therefore, our motor representations of the objects are guided by our current purposes and take into account both the constraints/possibilities of our body and the constraints/possibilities of our environment. In this perspective the subject, with his/her goals, is no more a passive spectator, and action is not simply the strict executive process that sequentially follows perception. The kind of motor response involved does have an effect on the perception of the present object/situation (Prinz, 1997; Hommel, Müsseler, Aschersleben & Prinz, 2001). Our conceptual knowledge is grounded and built on our action and interaction with the objects: *ago ergo cogito* (Glenberg, 1997).

Interestingly, the role of the body and of the context (the situatedness) in the representations is recently underlined also in social cognition. Also in this field the mental representations that underlie social behaviour were classically considered as abstract and stable. Recent evidence instead shows that also social representations, and the processes that underlie them, are adaptive and are modulated by the perceiver's current goals, communicative contexts, and bodily states (Smith & Semin, 2007).

1.4 Neural bases of simulation: a brief outline

The neural substrate for the idea of simulation resides in the phenomenon of *motor resonance*. Recent neuro-physiological studies have led to important discoveries about the premotor cortex of the macaque monkey, the so called F5 area. This area contains two kinds of visuo-motor neurons: canonical and *mirror neurons* (Di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992). Canonical neurons fire when a macaque executes specific actions, for example when it grasps an object with a precision grip, an all fingers grip or with a whole hand grip. They fire also when the macaque observes an object. Mirror neurons, instead, fire when the monkey observes a conspecific, or the experimenter, executing a goal-directed action, such as grasping a nut, but not when it observes just the nut.

Crucially to our aims, much evidence suggests that the homologue of F5 area in humans is the Broca area. In keeping with this, recently it has been demonstrated that the Broca area, traditionally known for its involvement in the production of language, contains a motor representation of the actions executed with the hand.

An fMRI (functional Magnetic Resonance Imaging: a technique to measure the hemodynamic response related to neural activity in the brain) study by Buccino, Binkofsky, Fink, Fadiga, Fogassi, Gallese, Seitz, Zilles, Rizzolatti and Freund (2001) showed that when subjects observe actions involving the mouth, the hand or the foot, different regions of the premotor cortex and of the Broca area are activated, depending on the different effector used for executing the action.

Symmetrically, also brain imaging and behavioral studies on language provide evidence of a somatotopic organization of the cortical areas. For example, Pulvermüller, Härle and Hummel (2001) have found topographic differences in the cerebral activity pattern generated by verbs relating to legs-, arms- and mouth-actions. Further evidence in favour of the tight link between language and action comes from a study by Buccino, Riggio, Melli, Binkofsky and Rizzolatti (2005) who performed both a TMS and a behavioural study. In the TMS (Transcranial Magnetic Stimulation: a noninvasive method to excite neurons in the brain) study they found that the motor evoked potentials (MEPs, that is a measure for the motor response) amplitude recorded from hand decreases during listening to hand action related sentences. They found a symmetrical motor response modulation on foot during listening to foot action related sentences. Consistently, in the behavioral study they showed that sentences describing actions with the hand or the foot activate the motor system in a specific way, that is: participants responded faster to hand related sentences if the response device was a pedal rather than a keyboard. A symmetrical modulation effect of language on motor system was found for foot related sentences. (I will discuss these points more deeply in the *Chapters 3 and 4*.)

Finally, as far as the tight link between the F5 area and the Broca area is concerned, it's worth to mention the proposal by Rizzolatti and Arbib (1998) about the important role that mirror neurons could have played in language evolution (see also Gentilucci & Corballis, 2006).

2 Language and embodiment: behavioral, neuro-physiological and kinematics evidence

This chapter addresses the embodied view of cognition applied to language. I will focus on concepts mediated by language, presenting behavioral and neuro-physiological evidence of the action/perception systems activation during words and sentences comprehension.

2.1 Behavioral, neuro-physiological and kinematics evidence

An increasing body of evidence shows that language understanding implies a mental simulation (Gallese & Goldman, 1998; Zwaan, 2004). A heated debate within the embodied cognition community concerns whether the simulation activated during language comprehension is specific and detailed, or rather general. In the following part I will discuss studies performed using behavioral, neuro-physiological or kinematics methodologies, the results of which indicate that the simulation enacted by words is highly specific – that is, sensitive to the shape and orientation of the objects mentioned, to their motion direction, to the effector involved in the sentences etc.

I will first review studies pertaining objects intrinsic and extrinsic properties. With the term “intrinsic properties” we refer to objects invariant properties, like for example objects shape and size. Conversely, “extrinsic properties” are objects properties that depend on the observer or on the particular condition of observation, such as for example the current orientation of an object. In the second part, I will report evidence that highlight the role of different kinds of action and motor information for language processing.

2.1.1 Intrinsic properties: shape

Zwaan, Stanfield and Yaxley (2002) addressed if the simulation evoked during sentence comprehension is sensitive to subtle differences pertaining an intrinsic property, the shape. Participants were presented with sentences describing animals or objects in a different location, implying a different shape (e.g., [1] "He saw the lemon in a bowl" *vs*. [2] "He saw the lemon in the glass"). Their task consisted in deciding whether the picture represented a word mentioned in the sentence. The match condition led to an advantage in reaction times. For ruling out possible objections about the kind of task that could overtly require a comparison, authors designed a second experiment in which subjects had just to name the object/animal in the picture. In both experiments the results were straightforward: the response latency was lower when there was a match between the sentence and the picture (for example, when the sentence [2] was followed by the picture of a slice of lemon rather than of a whole lemon). The results suggest that while comprehending a sentence we automatically activate a perceptual representation, even if the current task doesn't claim for it. These results also show that sentence context has an important role in the building of these representations, that are dynamic and flexible.

2.1.2 Intrinsic properties: size

The specificity of the simulation for size was tested in different kinematics studies (Gentilucci & Gangitano, 1998; Glover & Dixon, 2002). The peculiarity of the kinematics method is that it allows detecting the activation of motor system during words processing. Glover and Dixon (2002), for example, asked subjects to reach and grasp objects on the surface of which either the word "Large" or "Small" were printed. The semantic meaning of the label shaped the early stages of both reaching and grasping movements; the semantic effect decreased over the course of the movement. A possible neurological explanation of the language effect on movement was ascribed to the closeness of language and motor planning centres, in the left hemisphere (Rizzolatti & Arbib, 1998).

2.1.3 Intrinsic properties: color

In an embodied view, the property of color is deeply different from typical multimodal properties, such as shape, because it is perceived by only one sense. The difference between theses two kinds of properties was well described by John Locke (1690/1975) who distinguished by *primary properties*, such as shape, size, and motion, that could be perceived by multiple senses, and *secondary properties*, such as color, taste, and smell, that are unimodal. He proposed that secondary properties could be represented less stably than primary ones.

Connell (2007) analysed whether implicit perceptual information about object color is accessed during sentence comprehension. Participants were presented with sentences that implied a specific color for the object described, as for example: "John looked at the steak on his plate". They had to decide if the picture showed after the sentence was mentioned in the sentence. The critical manipulation concerned the color of the picture: for example, either a brown or a red steak was shown. They found that perceptual information on color is activated during this task. However, participants were quicker when the object color implied by the sentence did not match the object picture color. The explanation they provide, consistently with the embodied view, is that accessing to shape, that is a stable property, is crucial for a recognition task. Thus if the color of the picture and the color of the object implied by the sentence do not match, there will be a minimal interference. Instead, if they match, the information on color is somehow difficult to ignore, even if color is a rather unstable property. This leads to a stronger interference on shape recognition.

2.1.4 Extrinsic properties: orientation

Stanfield and Zwaan (2001) demonstrated that we mentally represent the object orientation implied by a sentence in a figurative way. They showed participants a sentence suggesting a particular orientation of an object, for example horizontal or vertical (e.g., “He hammered the nail into the wall” *vs*. “He hammered the nail into the floor”). Then participants saw a picture showing the same object in an orientation that matched or not the orientation implied by the sentence. Responses were faster when the orientation suggested by the text matched the one of the picture. An amodal symbol system theory could possibly explain these results but it does not predict them.

2.1.5 Modality

In line with the view that perception, action and cognition are closely related, Pecher, Zeelenberg and Barsalou (2003) demonstrated that concepts activate multimodal information. They selected concept nouns and properties pertaining vision, motor action, audition, taste, touch and smell. Subjects were presented with a sentence like “A *lemon* can be *sour*”. Their task consisted in judging if the sentence was true or false. Crucially, the task did not require to use mental imagery. Response times showed that switching modality, for example from a taste property (e.g.: *lemon – sour*) to an auditory property (e.g.: *leaves – rustling*), led to an increase in response times compared to the cases in which the modality remained constant. This demonstrates that concepts are multimodal rather than amodal. The only alternative explanation is that amodal symbols for the *same* modalities are more associated than amodal symbols for different modalities. This account was ruled out with a control experiment, in which they obtained analogous results (that is, slower response times when changing modality) using properties pairs much more associated than the pairs used in the first experiment. These findings clearly demonstrate that subjects simulate the content of the sentence, and that this mental representation activates a neural pattern in different modality specific domains. This explains why transferring processing from one brain system to another implies costs.

2.1.6 Perspective

Borghi, Glenberg and Kaschak (2004) demonstrated that the simulation we build during language comprehension is sensitive also to the perspective implied by the sentence. Participants read a sentence describing an object or a location from an inside (e.g., "You are eating in a restaurant"), an outside (e.g., "You are waiting outside a restaurant"), or a mixed (e.g., "You are walking toward and entering a restaurant") perspective. Then participants were presented with a concept-noun and they had to verify if the concept was or not a part of the location. For example, a "table" is a part typically found inside a restaurant, whereas a "sign" is typically found outside a restaurant. Responses were faster if the noun referred to an object more easily available in the perspective implied by the sentence. Interestingly, subjects also responded more quickly verifying that an object had a particular part if they were in the corresponding perspective and, within this perspective, for near than for far objects. Therefore, for example, they were faster if the *inside* sentence "You are eating in a restaurant" was followed by the *inside* part "table" than by the *outside* part "sign". In addition, the inside near part "table" was processed faster than the inside far part "kitchen". Results showed that the different perspectives suggested by the sentences control the accessibility of information, making available different conceptual knowledge.

In order to rule out a propositional explanation of the results, the authors computed the association degrees between sentences and parts, by using latent semantic analysis (LSA). The results were not explained by semantic associations between, say, *inside sentences* and *inside parts*: they are consistent with the idea that comprehension implies simulation.

Finally, authors investigated perspective sentences that do not imply any action and that described an object in a particular orientation (e.g., "There is a doll upright in front of you"). Subject had to verify whether the noun presented after the sentence was a part of the object named in the sentence or not. The response device was a vertically oriented box. In order to provide a positive answer in the first part of the experiment participants had to move the hand upwards, and in the second part they had to move the hand downwards. Results showed faster responses when there was compatibility between the kind of response (yes-is-up vs. yes-is-down) and the location of the part (upper *vs.* lower). Crucially, these results were obtained using sentences that did not suggest any action.

2.1.7 Motion event

Two experiments by Kaschak, Madden, Therriault, Yaxley, Aveyard, Blanchard and Zwaan (2005) focus on *motion* direction, showing that the simulation we form is sensitive to the direction implied by the sentence suggested movement. Participants listened to sentences describing motion in four *directions*: away (e.g., "He rolled the bowling ball down the alley"), towards (e.g., "The dog was running towards you"), upwards (e.g., "The smoke rose into the sky"), and downwards (e.g., "The snow fell onto the ground"). Simultaneously they saw black-and-white motion perceptual stimuli: a clockwise and contraclockwise moving spiral picture (suggesting a motion away or towards participants' body); or an up or down moving horizontal stripes (suggesting a motion upwards or downwards participants' body). Subjects had to decide if sentences were sensible or not. Results showed that in the mismatch condition participants were faster than in the match condition.

In the second experiment participants were requested to make a grammaticality judgement on the sentence. The authors' purpose was to examine if the same interference effect was found with a task that did not emphasize semantic processing. Again, they found quicker response times for the mismatch condition. This data provide support for the claim that language comprehension is grounded in perception and action, and that the simulation activated by language is fairly specific.

The mismatch advantage (*interference effect*) found by Kaschak et al. (2005) is apparently in contradiction with previous evidence, showing faster response times when the sentence content matches the perceptual stimulus or the motor response. According to Kaschak et al. we need further empirical investigation in order to better understand these apparently contradictory results. However a possible explanation could be given by the interaction between two factors: the *temporal overlap* and the *integratability* (the degree in which the perceptual input could be integrated into the simulation activated by language). So the advantage of the mismatch condition could be due to the fact that visual perceptual stimuli engage the processing mechanisms needed to simulate the contemporarily listened sentences. The difficulty relies on the shared contents between the percept and the simulation of the sentence, and on the contemporaneous temporal overlap.

According to Kaschak et al. (2005), in the previously shown experiments there was an advantage of the match condition because the perceptual stimuli were easy to integrate with the sentence. For example, the sentence: "He saw the lemon in the glass" (Zwaan et al., 2002) was followed by the picture of a slice of lemon, and not by a black-and-white stimuli. The match advantage in the *integratability* condition is expected for a temporal overlap as for *sequentially* presented stimuli. Instead, when the visual stimulus and the sentence are processed sequentially and they are not easy to integrate there should be a null effect, because the stimulus is processed independently of the sentence.

The effect of language comprehension on visual representation of a *motor event* was also addressed by Zwaan, Madden, Yaxley and Aveyard (2004). Participants had to listen to sentences implying a movement toward or away from the body. Then they were presented with two pictures of a ball, differing only in size: the first one could be smaller or bigger than the second one, thus suggesting a movement toward or away from the observer. Subjects' task consisted of pressing two different keys to decide if the two pictures represented the same objects or not. In the match condition participants heard a sentence like "The shortstop hurled the softball to you" and then they saw a picture of a ball followed by a picture of a bigger ball. In the mismatch condition participants heard the same sentence and then a ball followed by a smaller ball. Results showed that in the match condition response times were faster than in the mismatch condition, suggesting that subjects activated a mental dynamic simulation of the sentence. More interestingly, these results were obtained with a task that did not involve in any way the content of the sentences. An amodal theory of cognition (Pylyshyn, 1986) can hardly account for these results.

2.1.8 Action

Further evidence for language grounding is provided by Glenberg and Kaschak (2002). They demonstrated that the simulation built during language comprehension is sensitive to directional aspects in action. Subjects were required to judge the sensibility of sentences moving the arm toward or away from the body. Half of the critical items referred to an action to perform by moving the arm toward the body, and the other half to a similar action done in the opposite direction. Critical items could be imperative sentences (e.g., "Put your finger under your nose" *vs*. "Put your finger under the faucet"), as well as sentences implying a concrete transfer (e.g., "Courtney handed you the notebook" *vs*. "You handed Courtney the notebook"), or sentences implying an abstract transfer (e.g., "Liz told you the story" *vs*. "You told Liz the story").

They found an *action-sentence compatibility effect* (ACE) in each of the three conditions. Thus, for example, responses to the sentence "Open the drawer" were faster if participants were required to perform a movement toward their body than away from their body; the opposite was true for a sentence like "Close the drawer".

These results clearly support the idea that linguist meaning is grounded in bodily activity.

2.1.9 Affordances

The link between our knowledge and action was tested in a part verification task and in a sensibility judgment task by Borghi (2004). If concepts are represented as pattern of potential actions (Glenberg & Robertson, 2000) we would expect that different parts will be represented in a different way, depending on the more frequent action that we usually perform with the object. In other words, different objects parts can be good affordances depending on the situation at hand. So for example, in our representation of a "gas lighter" the *button* should be more salient than the *body* because *canonically* we use it for producing a spark. But the representation of the parts should change in relation to the requirements of the current situation. So for example, if we have just found a nice recipe in the book we were leafing through, the *body* gas lighter would become salient, allowing using the object as a bookmark. In the part verification task participants were faster when the object's part word showed after the sentence was congruent with the part activated by the action suggested by the sentence. That is, "The child divided the orange" activates the mental simulation of the splitting action, and so the most salient part will be the "slice" rather than the "pulp" of the orange. The alternative propositional explanation, based on the semantic association between the verbs and the affording/nonaffording objects part, was ruled out replicating the results with controlled materials.

2.1.10 Effector and goal

Studies in different areas of neuroscience and cognitive science demonstrate that simulations formed during language comprehension are sensitive to the effectors implied by the verb or by the sentence.

Pulvermüller et al. (2001) investigated brain activity elicited by visually presented verbs that could be referred to movements of the arms (e.g., "to write"), of the legs (e.g., "to walk") or of the face muscles (e.g., "to talk"). The behavioural part of the study consisted in a lexical decision task. In the physiological part they recorded Event Related Potentials (ERPs), that is a measure of the electrical activity produced by the brain in response to a sensory stimulus or associated with the execution of a motor, cognitive, or psycho-physiologic task. Behavioural results showed faster response times for face related verbs followed by arm related verbs and leg related verbs, supporting the idea that words semantic properties are reflected in the brain response they induce. Recorded ERPs revealed significant topographical differences 250 ms after stimulus appearance. Results seem to demonstrate that verbs that refer to actions performed using different effectors are processed in different ways in the brain.

Scorolli and Borghi (2007) also investigated the involvement of motor system in linguistic comprehension, using not single words but sentences composed by a verb and a concept noun. Verbs could refer to actions usually performed with the hands, the mouth or the feet. Subjects were requested to evaluate the sensibility of the sentences by pressing a pedal or saying 'yes' at the microphone. Response times showed that using the microphone they were faster with "mouth sentences" than with "hand sentences". Using the pedal there was not a significant difference between "mouth sentences" and "hand sentences"; instead "foot sentences" were significantly faster than "hand sentences". (I will discuss this study more deeply in *Chapter 3*.)

This suggests that the same motor areas are recruited when a person understands action sentences or is actually performing the action. Importantly, this modulation occurred even with a task in which the information related to the involved effector was really irrelevant, such as the evaluation of the sensibility of sentences.

It's difficult to account for these results by means of abstract symbol theories of meaning. If words in these sentences are abstract, amodal and arbitrarily related to their referents, why did the effectors referred to by the sentence and used for responding influence the latencies of subjects' reactions?

In line with the previous studies, Borghi and Scorolli (2009) demonstrate that the simulation activated by language is sensitive to the effector involved in the action expressed by the sentence and to the *specific* effector (right hand *vs.* left hand) used for responding, and that this sensitiveness seems to be modulated also by the goal implied by the sentence. Participants' task consisted in evaluating the sensibility of sentences regarding hand, mouth and foot actions (e.g., "Unwrap the candy" *vs.* "Eat the candy"; "Throw the ball" *vs.* "Kick the ball"). Participants responded by pressing two keys on the keyboard. The authors found a facilitation of sensible over non sensible sentences in right hand responses to hand and mouth sentences. This facilitation wasn't present in foot sentences. This finding suggests that the simulation evoked is quite detailed, as it is modulated both by the kind of effector the sentence refers to (hand *vs.* foot *vs.* mouth), and by the specific hand (dominant *vs.* non-dominant) the action expressed by the sentence typically involves. (This study will be explained in detail in *Chapter 4*.)

The advantage of the dominant hand obtained with both hand and mouth sentences is particularly significant because it implies that people are sensitive both to the effector involved and to the goals expressed by the sentence. That is, mouth-related actions as "biting an apple" imply the simulation of the whole process of eating the apple, including bringing it to the mouth with the hand. On the contrary, the hand is typically not involved in foot related actions, such as "kicking a ball". The relevance of the goal is consistent with ideomotor theories (e.g., Prinz, 1997), that stress that actions are represented not only in terms of body movement but also in terms of the distal perceptual effects they aim to generate. The present data are also in keeping with Fogassi, Ferrari, Gesierich, Rozzi, Chersi, & Rizzolatti (2005) findings about a kind of mirror neurons that differentially codes a motor act according to the final goal of the action sequence in which the act is embedded. Finally, the results are convergent with evidence indicating that at the neural level hand and mouth actions activate contiguous regions, confirming the existence of a strict interrelationship between the effector hand and the effector mouth. This is in line with recent studies showing that language evolves from gestures and manual actions (e.g., Corballis, 2002; Arbib, 2005; Parisi, Borghi, Di Ferdinando & Tsiotas, 2005)

2.1.11 The role of experience: ambiguous spatial word

Embodied theories underline the role of the physical experiences in guiding concept understanding (Barsalou,1999a; Glenberg, 1997; Wilson, 2002). Nonetheless, there is not much evidence on the role of experience in language comprehension. Most of the studies are restricted to paper-and-pencil tests (for example, concerning experience in motion, Boroditsky, 2000).

Alloway, Corley and Ramscar (2006) used a virtual environment for simulating an experience of motion. Virtual reality allowed them to directly test the embodied experiences on spatial perspective in order to investigate how ambiguous spatial terms are understood. Through virtual reality participants could experience either an ego-moving or an object-moving system. After having familiarized with the new environment, they were shown either an object moving linguistic prime (i.e., [1] "During the game, the green pillar is *in front of* the red pillar."), or a non-spatial question, unrelated to motion (i.e., [2] "During the game, most of the doors are closed.") They had to respond if the sentence was true or false. Results showed that participants were significantly influenced by the system of motion they represented. In fact, in the [1] case the prime overcame the embodied ego-moving schema of motion. On the contrary, in the [2] condition, in which the linguistic prime was unrelated to any system of motion, they were influenced by the ego-moving schema in the virtual environment, namely they responded to the target task coherently with the virtual suggested perspective.

Globally the results demonstrate that individual sensori-motor capabilities play an important role in guiding specific cognitive facilities. Focusing on language, it is crucial the finding that word meaning is not fixed, but influenced by our experience as well as by the linguistic context.

2.2 Conclusion

In this review I have shown that in the last ten years many studies have found support for the simulation theory, and have shown that the simulation we run during language comprehension is rather specific. Despite this huge amount of research, the amodal or propositional symbol system theory (Fodor, 1975; Pylyshyn, 1981) remains the dominant theory of knowledge representation. According to this theory the link between the internal symbols and the external referents is just an arbitrary one. It’s hard to falsify this theory, because it can explain psychological phenomena. However, in many cases the explanation it can provide is just a *post-hoc* one.

Instead, according to the perceptual symbol system theory, the relationship between the symbols and their referent is not arbitrary, so a change in the referent will cause a change in the perceptual symbol (Barsalou, 1999b). The advantage of this theory is not in its explicatory power (even if this theory explains the same effects in a more parsimonious way), but rather in its predictive power.

II part

'THE MEANING OF CONCRETE WORDS': SENSORI-MOTOR EXPERIENCE

3 The specificity of the simulation with respect to the body. Different effectors: the hand, the mouth and the foot

The purpose of this chapter is to address whether sentence comprehension modulates the motor system. Participants were presented with 24 pairs of nouns and verbs that could be referred to hand and mouth actions (e.g., to unwrap vs. to suck the sweet), in the first block, or, in the second block, to 24 hand and foot actions (e.g., to throw vs. kick the ball). An equal number of non sensible pairs were presented. Participants' task consisted of deciding whether the combination made sense or not: 20 participants responded by saying *yes* loudly into a microphone, 20 by pressing a pedal. Results support embodied theories of language comprehension, as they suggest that sentence processing activates an action simulation. This simulation is quite detailed, as it is sensitive to the effector involved. Namely, it leads to a facilitation in responses to 'mouth sentences' and 'foot sentences' compared to 'hand sentences' in case of congruency between the effectors – mouth and foot – involved in the motor response and in the sentence.

3.1 Introduction

As reviewed in *Chapter 1* and *2*, recent proposals in cognitive science and neuroscience claim that cognition is embodied. The embodied view claims that knowledge is not abstract but grounded in sensorimotor experiences, and that there is a deep unity among perception, action and cognition (Thelen & Smith, 1994; Pecher & Zwaan, 2005). This view of cognition contrasts with the classical perspectice, according to which the mind is a mechanism for manipulating arbitrary and amodal symbols. In the classical cognitive view, concepts are seen as being inherently non-perceptual: perceptual states arise in sensory-motor systems, but perceptual experience will be transduced in a completely new representational language. The resulting symbols do not correspond with the perceptual states that produced them. They are, therefore, amodal, and the link between the concept and the perceptual state is just arbitrary.

Instead, in the embodied view concepts are not conceived of as being given by arbitrary and amodal symbols but rather by perceptual symbols. These perceptual symbols are neural representations located in sensory-motor areas in the brain: there is no transduction process (Barsalou, 1999a). More precisely, concepts consist of the reactivation of the same neural activation pattern that is present when we perceive the objects or entities they refer to and when we interact with them (Barsalou, 1999a, Gallese & Lakoff, 2005, Glenberg, 1997). For example, the concept of *dog* refers to a real or an imagined dog and, when encountered, reactivates any previous experiences with this extra-linguistic entity. In this view, object attributes are thought to be stored near the same modality-specific neural areas that are active when objects are being experienced (Martin, Ungerleider & Haxby, 2000). Moreover, symbols, according to the embodied view, are not amodal, but multimodal – for example, they refer both to the tactile experience of caressing a dog as well as the auditory experience of hearing a dog bark (Barsalou, 1999a; Gallese & Lakoff, 2005).

Contemporary neuroscience provides evidence in support of the claim that concepts make direct use of sensory-motor circuits of the brain (Gallese & Lakoff, 2005). There is much neural evidence to indicate, for example, that the same areas are involved when forming motor imagery and when activating information on objects, particularly on tools. For example, evidence gathered through Positron Emission Tomography indicates that the naming of tools, as opposed to the naming of animals, differentially activates the left middle temporal gyrus, which is also activated by action generation tasks, and the left premotor cortex, generally activated when participants imagine themselves grasping objects with their dominant hand (Martin, Wiggs, Ungerleider & Haxby, 1996). Along these same lines, fMRI studies have shown that the premotor left cortex responds selectively to images of tools, but not to images of animals and houses (Chao & Martin, 2001; see also Grafton, Fadiga, Arbib & Rizzolatti, 1997).

An important consequence of this embodied view concerns language, as it makes use of concepts. According to the embodied theory there is no 'language module'. Instead, language makes direct use of the same brain structures used in perception and action. Understanding language implies forming a "simulation", that is the recruitment of the very neurons that would be activated when actually acting or perceiving the situation, action, object or entity described by language (Barsalou, 1999a; Gallese & Lakoff, 2005; Gibbs, 2003; Glenberg, 1997; McWhinney, 1999; Zwaan, 2004).

There is much behavioural evidence in support of the role simulation plays in sentence comprehension (e.g., Borghi, 2004; Glenberg & Kaschak, 2002; Kaschak et al., 2005; Zwaan & Taylor, 2006). For example, Zwaan et al. (2002) presented participants with two kinds of sentences (*the ranger saw the eagle in the sky* vs. *the ranger saw the eagle in the nest*), followed by a picture of an object. Participants were required to indicate whether or not the object in the picture was the same object mentioned in the sentence by pressing a different key on a keyboard. The authors found an advantage in the congruent condition, in contrast with the predictions of a classical amodal vision. Stanfield and Zwaan (2001) found similar results when they investigated the effect of the orientation of the objects in visual images presented to subjetcs participating in an experiment investigating the role of simulation in sentence comprehension. When participants were presented with a sentence like *John put the pencil in the drawer*, their response times were faster when recognizing a horizontally-oriented pencil than when recognizing the same pencil presented vertically. The opposite was true in the case of a sentence like *John put the pencil in the cup*. Glenberg and Kaschak (2002) asked participants to indicate whether or not a sentence made sense by pushing one of two buttons whose position entailed either moving toward the body or away from the body. Response times were longer when responding by pushing the button that required a movement in the opposite direction from that implied by the sentence. For example, participants were faster in responding that *Close the drawer* made sense when pushing the proper button entailed moving away from the body rather than toward it. The simulation activated while processing a sentence that referred to objects' movement seems to be quite detailed, as it contains directional information. Recently Borreggine and Kaschak (2006) replicated the study by Glenberg and Kaschak (2002) in order to investigate timing effects during sentence processing. They manipulated the delay between the acoustic sentence presentation and the visual cue that triggered the response. This cue indicated whether the participant should press a button located near or far from the body (towards vs. away movement) in order to respond "yes". The visual cue could come at the beginning of the sentence presentation or after it (delay of 0, 50, 500, or 1000 ms). The compatibility effect between action and sentence (ACE) was present only when the motor instruction was presented simultaneously with the beginning of the sentence rather than after the sentence presentation. This suggests that the simulation process takes place when participants can plan their motor response while processing the sentence.

Even though the reported evidence suggests that during sentence comprehension we activate simulations, the extent to which these simulations are specific is still a matter of debate. In our work we sought to investigate the degree of specificity of these simulations. More specifically, we sought to understand whether reading sentences related to actions to be performed with different effectors (mouth and foot) activates the same neural systems activated during the effective execution of these actions. Though behavioural in nature, our study has relevant implications for physiological and neural models of the relationships between language and the motor system.

Participants were presented with pairs of nouns and verbs that referred to 'hand actions' and 'mouth actions', in the first block, or to 'hand actions' and 'foot actions', in the second one. They were asked to decide whether the combination made sense. Half of them indicated their responses by using a microphone, half by pressing a pedal. 'Hand sentences' were used as a baseline.

The rationale is as follows: if the simulation is specific, that is, if the same neurons are recruited while understanding an action sentence as while performing an action with a specific effector, then 'mouth sentences' should be processed faster than 'hand sentences' when responding with the microphone than with the pedal. Similarly, 'foot sentences' should be processed faster than 'hand sentences' when responding with the pedal than with the microphone.

3.2 Method

3.2.1 Participants

Forty students of the University of Bologna took part in the experiment. All were native Italian speakers, right-handed, and all had normal or corrected-to-normal vision. They all gave their informed consent to the experimental procedure. Their ages ranged from 18 to 29 years old.

3.2.2 Materials

Materials consisted of word pairs (sentences) composed of a transitive verb and a concept noun. There were two different blocks: hand – mouth sentences, hand – foot sentences. For each block, we chose 12 nouns which refer to objects of daily use, each preceded by an action verb. In the first block (block mouth – hand sentences), verbs could refer either to an action usually performed with the mouth (e.g., *to suck the sweet*), or with the hand (e.g., *to unwrap the sweet*). In the second block (block foot –

hand sentences), verbs could refer to an action usually performed with the foot (e.g., *to kick the ball*) or to an action typically performed with the hand (e.g., *to throw the ball*).

We decided to use two blocks because of the difficulty in finding triads of verbs that could be combined with the same noun, referred to actions with the three different effectors and had the same association rate. For example, we usually act with an object like an *ice cream* with the hand or the mouth, but not with the foot; similarly we typically interact with an object like a flower, *daisy*, with the hand or the foot, but not with the mouth. For this reason, the first block contained nouns that could be combined with both 'mouth verbs' and 'hand verbs', while the second block contained nouns that could be combined with both 'foot verbs' and 'hand verbs'.

A pre-test was performed before the experiment in order to be sure that the verb-noun pairs had the same association rate in the two conditions. We required 18 subjects to produce the first five nouns they associated to each verb. Then we checked whether the noun we had chosen to associate with the verb of the critical pairs was present among the nouns they produced, and in which position it was produced. Then we calculated the weighted means for each participant, taking into account whether the noun was produced or not and, if it was produced, its production order. The weighted means of the productions for each participant were submitted to two different mixed factor ANOVAs, one for each block of sentences ('hand sentences' vs. 'mouth sentences'; 'hand sentences' vs. 'foot sentences'). The results showed that there was no significant difference in production means between 'mouth sentences' and 'hand sentences', F (1,11) = 0.22, MSe = .09, p = .65, and between 'foot sentences' and 'hand sentences', F (1,11) = 0, MSe = .05, p = 1. This means that our results could not be explained on the basis of the degree of association between verb-noun pairs that we had chosen.

At last we obtained 48 verb-noun pairs balanced for association rate. In addition to the critical pairs, we added 272 filler pairs. 40 were sensible verb-noun pairs – abstract sentences (e.g. *to dream the summer*). The remaining 232 were non sensible verb-noun pairs – false sentences (eg. *to switch off the shoe*) –. Each pair was presented four times in one of the two blocks.

3.2.3 Procedure

Participants were randomly assigned to one of two groups. Members of both groups were tested individually in a quiet laboratory room. They sat on a comfortable chair in front of a computer screen and were instructed to look at a fixation cross that remained on the screen for 500 ms. Then a verb appeared on the screen. After 200 ms it was substituted by a noun, which was preceded by a determinative article. For each verb-noun pair, participants were instructed, if the combination made sense, to say *yes* loudly (first group) or to press a pedal with the right foot (second group), and to avoid responding if the combination did not make sense. Each noun was presented in the two different combinations, that is, preceded by a verb of 'mouth action' or 'hand action' in the first block, and by a verb of 'foot action' or 'hand action' in the second block. The timer started operating when the concept noun appeared on the screen, in order to avoid problems related to length and frequency of the noun, so in the response times analyses we compared each noun (e.g., *candy*) with itself. All participants were informed that their response times would be recorded and were invited to respond as quickly as possible while still maintaining accuracy. Stimuli were presented in a random order. Sixteen training trials preceded the experimental trials, in order to allow the participants to familiarize with the procedure.

3.3 Results

All incorrect responses were eliminated. As the error analyses revealed that there was no speed-for-accuracy tradeoff, we focused on the RT analyses. To screen for outliers, scores 2 standard deviations higher or lower than the mean participant score were removed for each participant.

The remaining response times were submitted to two different mixed factor ANOVAs, one for each block (‘hand sentences’ vs. ‘mouth sentences’; ‘hand sentences’ vs. ‘foot sentences’). The factors of each ANOVA were Sentence Modality (‘hand’ vs. ‘mouth’ for the first analysis; ‘hand’ vs. ‘foot’ for the second one) and Response Modality (microphone vs. pedal), with Response Modality as a between participants variable.

In the block ‘mouth-hand’, participants responded 84 ms more quickly with the pedal than with the microphone, F (1, 38) = 12.39, MSe = 11322.55, p < .001. The advantage of the pedal over the microphone (87 ms) was present also in the block ‘foot-hand’, F (1, 38) = 14.74, MSe = 10167.86, p < .0005. In addition, in the block ‘foot-hand’ we also found a significant effect of the main factor Sentence Modality, with ‘foot sentences’ 21 ms faster than ‘hand sentences’, F = 17.98, MSe = 482.52, p < .0001.

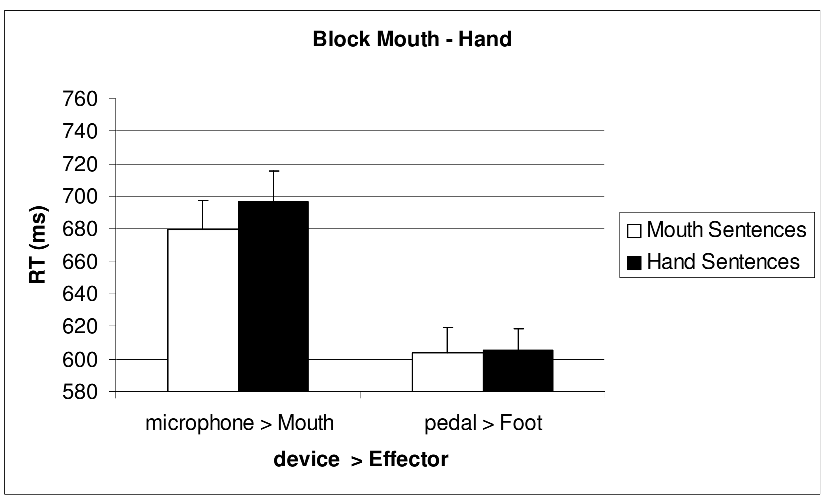


Figure 1. Block Mouth – Hand. Bars represent standard error.

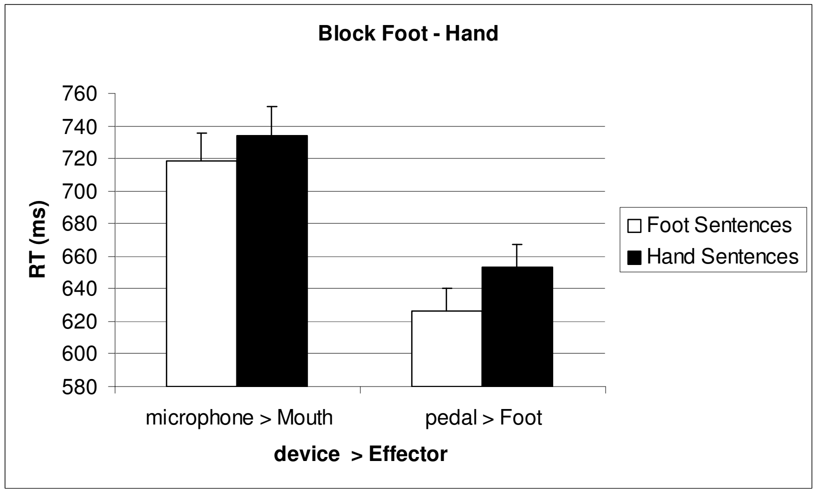


Figure 2. Block Foot – Hand. Bars represent standard error.

Further analyses were performed in order to better understand the results. We performed four separate ANOVAs, one for each Response Modality (microphone vs. pedal) and for each block (‘hand sentences’ vs. ‘mouth sentences’; ‘hand sentences’ vs. ‘foot sentences’).

The first two ANOVAs performed on participants who responded with the microphone confirmed the hypotheses advanced. As predicted, participants using the microphone responded with significantly greater speed to ‘mouth sentences’ than to ‘hand sentences’, F (1,19) = 8.28, MSe = 377.65, $p < .009$. The difference between ‘foot sentences’ and ‘hand sentences’ was less marked, F (1,19) = 5.45, MSe = 405.84, $p < .05$. Even though the last difference also reached significance, the marked difference between the effect sizes ($p <.009$ vs. $p <.05$) confirms that the simulation is effector-specific.

The ANOVAs performed on participants who used the pedal as their responding device showed that there was no significant difference between ‘mouth sentences’ and ‘hand sentences’, that is, between sentences referring to effectors not involved while using the device, 2 ms, F (1,19) = 0.0056, MSe = 559.41, $p < .81$.

Instead, as predicted, we found that response times were significantly faster, 26 ms, for 'foot sentences' than for 'hand sentences', $F(1,19) = 12.84$, $MSe = 559.21$, $p < .002$.

3.4 Discussion

The results support the view that the act of comprehending sentences leads to the creation of an internal simulation of the action read. This simulation seems to be fairly specific, as it leads to a different modulation of the motor system depending on the effector (hand, mouth, foot) necessary for performing the actions described by the sentence. This suggests that the same motor areas are recruited whether a person is understanding action sentences or actually performing the action. Importantly, this modulation occurred even with a task in which the information related to the involved effector was really irrelevant, such as the evaluation of the sensibility of sentences. Our results clearly show that 'mouth sentences' were processed faster than 'hand sentences' when participants were responding with the microphone rather than with the pedal. The same facilitation effect was obtained with 'foot sentences' compared to 'hand sentences' when participants were responding with the pedal rather than with the microphone. Even though our study clearly suggests that an internal simulation occurs, our results do not permit us to definitively determine when this process takes place because we recorded reaction times after the appearance of the noun. Namely, the motor resonance effect could occur either during sentence comprehension or after the sentence has been understood in order to prepare for action. Data from Borreggine and Kaschak (2006) suggest that the ACE effect, at the very least, was due to the simultaneous occurrence of a motor preparation phase and sentence comprehension. However, to our knowledge there has been no systematic study on the influence of timing on effector-specific effects in sentence comprehension. In order to solve this complex matter, more detailed studies on the relationship between timing and effector specific effects on sentence comprehension are needed. Evidence on timing could provide stronger support to the idea that a simulation process is necessary and not just epiphenomenal in order to understand the sentence. Our results are also in line with previous fMRI studies showing that listening to sentences expressing actions performed with the mouth, the hand and the foot produces activation of different sectors of the premotor cortex, depending on the effector used in the listened sentences (Tettamanti, Buccino, Saccuman, Gallese, Danna, Scifo, Fazio, Rizzolatti, Cappa, & Perani, 2005). Of particular significance, they represent a behavioural extension of these results.

Some may object to the results of our study on the grounds that the advantage of 'foot sentences' over 'hand sentences' is significant not only with the pedal but also with the microphone. However, this effect does not go against our main hypothesis – that is, that the effector used to respond facilitates responses to sentences implying the same effector – for a number of reasons. First, the effect is much stronger with the pedal than with the microphone, as the comparison of the effect sizes demonstrates. Second, 'foot words' have wider cortical distributions compared to 'mouth words', that have a more narrow distribution (Pulvermüller, 2005). This can easily account for the slight asymmetric result we found.

Our results are in line with recent neurophysiological and behavioural evidence. Pulvermüller et al. (2001) recorded neurophysiological (they calculated event-related current source densities from EEG) and behavioural responses (reaction times and errors) to verbs referring to actions performed with the face, the arms and the legs. They found topographical differences in the brain activity patterns generated by the different verbs in a lexical decision task, starting from 250 ms after word presentation. The behavioral experiment indicated that response times were shorter for face-related words compared to leg-related words, whereas the arm-related words were in the middle.

Our study represents both an extension and a modification of the results attained by Pulvermüller et al. (2001). First of all, the study by Pulvermüller et al. focused on verb comprehension, whereas the purpose of our research is to study whether understanding simple sentences composed of a transitive verb and a noun activates the motor system. In addition, the kind of task we used implied access to semantic knowledge, unlike the study by Pulvermüller et al., who used a lexical decision task on verbs. Importantly, however, we used a task for which the information pertaining to the kind of effector involved in the action described was not relevant. Given that Pulvermüller et al. found a significant difference between face-related and arm-related verbs on the one hand and leg-related verbs on the other – with manual responses –, we decided to compare 'mouth sentences' and 'foot sentences' and to use the 'hand sentences' as a baseline. Moreover, instead of employing a manual response, we used either a 'mouth response' or a 'foot response' (microphone and pedal). Namely, our purpose was to directly test whether or not understanding a sentence directly involves the motor system, affecting motor responses with the effector referred to by the sentence.

Another recent study using both transcranial magnetic stimulation and a behavioral paradigm provides evidence for a modulation of the motor system depending on the effector referred to by action sentences. Buccino et al. (2005) presented three kinds of sentences: hand action, foot action and abstract content related sentences. Participants were required to respond with the hand or the foot if the verb was concrete and had to refrain from responding if the verb was abstract. Results showed that if subjects responded with the same effector necessary for executing the action described by the sentence, they were slower than if they had to respond with the other effector. Although this study shows that the meaning of the sentence modulates motor system activity, the authors found an inhibition rather than a facilitation. Even though our study investigates the difference between 'foot actions' and 'mouth actions' and Buccino et al. (2005) study the difference between 'foot actions' and 'hand actions', further differences between the two behavioural studies may account for the result. The first is the modality used to deliver the stimuli. In our experiment, participants had to read the sentences, whereas in the study by Buccino et al. (2005), stimuli were acoustically presented. Furthermore, the stimuli were not the same. More importantly, Buccino et al., also used a task that implied a higher depth of processing than lexical decision, as we did, but they required the participants to evaluate the action described rather than the meaning of the whole sentence. This is clearly implied by the fact that they gave the "go" signal to respond in coincidence with the second syllable of the verb, when the noun hadn't yet been presented. On the contrary, we recorded response times from the noun presentation, and focused on comprehension of the sentence rather than of the verb alone. This explanation is in line with recent experiments on language and motor resonance that have shown that the timing between linguistic stimulus and motor response is crucial (e.g., Borraggine & Kaschak, in press; Zwaan & Taylor, 2006). In addition, in our task the information relating to the effector is really irrelevant, given that we asked participants to evaluate whether the sentence made sense and didn't require them to focus on the verb meaning.

In conclusion, our results clearly show that understanding action sentences implies an effector specific modulation of the motor system, suggesting that a simulation effect takes place. This modulation leads to a facilitation of responses in case of congruency between the effector – mouth and foot – involved in the motor response and the effector involved in the sentence.

4 The specificity of the simulation with respect to the body and to the goal. The hand: dominant vs. non-dominant hand

In five experiments participants were presented with pairs of nouns and verbs. They were asked to decide whether the combinations made sense or not. Half of the participants responded "yes" with the dominant hand, half with the left hand. When pairs referred to manual and mouth actions, participants responded faster with the dominant than with the left hand with sensible sentences. When pairs referred to manual and foot actions the result was opposite. Results suggest that language processing activates an action simulation that is sensitive both to the effector involved and to the goal expressed by the sentence.

4.1 Introduction

Concepts are the minimal units of our knowledge, a sort of "mental glue" linking our past experiences with our current interaction with the world (Murphy, 2002). This paper will focus on object concepts mediated by words, and particularly on the relationship between words and action.

In contrast with the view that concepts are generated by arbitrary and amodal symbols (Landauer & Dumais, 1997), the embodied view suggests that concepts are grounded in sensorimotor processes (Barsalou, 1999a; Gallese & Lakoff, 2005; for a review on object concepts and action see Borghi, 2005). Concepts are not amodal but multimodal, and conceptual information is distributed over modality specific domains (Barsalou, Simmons, Barbey, & Wilson, 2003; Boronat, Buxbaum, Coslett, Tang, Saffran, Kimberg, & Detre, 2005; Gallese & Lakoff, 2005; Martin et al., 1996). Thus, according to the embodied theory, thinking of a telephone leads to the activation of auditory, visual, and tactile information – the sound of the telephone ringing, the color of the receiver, the smoothness of its surface etc. In other words, thinking about an object leads to a re-experiencing (simulation) of the interaction with the object (Barsalou, 1999a; Barsalou et al., 2003). Simulations consist of reenactments of our sensorimotor experiences with objects and entities. Significantly, these experiences are both perceptual and motor. It has been shown that a subset of the same neurons fire for sensory modalities like vision, hearing, touch, and are integrated with motor information (for a review, see Fogassi & Gallese, 2004).

Accordingly, the neural areas recruited when we think about an object or about an entity and prepare to act are the same that are recruited when we perceive and interact with its referent. The multimodality of object concepts and the centrality of action information in their construction is demonstrated in a variety of experiments showing that visual stimuli activate motor information. Even with tasks that are intended as unimodal, the multimodality of concepts emerges (Smith, 2005). For example, Tucker and Ellis (2001) asked participants to evaluate whether different-sized objects are artifact or natural kinds by mimicking a precision or a power grasp. They found a congruency effect between the object size and the kind of grip used to respond, even if the object size was not relevant to the task.

According to the embodied view, words mediating concepts also enhance the neural pathways involved in perceiving objects and interacting with them: thus, the word "telephone" would re-enhance the experiences of past interactions with telephones. Substantial evidence from fields ranging from psychology to neuroscience to cognitive linguistics (for reviews see Bergen, 2005; Gibbs, 2003; Pecher & Zwaan, 2005) provides support for this embodied view of linguistic meaning. The indexical hypothesis put forth by Glenberg and Robertson (2000) explains in an embodied perspective the nature of the relationships between words and their referents.

According to this hypothesis, words are linked to objects in the world, their referents, or to analogical representations such as pictures or perceptual symbols (Barsalou, 1999a). For example, the word “handle” refers to its referent, a handle, or to an analogical representation of the handle. Therefore, words that refer to objects would evoke first of all perceptual information relative to such objects. Given the close relationship between perceptual and motor processes, words should also evoke motor information. Depending on their perceptual features, in fact, objects can activate affordances (Gibson, 1979). For instance, different kinds of handles may afford different actions: some must be turned, others are pushed upon as when opening a door, etc.

When applied to words and sentence comprehension, the simulation theory holds that language comprehension entails a mental simulation of the situation or action described by the sentence (Zwaan, 2004). The neural substrate for the idea of simulation resides in the phenomenon of motor resonance. Recent neurophysiological studies have produced important discoveries regarding the macaque monkey’s premotor cortex (area F5). Practically speaking, this area contains a vocabulary of “motor acts” (Gentilucci, 2003). Unlike F1 neurons, which encode different kinds of movements, F5 neurons refer to goal-directed actions. Some neurons are sensitive to a general action category (hold, grasp, tear etc), others to the way an object can be grasped (e.g., precision vs. whole hand grasp). Further neurons are concerned with the temporal segmentations of actions (e.g., hand opening, closing, holding etc.) (Fadiga, Fogassi, Gallese, & Rizzolatti, 2000). Recent studies have shown that many F5 neurons respond to actions performed with different effectors, provided that they share a common goal, for example discharging when reaching for an object with the left hand, the right hand or with the mouth. The F5 area contains two varieties of visuomotor neurons: canonical and “mirror” (Di Pellegrino et al., 1992; for a recent review see Rizzolatti & Craighero, 2004). Canonical neurons discharge when macaques see graspable objects and when they execute specific actions (for example, when they grasp an object with a precision or with a power grip), while mirror neurons fire when the monkey performs an action or when it observes another monkey or an experimenter performing a goal-directed action, such as, for example, grasping an object. Importantly, they do not discharge when the object alone is presented. Recently it has been proposed that these neurons may help explain various cognitive phenomena such as empathy, mind reading abilities and conceptual organization (Gallese & Goldman, 1998; Gallese & Lakoff, 2005).

Of particular relevance in relation to our aim is the fact that recent studies suggest that the homologue of the F5 area in humans is Broca's area, and it has been proposed that mirror neurons may play a role in language evolution (Rizzolatti & Arbib, 1998). Broca's area was considered to be devoted to speech production. Recently, however, it has been shown that a motor representation of hand actions is present in this area. In addition, Buccino et al. (2001) found that different regions of the premotor cortex and Broca's area are activated depending on the effector involved in their fMRI study that required participants to observe videos of actions involving the mouth, the hand and the foot. Other brain imaging and behavioral studies provide evidence, consistent with these findings, that cortical areas are organized in a somatotopic way. For example, Pulvermüller et al. (2001) found topographical difference in the brain activity patterns generated by verbs referring to actions performed with the legs, the face, and the arms starting from 250 ms after word presentation. Other recent evidence suggests that the simulations activated while processing a sentence are quite detailed. Buccino et al. (2005) showed that simulations run while processing action sentences are sensitive to the kind of effector required to perform the action. In Buccino et al.'s study, participants had to listen to sentences of three kinds: abstract sentences, sentences describing actions performed with hands, and sentences describing actions performed with feet. The task required participants to respond with the hand or foot, for concrete sentences, and to avoid responding for abstract sentences. The results showed that sentences can prime the motor system in an effector specific way.

Our experiments sought to test whether the simulations running while processing pairs of verbs and nouns (sentences) are detailed enough to be sensitive to the difference between the dominant and the non-dominant hand. It is well known that right-handed individuals are more dexterous to perform skilled actions with their right hand. This could lead to a general advantage in response times with right hand responses. However, we predict an advantage of right hand responses only during the comprehension of words that refer to sensible actions. Namely, as we typically use the dominant hand to perform skilled actions with objects (e.g., writing with a pen), one might expect that if while reading a verb-noun combination we form a mental simulation of such an action, we would activate more the dominant (right) than the non-dominant hand. This advantage of the dominant hand should not occur when the simulation we run is not coherent, that is, when the verb-noun combination is meaningless. Thus, in a sentence sensibility task we predict faster responses of the dominant hand compared with the non-dominant one in the case of sensible combinations, whereas in the case of combinations that did not make sense we do not predict any advantage of the dominant hand. If we found an advantage of the dominant hand for sensible combinations referring to hand action, this would suggest that the simulations formed while reading sentences (or, more precisely, by reading verb-noun pairs) are very detailed, that is, that they are not only determined by the kind of effector (e.g., hand vs. foot), but also by the specific effector (e.g., right vs. left hand). But what becomes of the advantage of the dominant hand when we process sensible combinations referring to mouth actions (e.g., bite an apple) or to foot actions (e.g., kick a ball)? In Experiment 2 and 3, sentences involving a hand movement and sentences involving the mouth or a foot movement were compared. If the simulation formed is sensitive to the effector alone, then we should not find the advantage of the dominant hand in the case of pairs that refer to mouth and foot movements. However, if the sensitivity to the effector involved is modulated by the goal expressed in the sentence, as the literature on mirror neurons and on motor resonance suggests, then we should find an advantage of the dominant hand with mouth actions as well, but not with foot actions. This is because eating something typically implies bringing it to the mouth with the hand while performing an action with the foot does not imply a prior hand action.

4.2 Experiment 1.a

The aim of Experiment 1.a was to test whether or not an internal simulation of the action described is activated during comprehension of a verb-noun combination describing a hand action with an object. Participants were presented with verbs followed by nouns; their task consisted in pressing a different key in order to decide whether the combination verb-noun was sensible or not (e.g., to paint – the picture vs. to melt – the chair). All verb-noun pairs that made sense referred to hand actions with objects. Participants were randomly assigned to two different groups; half of them were required to respond “Yes, it makes sense” with the dominant hand and “No, it doesn’t make sense” with the left hand; the other half were asked to do the opposite.

If comprehending a sentence entails a simulation of the described action, then reaction times (RTs) with sensible sentences should be faster with the dominant hand than with the left hand. Such an advantage of the dominant hand should not appear in the case of combinations that didn’t make sense.

4.2.1 Method

4.2.1.1 Participants

Fourteen volunteers took part in the experiment. They were all students of the University of Bologna, native Italian speakers and right-handed according to the Edinburgh Handedness Questionnaire (Oldfield, 1971).

4.2.1.2 Materials

Materials consisted of word pairs composed of a verb and a noun. We constructed 48 critical pairs composed of a verb followed by a concept noun. 24 concept nouns designating common objects, for example, toothbrush, pencil, shoe, spoon, and hammer were chosen. Half of the objects are typically manipulated with the dominant hand; the other half requires bimanual manipulation. In addition, for each object we selected one verb referring to a skilled action to perform with the dominant hand, and another verb referring to an action not necessarily performed with the dominant hand.

Each concept noun could be paired with one of 2 verbs (e.g. spoon – to eat; spoon – to dry). Of the 2 critical verbs, one designated an action which could be performed with both hands, another referred to an action to be performed with the dominant hand. For example, the object “picture” was paired with the action “to paint” and with the action “to take off”, the object “spoon” with the action “to eat” and “to dry”. Consider that typically the first kind of action referred to an object’s function; for this reason it typically requires a skilled behavior to be performed with the dominant hand. For example, the action of “hammering” (in Italian it is expressed through a verb and a noun, “battere con il martello”) requires more skills than the simple action of “lifting a hammer”. In order to select the materials, an independent group of 16 participants evaluated a set of 56 sentences on a 7 point scale according to the degree of necessity to use the dominant hand to perform the described action with the object. We chose the 48 pairs with a higher difference between the degree of dominance of the two actions performed with the same object: for example, “to paint a picture” was selected as a Right Dominant action, “to take off a picture” as a Not-Right Dominant one. From now on the pairs implying a Right Dominant hand action will be called Right-Dominant, the pairs that do not imply a right dominant action will be named Not-Right-Dominant.

In addition to the 48 critical pairs, 48 filler pairs were constructed. In these pairs, each of the 24 concept noun was combined with 2 verbs leading to sentences which didn't make sense. So, each concept noun appeared 4 times, twice in a critical pair and twice in a filler pair.

The materials of all the experiments can be found at the following links: http://laral.istc.cnr.it/borghi/BS-Exp1a.htm,http://laral.istc.cnr.it/borghi/BS-Exp1b.htm,http://laral.istc.cnr.it/borghi/BS-Exp2.htm,http://laral.istc.cnr.it/borghi/BS-Exp3.htm .

4.2.1.3 Procedure

Participants were randomly assigned to one of two groups. Participants in both groups were tested individually in a quiet laboratory room. They sat in front of a computer screen and were instructed to look at a fixation cross that remained on the screen for 1000 ms. Then a verb appeared on the screen. After 600 ms the verb was substituted by a concept noun. The timer started operating when the concept noun appeared on the screen. For each verb-noun pair, participants were instructed to press a key if the combination made sense, and to press another key if the combination did not make sense.

Participants in the first group were asked to respond "yes" with their left hand and "no" with their right hand; participants in the other group were required to do the opposite. All participants were informed that their response times would be recorded and invited to respond as quickly as possible while still maintaining accuracy. Stimuli were presented in a random order. The 96 experimental trials were preceded by 12 training trials.

4.2.2 Results

One participants' data were removed as their responses included errors over 15%. All incorrect responses were eliminated. As the error analysis revealed that there was no speed-for-accuracy tradeoff, we focused on the RT analysis. To screen for outliers, scores 2 standard deviations higher or lower than the mean participant score were removed for each participant. Removed outliers accounted for 3.6% of response trials.

The remaining response times were submitted to a 2 (Sensibility: Sensible vs. Non-Sensible verb-noun pairs) X 2 (Mapping: yes-right / no-left vs. yes-left / no-right) mixed factor ANOVA with Mapping as a between participants variable. Due to our experimental design, in the analysis conducted with items as random factor, the factor Mapping turned into the factor Response Hand (Right vs. Left). In the analysis on items Response Hand was manipulated within items, while Sensibility was manipulated between items. Analyses denoted F^1 were conducted with participants as a random factor; analyses denoted F^2 with items as a random factor in the design (for analyses with participants and items as random factors, see Clark, 1973; Coleman, 1964).

Participants responded 50 ms more quickly to Sensible than to Non-Sensible sentences, F^1 (1,11) = 6.71, *MSe* = 2405.21, $p<.05$; F^2 (1, 62) = 10.36, *MSe* = 6830.29, $p<.005$. Most interestingly, responses were quicker when participants had to respond to sensible sentences with the right hand (*M* = 572.98 ms) than with the left hand (*M* = 711.63 ms), as clearly indicated by the main effect of Mapping, F^1 (1,11) = 6.74, *MSe* = 18425.54, $p<.05$, in the analysis on participants. In fact in this kind of analysis the variable Response Hand is not considered per se, as it is embedded in the Mapping factor. In the items analysis, the same outcome is showed by the significant effect of Response Hand, F^2 (1,62) = 3.25, *MSe* = 15222.55, $p=.07$ and by the interaction between Sensibility and Response Hand, F^2 (1, 62) = 121.74, *MSe* = 4681.91, $p<.0000001$ (see Figure 1 top). The data suggest that left-hand responses were faster for non-sensible than for sensible sentences. This result was unexpected. However, we can tentatively explain the advantage of the left hand with non-sensible sentences as a direct consequence of some sort of inhibition mechanism. In other words, it is possible that, given that non-sensible sentences activated an incoherent simulation, participants “blocked” their right hand, and this produced as outcome faster responses with the left hand.

Further analyses were performed considering only the Sensible sentences. Response times were submitted to a 2 (Response Hand: Right vs. Left) X 2 (Verb Dominancy: Right-Dominant vs. Not-Right-Dominant action) mixed factor ANOVA, with Response Hand as a between participants variable. In the analysis conducted with items as random factor both Response Hand (Right vs. Left) and Verb Dominance were manipulated within items. Right Hand responses were 111 ms faster than Left Hand responses, F^1 (1, 11) = 4.06, *MSe* = 79380.84, $p<.07$; the effect was found also in the analysis on items, F^2 (1, 23) = 41.72, *MSe* = 5301.87, $p < .00001$. Right-Dominant verb-noun pairs were processed 78 ms faster than Not-Right-Dominant pairs, F^1 (1, 11) = 21.19, *MSe* = 1866.20, $p<.001$; the effect was significant also in the items analysis F^2 (1, 23) = 23.22, *MSe* = 5723.06, $p < .0001$. The interaction between Verb Dominancy and Response Hand was significant only in the items analysis, F^2 (1, 23) = 5.48, *MSe* = 2789.60, $p < .05$. Both the analysis on participants and items showed the same pattern: participants were faster with Right-Dominant verb-noun pairs than with Left Dominant ones both with the Right and the Left Hand. This pattern suggests that verbs referring to skilled actions activate more strongly both effectors in comparison to verbs referring to more general actions.

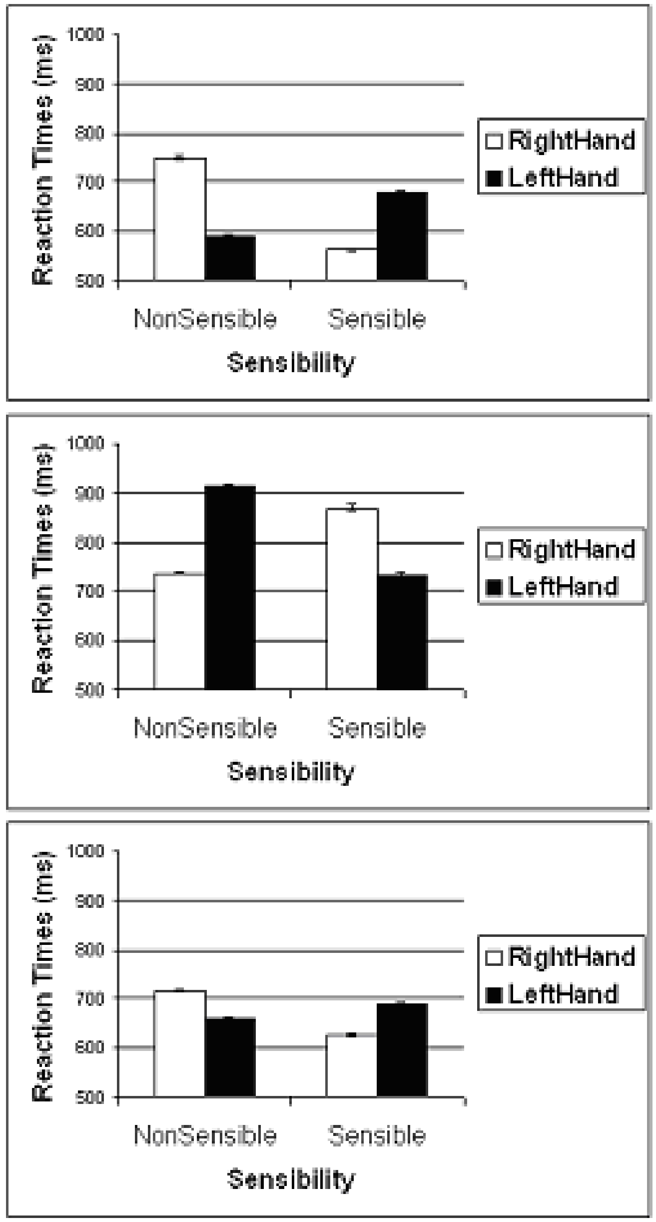


Figure 1. The interactions between Response Hand and Sensibility in Experiment 1a, 2, and 3. Means on items. Bars represent standard error.

In order to be sure that the results were not a result of familiarity, an independent group of 16 participants was asked to evaluate sensible sentence familiarity on a 7 point scale. The correlation between the RTs and the familiarity ratings were quite low (r = -0.29), which led us to exclude the possibility that our results were due to familiarity of the verb-noun combinations.

4.3 Experiment 1.b

A control experiment was performed, in order to verify whether the advantage of the dominant hand we found in Experiment 1.a was specific to action sentences or whether it was simply due to a semantic compatibility between right hand responses and sensible sentences. If the results found in Experiment 1.a are due to semantic compatibility, then we should find the advantage of the dominant hand with sensible sentences also with sensible sentences that do not refer to action. Such an advantage of the dominant hand should not appear in the case of sentences that don't make sense.

4.3.1 Method

4.3.1.1 Participants

Fifteen students of the University of Bologna took part in the experiment. They were selected with the same criteria used for Experiment 1.a.

4.3.1.2 Materials

Materials consisted of word pairs composed of a verb and a noun, as in Experiment 1.a. We constructed 48 critical pairs composed of a verb followed by a concept noun. None of the concept nouns referred to graspable objects, and the selected verbs did not refer to body actions. Some examples of the pairs are: "to think-solution", "to memorize-event", "to evaluate-color", "to respect-rule". In addition to the 48 critical pairs, the same 48 filler pairs used in Experiment 1.a were utilized.

4.3.1.3 Procedure

The procedure was exactly the same as in Experiment 1.a.

4.3.2 Results

All incorrect responses were eliminated. No speed-for-accuracy tradeoff was present, so we will discuss the RT analysis. The same trimming method of Experiment 1.a was used. Removed outliers accounted for 3.9 % of response trials. Two ANOVAs, one with participants and another with items as random factor, were performed, with the same factors of Experiment 1.a. Participants responded 33.15 ms more slowly to Sensible than to Non-Sensible sentences, F^1 (1,13) = 12.16, MSe = 674.89, $p < .005$; the effect was significant also in the items analysis, F^2 (1, 92) = 7.67, MSe = 6456.06, $p < .01$, and is probably due to the complexity of abstract noun-verb combinations. More importantly to our aim, neither the main effect of Mapping - in the analysis on participants, F^1 (1,13) = .00, MSe = 50408.22, p = .99, nor the effect of Response Hand in the items analysis, F^2 (1,92) = 0.10, MSe = 4522.33, p = .75, nor the interaction between Sensibility and Response Hand in the items analysis reached significance, F^2 (1,92) = 0.00, MSe = 4522.33, p = .98.

4.3.3 Discussion

The results are in line with the simulation hypothesis. As predicted, the results of Experiment 1.a showed that the dominant hand was activated by reading verb-noun pairs describing manual actions. Crucially, the advantage of the dominant hand concerned only the pairs describing actions that can actually be committed with the objects in question. The results of Experiment 1.b confirm that the dominant hand advantage is not due to a simple semantic compatibility between right-hand responses and sensible sentences. Bekkering, Wohlschläger and Gattis (2000) obtained similar results in an action imitation experiment which demonstrated that children use their dominant hand more frequently during grasping than during other kinds of manual actions, such as pointing. Further support to the simulation hypothesis was given by the advantage of Right-Dominant compared to Not-Right-Dominant actions, even though there was no evidence of a specific advantage of the dominant hand with right-dominant actions. Rather, it seemed that all skilled manual actions implying an interaction with objects, as the ones used, pre-activated both hands.

4.4 Experiment 2

The advantage of the dominant hand found in Experiment 1 provides support for the simulation theory. Experiment 2 was designed in order to verify whether the effector referred to by the sentence might influence response times. For this reason, we used both foot and manual verbs that can be followed by the same noun (e.g., kick vs. throw the ball). As in Experiment 1, participants were instructed to indicate their decision by pressing a different key to show whether the verb-noun combinations made sense or not. As mentioned in the introduction, previous evidence (Pulvermüller et al., 2001; Pulvermüller, 2003) suggests that different cortical areas are activated while hearing sentences referring to different effectors. Behavioral evidence on the differential role of manual and foot actions has also been provided (Buccino et al., 2005). However, it has not yet been demonstrated whether responding with the right or with the left hand is sensitive to the fact that actions referred to by the sentences are performed with different effectors. If, while reading and comprehending the meaning of a sentence, participants are sensitive to the effector implied by the verb, no evidence of an advantage of the dominant hand with sensible foot-sentences should be found. More specifically, we predicted that, in the analysis performed only on sensible sentences, responses with the right hand should be faster with hand actions than with foot actions.

4.4.1 Method

4.4.1.1 Participants

Twenty-two volunteers took part in the experiment. They were selected according to the same criteria used in Experiment 1.

4.4.1.2 Materials

As in the previous experiment, stimuli consisted of pairs composed of a verb and a noun. We selected 24 object concept-nouns that could be preceded either by a verb indicating a manual action (e.g., to throw – the ball; to pick up – the grapes; to throw – the sandal; to rip – the grass) or by a verb referring to an action to perform with the foot (e.g., to kick – the ball; to press – the grapes; to wear – the sandal; to step on – the grass). We chose a further 48 verb-noun pairs that referred to actions which do not make sense.

4.4.1.3 Procedure

Participants were divided into two groups. Half of them were asked to respond "yes" with their left hand and "no" with the right hand; the other half was asked to do the opposite. The procedure was exactly the same as in Experiment 1.

4.4.2 Results

All incorrect responses were eliminated. As in Experiment 1, there was no evidence of a speed-accuracy tradeoff. To screen for outliers, we used the same criterion as in the previous experiment. Removed outliers accounted for 3.4% of response trials. The remaining response times were submitted to a 2 (Sensibility: Sensible vs. Non-Sensible verb-noun combination) X 2 (Mapping: yes-right / no-left vs. yes-left / no-right) mixed factor ANOVA with Mapping as a between participants variable. In the analysis conducted with items as random factor, Sensibility was manipulated between items, whereas Response Hand was manipulated within items. Participants responded 33 ms more quickly to Sensible than to Non-Sensible sentences, F^1 (1,20) = 6.11, *MSe* = 1998.57, *p*<.05; however, the effect was not significant in the items analysis. Crucially participants were slower (*M* = 863.51 ms) when they had to respond to sensible sentences with the Right Hand rather than with the Left one (*M* = 701.73 ms), as indicated by both the Mapping factor in the analysis on participants, F^1 (1,20) = 4.13, *MSe* = 69086.66, *p* =. 055, and the interaction between Sensibility and Response Hand in the items analysis, F^2 (1, 46) = 81.31, *MSe* = 7307.51, *p*<.0000001 (see Figure 1 middle). The effect was opposite to the effect found in the Experiment 1.a, as responses with the right hand were inhibited. There seems to be an interference leading to slower RTs with the right hand. Newman-Keuls post-hoc analysis indicates that the fastest responses were obtained in responses triggered by Sensible sentences with the left hand and by Non-Sensible sentences with the right hand, which differed from both Sensible sentences with the right hand and

Non-Sensible sentences with the right hand (p <.01). The results are exactly the opposite of the results found in Experiment 1.a and support the simulation hypothesis. In fact, the presence of actions to perform with foot probably led to the inhibition of participants' dominant hand. Given that grasping actions are preferentially performed with the right hand, it is exactly this hand that has to be mostly inhibited. This inhibition might have induced, as a side effect, the advantage in response times of the left over the right hand.

We performed two further 2 (Sensible-Sentence Response Hand: Right vs. Left) X 2 (Sentence Modality: Hand vs. Foot) ANOVAs, one on participants and the other on items, considering only responses to Sensible sentences. We found that right hand responses (M = 850 ms) were slower than left hand responses (M = 680 ms), both in the analysis with participants as random factor, F^1 (1, 20) = 3.77, MSe = 83880.65, p =.066, and in in the items analysis, F^2 (1, 11) = 57.44, MSe = 3254.09, p<.00001. Foot actions were processed 9 ms slower and produced more errors (the percentage of errors was, respectively, 7.95% vs. 4.74% of the sensible trials) than hand actions; however, the effect of Response Hand did not reach significance in the analyses on participants and on items. The interaction between Response Hand and Sentence Modality was not significant, probably due to the order of presentation of the trials (random vs. blocked). Namely, participants may have adopted a general response strategy because foot and hand sentences were presented randomly in the same block.

An independent group of 13 participants evaluated sentences for familiarity on a 7-point scale. In addition, given the peculiarity of foot sentences, we decided to check the imageability of sentences as well. The correlation between the RTs and the familiarity and imageability scores were very low (respectively r = -0.18; r = -0.04), leading us to exclude the possibility that our results were due to these factors. The reason why we did not pre-select the materials but used post-hoc analyses depends on our study's purpose. Basically we needed noun-verb couples, in which the noun was the same in the two conditions. Using the same name we intended to minimize the effect due to length, age of acquisition, frequency, imageability of different nouns. We dealt with this issue starting the timer at the noun presentation. In Italian it is very difficult to find noun-verb combinations that satisfy our request, that is that can be associated with two verbs referring to actions performed with different effectors.

4.4.3 Discussion

As predicted, the results differed from those obtained in Experiment 1.a as the right hand advantage with sensible sentences was not replicated. This suggests that sentence comprehension implies a simulation of the action described, and that this simulation is quite detailed, as it apparently takes into account the specific effector involved.

However, in the analysis performed only with sensible sentences, the disadvantage of the dominant hand was present both with hand and with foot sentences. This result can be accounted for by the fact that participants may have adopted a general response strategy because foot and hand sentences were presented randomly and not in a blocked way. This account will be tested in Experiment 4.

Sensitivity to the effector involved in the verb-noun combination was demonstrated both by the overall disadvantage of the dominant hand and by the fact that foot sentences lead to the production of more errors than hand sentences. The disadvantage of foot over hand actions replicate the behavioral results found by Pulvermüller et al. (2001). In our study this difference between kinds of actions cannot be due to length and frequency of the target-noun, as the noun was the same in both conditions, and can hardly be attributed to familiarity and frequency of the preceding verb, as the timer started when the noun was presented on the screen. Rather, they are probably due to the simulation elicited by the verb-noun combination.

4.5 Experiment 3

Experiment 2 showed that the advantage of the dominant hand was not present when both hand and foot sentences were presented. In Experiment 3 we compared hand and mouth sentences; that is, we used the same noun in combination either with a verb referring to a hand action or to a mouth action (e.g., to peel – the apple vs. to bite – the apple; to grasp – the pill vs. to swallow – the pill).

If we accept that a simulation process takes place during language comprehension, we can advance two possible predictions. First of all, if the simulation driven by the sentence is only effector specific, with sensible sentences there should be a processing difference between hand and mouth sentences, as found by Pulvermüller et al (2001). Alternatively, it is possible that we simulate the action not only at a proximal level, that is at the level of effector, but also at a distal level; that is, that we are sensitive both to the effector referred to by the sentence and to the goal the sentence expresses. If actions are represented and encoded at a distal level, in terms of goals, then the advantage of the dominant hand should be present with both mouth and hand sentences (Hommel et al., 2008). To clarify: a mouth-action, such as licking an ice cream, typically implies / follows a manual action such as, for example, grasping the ice cream. As it can be seen from the examples, all nouns we selected for this experiment afford hand-mouth interaction. The sensitivity both to the effector and the goal would lead to an advantage of the dominant hand with sensible sentences even when the verb refers to actions typically performed with the mouth, such as, for example, "bite an apple".

4.5.1 Method

4.5.1.1 Participants

Thirty-eight students of the University of Bologna volunteered for the experiment. They were native Italian speakers, with normal or corrected vision, and right-handed according to the Edinburgh Handedness Questionnaire (Oldfield 1971).

4.5.1.2 Materials

As in Experiment 1, stimuli consisted of pairs composed of a verb and a noun. 56 critical pairs were constructed. 28 object concept-nouns could be preceded either by a verb indicating a prehensile action (e.g. to grasp – the pill; to pick up – the apricot; to cut – the steak; to unwrap – the candy) or an oral action, that is, an action performed with the mouth (e.g., to swallow – the pill; to bite – the apricot; to chew – the steak; to suck – the candy). A further 56 pairs referred to actions which did not make sense.

4.5.1.3 Procedure

The procedure was exactly the same as in the previous experiments. Participants were divided into two groups. As in the previous experiments, one group was asked to respond “yes” with the right hand and “no” with the left hand; the other group was required to do the opposite.

4.5.2 Results

One participant was eliminated as his/her responses contained errors over 15 %. The error analysis showed no evidence of speed-accuracy tradeoff, so we focused on response time analysis. Data were filtered according to the same criterion used in previous experiments. Removed outliers accounted for 4% of response trials. The remaining response times were entered into a 2 (Sensibility: Sensible vs. Non-Sensible verb-noun combination) X 2 (Mapping: yes-right / no-left vs. yes-left / no-right) mixed factor ANOVA, with mapping as a between participants variable. In the analysis conducted with items as random factor, Sensibility was manipulated between items, whereas Response Hand was manipulated within items.

Participants responded 28 ms more quickly to Sensible than to Non-Sensible sentences, F^1 (1,35) = 7.01, *MSe* = 2011.85, $p<.05$; the effect of Sensibility was significant also in the items analysis, F^2 (1, 54) = 5.06, *MSe* = 4724.36, $p<.05$. More interestingly, even though the factor Mapping did not reach significance in the participants analysis, the predicted interaction between Sensibility and Response Hand was significant in the items analysis, F^2 (1, 54) = 80.63, *MSe* = 1259.62, $p<.0000001$ (see Figure 1 bottom). Newman-Keuls post-hoc analysis indicates that the fastest responses were obtained by Sensible sentences with the right hand, followed by Non-Sensible sentences with the left hand, Sensible sentences with the left hand and, finally, by Non-Sensible sentences with the right hand ($p <.01$). A possible concern regards the discrepancy we found in this experiment between the analysis on participants and the analysis on items A possible cause of this discrepancy might lie in the individual differences among participants. For this reason we selected the 11 faster participants in each condition, thus obtaining a sample of 22 participants, equal in number to the sample of Experiment 2. In the analysis with subjects as random factor, the factor Mapping approached significance, F^1 (1,20) = 3.81, *MSe* = 12738.08, p = .065, in keeping with the results obtained in the items analysis. This might suggest that the effect of Mapping is a rather precocious one, and that the effect was obscured when participants employed longer response times. Therefore, the simulation effect can be more clearly detected with fast-respondents than with slow-respondents. Two further 2 (Sensible-Sentence Response Hand: Right vs. Left) X 2 (Sentence Modality: Hand vs. Mouth) ANOVAs were performed, one on participants and the other on items, considering only responses to Sensible sentences. The factor Sentence Modality was significant due to the fact that mouth sentences were 35 ms faster than hand sentences, F^1 (1, 35) = 11,81, *MSe* = 1899.02, $p < .01$; F^2 (1, 13) = 5.64, *MSe* = 4554.56, $p <. 05$. Interestingly, in the items analysis the factor Response Hand was also significant, as right hand responses were faster than left hand responses, F^2 (1, 13) = 25.44, *MSe* = 1861.85, $p <.0005$. As previously explained, this discrepancy with the Participants analysis might be due to the fact that in the participants' analysis the variable Response Hand is not considered per se, as it is embedded in the Mapping factor. The interaction between Response Hand and Sentence Modality was not significant. As in Experiment 2, it is probably due to the fact that mouth and hand sentences were presented randomly in the same block.

As in the previous experiments, 14 participants were required to rate the noun-verb pairs for familiarity on a 7-point scale. Because the correlation between response times and familiarity was quite low (r = -0.31), it is possible to exclude the possibility that our results are due to item familiarity.

4.5.3 Discussion

The results replicate those found in Experiment 1.a and are in line with the simulation hypothesis. As predicted, in the analysis performed with all sentences, the fastest responses were obtained through right hand responses to sensible sentences. This suggest that while reading a sentence participants simulate a hand movement necessary either to perform a manual action or to bring to the mouth an object with which to perform the mouth action. More specifically, the advantage of the dominant hand found with both hand sentences and mouth sentences suggests that action information is encoded in terms of goals rather than at a proximal level (Hommel et al., 2001). Consider that with the term goal we do not refer to the final goal. For example, we do not refer to the "relief of headache" that follows the action of swallowing a pill, but to the fact that the hand action typically represents a precondition of the mouth action. Thus, for example, the hand is engaged in grasping the pill before swallowing it. This interpretation based on the significance of goals can also account for the results obtained in the analyses performed only with sensible sentences, that is, the fact that faster RTs were obtained with mouth sentences than with hand sentences. Manual actions (at least, the manual actions we selected for this experiment) are typically more general. That is, they can lead to different action sequences and might be justified by different goals. For example, you can grasp an apple in order to put it somewhere else, to bite it, to give it to somebody else, to peel it and so on. On the contrary, mouth actions, even though they activate also hand simulations, are typically more constrained than hand actions, as they tend to refer to a specific goal. For example, biting an apple is simply a way to eat it. An alternative explanation of the advantage of the right hand with both hand and mouth sentences is similar to the one advanced for Experiment 2: it is possible that participants have adopted a general response strategy because mouth and hand sentences were presented randomly and not in a blocked way.

4.6 Experiment 4

In Experiment 2 we found slower RTs with the right than with the left hand and in Experiment 3 a facilitation of the right hand. However, the analyses on sensible sentences did not show any dominant hand advantage in the hand over the foot sentences (Experiment 2) and in the hand over the mouth sentences (Experiment 3). The results obtained in Experiment 2 and 3 could be due to the fact that participants may have adopted a general response strategy because foot and hand sentences (Experiment 2) and mouth and hand sentences (Experiment 3) were presented randomly in the same block. Other studies in different areas have demonstrated the effects of the composition of the experimental list (random vs. blocked presentation) on behavioural tasks (e.g., Tessari & Rumiati, 2004). Experiment 4 was designed to address whether the random vs. blocked presentation of the stimuli may have influenced the results. Namely, we presented the sentences in a blocked way and asked right-handed participants to respond to sensible sentences with the right hand and to non sensible sentences with the left one. If the absence of the right-hand facilitation effect in Experiment 2 and 3 was due to the random presentation of the stimuli, we predict to find a facilitation of right-hand responses with hand compared to foot sentences, but no facilitation with hand compared to mouth sentences.

4.6.1 Method

4.6.1.1 Participants

Eight volunteers took part in the experiment. They were selected according to the same criteria used in previous experiments.

4.6.1.2 Materials

The materials were the same of the previous experiments. The only difference consisted in the blocked presentation of the stimuli. Stimuli were presented in 4 different blocks, two including the foot sentences and the hand sentences presented in Experiment 2, and two including the mouth sentences and the hand sentences presented in Experiment 3. The block presentation order was balanced across participant.

4.6.1.3 Procedure

All participants were asked to respond “yes” with their right hand and “no” with the left hand.

4.6.2 Results

All incorrect responses were eliminated. Errors analyses did not show any evidence of a speed-accuracy tradeoff. To screen for outliers, we used the same criterion as in the previous experiments. Removed outliers accounted for 4.52 % (Foot-Hand Block) and 4.90 % (Mouth-Hand Blocks) of response trials. The remaining response times were submitted to four different ANOVAs, two for each pair of blocks (‘hand sentences’ vs. ‘mouth sentences’; ‘hand sentences’ vs. ‘foot sentences’), one with participants and another with materials as random factor. The reason why we did not analyze the data with a 3 levels ANOVA (foot-hand-mouth) was that the nouns were not the same for the three conditions.

4.6.2.1 Foot and Hand Blocks

RTs were submitted to two 2 (Sensibility: yes, sensible vs. no, no-sensible) X 2 (Sentence Modality: Hand / Foot sentence) ANOVAs, with Sentence Modality and Sentence Sensibility as within participants and within items variables.

Right hand responses were 192 ms faster than left hand responses, F^1 (1, 7) = 21.94, *MSe* = 3364, 31, p<.005; the effect was significant also in the items analysis, F^2 (1, 11) = 7.64, *MSe* = 13.828.99, p< .05. Crucially, in the participants analysis the interaction between Sensibility and Sentence Modality was significant, F^1 (1, 7) = 6.42, *MSe* = 1974.90, p<.05; F^2 (1, 11) = 1.87, *MSe* = 9260.82, p<.19 (see Fig. 2 top). Newman-Keuls post-hoc analysis indicates that the fastest responses were obtained in responses triggered by Hand Sentences with the right hand. With hand sentences, right hand responses were 136 ms faster than left hand responses (p =.002), whereas with foot sentences they were only 56 ms faster than left right responses (p =.04).

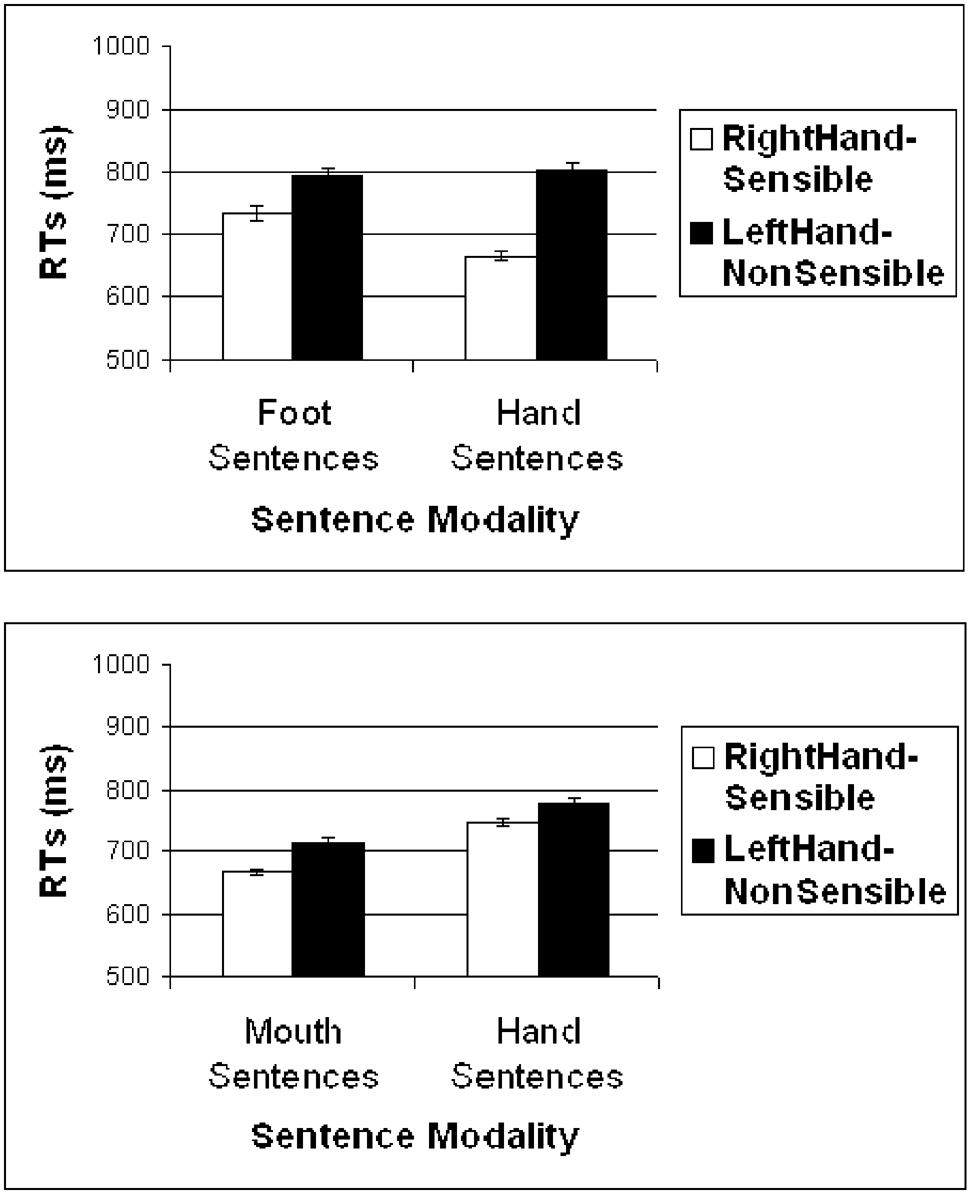


Figure 2. The interaction between Response Hand and Sentence Modality in Experiment 4. Bars represent standard error.

4.6.2.2 Mouth and Hand Blocks

We performed the same ANOVAs with the same factors as in the previous analysis: 2 (Sensibility: yes, sensible vs. no, no-sensible) X 2 (Sentence Modality: Hand / Mouth sentence) ANOVAs. Participants responded 39 ms more quickly with the Right than with the Left hand, F^1 (1,7) = 4.31, *MSe* = 2802.61, $p<.07$; the same effect was found in the items analysis, F^2 (1,11) = 8.49, *MSe* = 1715.829, $p< .05$. More interestingly, as in Experiment 3, mouth sentences were responded to 70 ms more quickly than hand sentences, F^1 (1, 7) = 11.90, *MSe* = 3306.93, $p<.01$; F^2 (1, 11) = 8.66, *MSe* = 6195.619, $p< .01$. As predicted, no interaction was found (see Fig. 2 bottom).

4.6.3 Discussion

The results of this control experiment suggest that the missing effect of Experiment 2 was due to the random presentation of the stimuli. This was not the case for Experiment 4. Thus we can conclude that the comprehension of hand and mouth sentences leads to the activation of the right hand, whereas this is not true for foot sentences. This confirms that sentence comprehension implies a simulation of the action described, and that this simulation takes into account the specific effector involved.

4.7 General Discussion

The results found across the 4 experiments are in line with the predictions of the embodied theory. Namely, they suggest that the comprehension of the meaning of verb-noun pairs implies a mental simulation. This simulation is quite detailed, as it is modulated both by the kind of effector the sentence refers to (hand, foot, mouth), and by the specific hand (dominant, non-dominant) the action expressed by the sentence typically involves. As to the differences due to the kind of effector involved, noun-verb pairs referring to mouth actions were processed faster than pairs referring to hand actions, and the latter were processed faster than pairs referring to foot actions. These results are consistent with the behavioral results found by Pulvermüller et al. (2001), who found a difference in lexical decision between face-, arm- and leg- related verbs. However, our study differs from Pulvermüller et al.'s for two main reasons. First of all, the effect we found concerned noun-verb pairs (sentences) rather than single verbs. Secondly, we used a method implying a deeper processing of the words' meaning instead of a lexical decision task. We also found a difference between the dominant and the non-dominant hand. As predicted, the advantage of the dominant hand concerned sensible sentences related both to hand and to mouth (Experiment 1.a and 3). Significantly, the facilitation of the dominant hand with hand and with mouth sentences was present only with sensible sentences, thus confirming the hypothesis that it was due to a simulation process and not to a general advantage of the right over the left hand. In Experiment 2, in which sensible sentences referred to actions involving both hand and foot, we found slower RTs with the right than with the left hand rather than a facilitation of the right hand. The missing effect of hand sentences with the dominant hand in Experiment 2 was due to the random presentation of hand and foot sentences. Namely, in Experiment 4, when hand and foot sentences were presented in different blocks, we found a marked advantage of the dominant hand with sensible hand sentences, but not with sensible foot sentences. The analyses of sensible sentences allowed us to draw some conclusions regarding the role played by the effectors and the importance of goals in simulating. We believe the advantage of the dominant hand obtained with both hand and mouth sentences (even if mouth sentences were processed faster than hand ones) to be particularly significant because it means, by implication, that during sentence comprehension participants are sensitive both to the effector involved and to the goals expressed by the sentence. Namely, mouth-related actions as "biting an apple" imply the simulation of the whole process of eating the apple, including bringing it to the mouth with the hand. On the contrary, the hand is typically not involved in foot related actions, such as “kicking a ball”.

Our study is in line with studies showing the deep interrelationships between language and motor system. We will briefly review recent evidence suggesting that words activate the motor system. First, there is evidence that the semantic meaning of words affects the grasping and reaching kinematics (Gentilucci, 2003). For example, Glover and Dixon (2002) found that the meaning of the words “large” or “small” printed on objects had an effect on the grip aperture in the initial grasp kinematics. Second, behavioral evidence shows that words activate motor information (Tucker & Ellis, 2004). For example, Borghi et al. (2004) found with a part verification task that participants responded more quickly when required to press a button in a direction compatible with an object’s part location (e.g. responding upward to verify that a horse has a head) than when responding in a direction incompatible with the part location. Other studies focused on the mental simulation activated while processing sentences rather than single words. With a sentence sensibility task Glenberg and Kaschak (2002) found that response times were faster in case of congruency between the movement implied by the sentence (away vs. toward, e.g., “to close the drawer” vs. “to open the drawer”) and the direction implied by the movement required to respond. Recent studies on sentence comprehension suggest that the simulation triggered by the sentence is quite detailed (see for example Bergen & Wheeler, 2005; Richardson, Spivey, Barsalou & McRae, 2003; Scorolli & Borghi, 2007; Spivey & Geng, 2001). Zwaan et al. (2004) asked participants to listen to sentences implying a movement toward or away, such as, for example: “The kids tossed the beach-ball over the sand toward you” vs. “You tossed the beach ball over the sand towards the kids.” After listening to the sentence, participants were shown two sequentially presented objects, one larger and another smaller, implying either a movement toward the observer (if the smaller object was followed by the larger one) or away (if the larger object was followed by the smaller one) from him / her. They found a congruency effect between the movement implied by the sentence and the visual object presentation sequence. Kaschak et al. (2005) asked participants to evaluate whether or not sentences implying different kinds of motion (away, towards, up- and downwards: e.g., “The car left you in the dust”, motion away) made sense. At the same time, they presented visual stimuli moving either in the same or in the opposite direction as that implied by the sentence. The interference effect they found suggests that the simulation is quite detailed, and that the same neural areas are recruited while processing motion sentences and observing motion stimuli (for a more detailed discussion on the differences between interference and facilitation effects in studies on language and motor system, see Borreggine & Kaschak, 2006; De Vega, Robertson, Glenberg, Kaschak & Rinck, 2004). Recent support for a simulationist view of language comprehension is also provided by Zwaan and Taylor (2006). They showed that sensibility judgments for manual rotation sentences were made more quickly when the manual response to the sentence was in the same rotation direction as the manual action described by the sentence. This suggests that comprehension of manual rotation sentences produces motor resonance, as evidenced by the effect of this of sentence comprehension on actual motor responses. In addition, they showed that motor resonance during sentence processing occurred relatively quickly and locally. By asking participants to read sentences like “Before /the / big race / the driver / took out / his key / and / started / the / car” while turning the knob one frame at a time, they found that the advantage in cases of congruency between actual turning direction and the motion implied by the sentence was localized in the verb region. In line with the reported findings, our study shows that sentence comprehension activates a simulation process. Importantly, this simulation is quite detailed, as it is modulated both by the kind of effector the sentence refers to (hand, foot, mouth), and by the specific hand (dominant, non-dominant) the action expressed by the sentence typically involves. Accordingly, our study shows that objects affordances influence not only the understanding of nouns referring to objects but also the understanding of different kinds of words and of more complex linguistic structures, such as different kinds of words combinations. As MacWhinney (1999) puts it, not only nouns but verbs as well provide affordances and elicit simulations: “when we hear the word walk, we immediately activate the basic elements of the physical components of walking. These include alternating motion of the legs, counterbalanced swinging of the arms, pressure of the knees and other joints, and the sense of our weight coming down on the earth” (p. 219).

A last point is worth noticing. We believe our study has implications for studies on the neural basis of language understanding. The relevance of goal we found is consistent with the idea of motor resonance, with ideomotor theories (e.g., Prinz, 1997) and with the recent evidence found by Umiltà, Kohler, Gallese, Fogassi, Fadiga, Keysers and Rizzolatti (2001), that mirror neurons fire in accordance with the activated goal, and not only with the activated effector. From a neural point of view, the similar effects found with the mouth and the hand sentences are justified by the common activation of the Broca area (Buccino et al., 2001). This is convergent with evidence indicating that at the neural level hand and mouth actions activate contiguous regions, which is not the case with foot and hand actions. Our study confirms the existence of a strict interrelationship between hand and mouth actions and it is in line with recent studies showing that language evolves from gestures and manual actions (e.g., Corballis, 2002; Arbib , 2005; Parisi et al., 2005).

5 The specificity of the simulation with respect to the external world. An intrinsic object property - weight - and the perception of action

Does comprehending sentence about lifting a weight interfere with judgments of weights lifted by others? Observers read a sentence describing the lifting of a heavy or light weight. Then they were shown a video depicting the lifting of a large or small box, and the observers estimated the box's weight. In the second experiment, boxes lifting practice preceded the observation of the videos and led to a dramatic increase in the correlations between judged and observed weight. For the light videos, the light sentences produced the lowest correlations; for the heavy videos the heavy sentences reduced the correlations. A modification of the MOSAIC model explains these results: reading about the lifting of a light/heavy object occupies a module that would otherwise be used in making a weight judgment. Previous work has demonstrated effects of action systems on comprehension; these results demonstrate a reciprocal effect of comprehension on use of motor system to make judgments.

5.1 Introduction

Behavioral, kinematic and neurophysiological data convincingly demonstrate that language comprehension is grounded in perception, action, and emotional systems. Behavioral evidence shows that words activate motor information. For example, Glenberg and Kaschak (2002) with a sentence sensibility task found that response times were faster when there was a congruency between the movement implied by the sentence and the movement required to press the response key. In addition, there is evidence that the meaning of words affects reaching and grasping kinematics (Gentilucci, 2003). Recent support for a simulationist view of language comprehension is also provided by Buccino et al. (2005) showing with transcranial magnetic stimulation (TMS) and behavioral studies that simulation while processing action sentences are sensitive to the kind of effectors required to perform the action.

In our study we asked a novel question: will the mere act of comprehending language affect the perception of action? We tested this prediction using a weight judgment task. Hamilton, Wolpert and Frith (2004) reported that when observers actively lifted a weight, it affected their judgments of weights being lifted by others. Literally lifting a weight lighter than that of the box being observed resulted in an heavier judgments of the observed box, and literally lifting a weight heavier than that of the box being observed resulted in lighter judgments. They explain the results using the MOSAIC model of action control, in which there are multiple modules that play a role in both the perception and production of actions. For example, there may be different modules producing different amounts of force for the control of lifting 50 g, 75 g, 100 g, and so on. Weight judgments result from computing an average of the modules activated by the observation of lifting (those corresponding to lifts of weights near the one being observed). However, actual lifting takes priority in using a module, thereby removing that module from computation of the average and biasing the judgment in the opposite direction. This explanation is similar to that provided by the Theory of Event Coding (TEC, Hommel et al., 2001), which suggests that motor and perceptual processes can make use of the same neural mechanism, but that action plans take priority over the perceptual judgment.

In contrast to literally lifting a weight, we asked whether comprehending a sentence about lifting a weight would interfere with subsequent judgments of weights being lifted by others. The rationale is as follows: the motor system is used in making judgments of weights lifted by others. If language comprehension affects the motor system, then the comprehension task should also affect weight judgments. In two experiments, observers read a sentence describing the lift of a heavy weight (e.g., “Lift a bowling bowl from the cart to the table”) or a light weight (e.g., “Lift a wine glass from the cart to the table”). The sentence was followed by a video (Bosbach, Cole, Prinz and Knoblich, 2005) depicting the lift of a large box or a small box. Then the observer estimated the weight of the box. On the basis of the MOSAIC model we expected a modulation in the weight judgments. Reading about the lifting of a light object will occupy a light module. Because light modules contribute to the judgment of the weight of light boxes, this reading will interfere with the weight judgments. In contrast, reading about the lifting of a heavy object will occupy a heavy module that would not participate in the judgment of the weight of a light box. Hence there should be little interference. Similar predictions are made for the judgments of the heavy boxes. Namely, reading about the lifting of heavy objects will cause more interference in judgments of heavy boxes than reading about the lifting of light objects.

5.2 Method

5.2.1 Participants

Thirty-eight volunteers took part in the first experiment and thirty-two volunteers took part in the second one. They were all students of the University of Bologna, native Italian speakers and right-handed according to the Edinburgh Handedness Questionnaire (Oldfield, 1971).

5.2.2 Materials

We created 64 Light Sentences (e.g. [1] “Move the rubber ball from the rug into the drawer”), and 64 Heavy Sentences (e.g. [2] “Move the gas tank from the ground floor to the attic”). Following the sentence was a comprehension question to encourage reading for comprehension. Example questions are: “Can the object that was on the rug be drunk?”, light sentence [1]; “Is the object in the attic edible?”, heavy sentence [2]. We also used 4 Light Videos (50 g, 300 g, 600 g, 900 g) and 4 Heavy Videos (3 Kg, 6 Kg, 12 Kg, 18 Kg) used by Bosbach et al. (2005).

5.2.3 Procedure

Each trail began with a sentence displayed on a computer screen. The sentence could refer to the lifting of a light object or of a heavy object. After reading the sentence, participants were required to press the spacebar. Then, the comprehension question appeared on the computer screen. If the answer was affirmative, participants pressed the spacebar again, otherwise they had to refrain from responding. Reactions times slower than 2000 ms were considered as no response. After 2000 ms the participants were shown a video of an actor lifting a small box or a large box, and 2000 ms later a question related to the video appeared on the screen: *“What is the box’s weight?”* and four possible weights were suggested. Participants had to estimate the box’s weight choosing among four possibilities, using keys 2, 3, 8, 9, associated to the four weights in increasing order (key 2: for the lightest weight; key 9: for the heaviest weight). The 128 trials were preceded by five practice trials.

In Experiment 2, the procedure was modified to include a motor training phase before the 128 trials. Participants were asked to lift four light boxes and four heavy boxes whose weights matched to the weights of the boxes shown in the videos.

5.3 Results

We eliminated trials on which the comprehension question was answered incorrectly, and we analyzed the weight judgments.

Participants committed many errors (experiment 1: 48.60%; experiment 2: 45.46%) in the weight judgment task. Due to the high percentage of errors, it was impossible to perform a reliable analyses on reaction times. Seven participants from the first experiment and five from the second one, who made more than 55% errors, were excluded from further analyses. We then analysed the correlations between the observed and the judged weights of the boxes lifted in the videos.

5.3.1 Experiment 1

The correlations were submitted to a 2 (kind of Sentence: Heavy *vs*. Light) X 2 (kind of Video: Heavy *vs.* Light) ANOVA, with both kind of Sentence and kind of Video as within factor variables. Heavy Videos produced higher correlations, F (1, 30) =4.91, MSe = 0.23, p < .03, perhaps due to the difficulty in deriving the weight from kinematic visual cues for light compared to heavy videos. No other significant effects were found.

In Experiment 1, the correlations' average between judged and observed weight was poor (M = 0.65; SD = 0.45), especially for the light boxes. For this reason we designed Experiment 2, in which we introduced a motor preparation phase.

5.3.2 Experiment 2

During the motor training the observers were required to practice lifting large and small boxes (modelled on those in the videos) before the reading and judgment task. The introduction of this training led to an increase in performance. In this experiment participants obtained higher correlations, with a lower standard deviation ($M = 0.79$; $SD = 0.32$) than in Experiment 1. The correlations were submitted to a 2 (kind of Sentence: Heavy *vs.* Light) X 2 (kind of Video: Heavy *vs.* Light) ANOVA, with both kind of Sentence and kind of Video as within factor variables. As in Experiment 1, correlations were higher for Heavy than for Light Video, F (1, 26) = 4.86, $MSe = 0.13$, $p < .04$.

Crucially, in the second experiment the interaction between the kind of Sentence and the kind of Video was significant: F (1, 26) = 5.89, $MSe = 0.05$, $p < .02$. Newman-Keuls post-hoc analysis indicated that this was chiefly due to the disadvantage of Light Videos with Light Sentences compared to Light Video with Heavy Sentences $p < .03$. Thus, reading sentences about lifting different weights seems to affect the perception and the evaluation of observed objects, an effect consistent with the claim that language comprehension can affect perception and action systems.

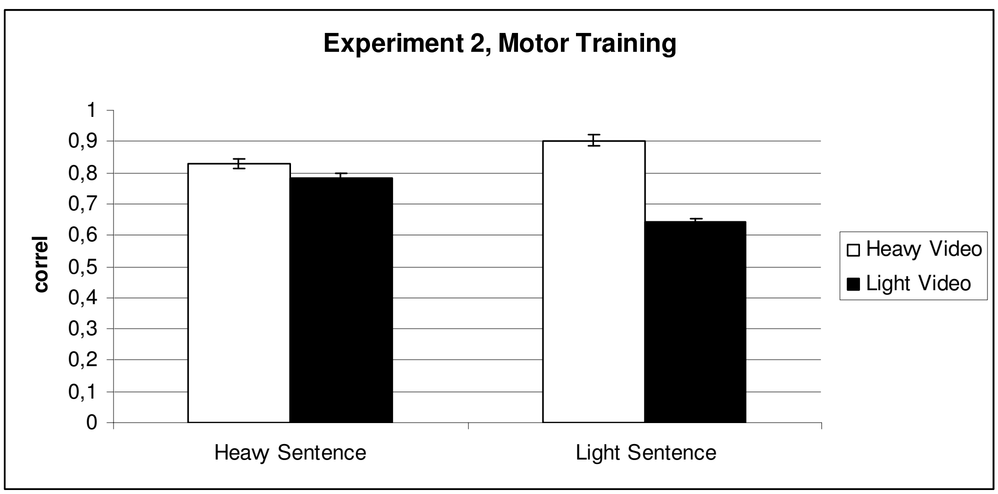


Figure 1. The interaction between the kind of Sentence and the kind of Video. Bars represent standard error.

Finally the correlations of the first and the second experiment were submitted to a 2 (kind of Sentence: Heavy *vs.* Light) X 2 (kind of Video: Heavy *vs.* Light) X 2 (kind of Experiment: Experiment 1 *vs.* Experiment 2) ANOVA, with both kind of Sentence and kind of Video as within factor variables, and with kind of Experiment as between factor variable. Participants obtained significantly higher correlations for the second experiment (M = 0.79) than for the first one (M = 0.65): F (1, 56) = 4.17, MSe = 0.26, $p < .05$. The motor preparation phase seemed to improve the ability to judge the boxes' weights.

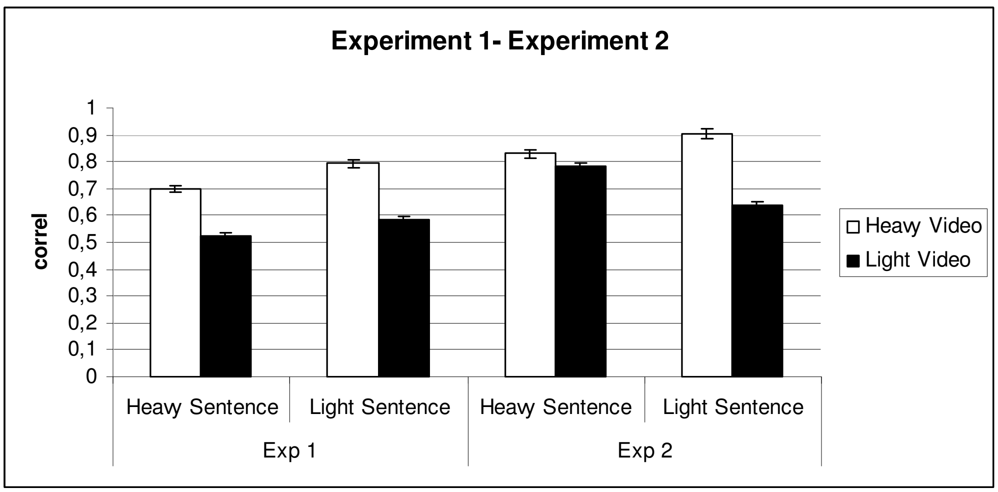


Figure 2. After the motor training -exp. 2-, participants obtained significantly higher correlations (M = 0.79 vs. M = 0.65). Bars represent standard error.

5.4 Conclusions

In the first experiment, the correlations' average between judged and observed weight was poor, especially for the small boxes, maybe due to the complexity of the task. In the second experiment, where observers were required to practice lifting large and small boxes (modeled on those in the videos) before the reading and judgment task, we obtained a dramatic increase in the correlation. In addition, for the Light Videos, the Light Sentences produced the lowest correlations, whereas for the Heavy Videos, Heavy Sentences produced the lowest correlations, although the latter effect was not significant. This interference effect is in line with the Hamilton et al. (2004) data and the MOSAIC model. First, comprehending the sentence describing a lift requires a simulation using the motor system. This simulation temporarily occupies a particular module (e.g., the module for lifting a 250 g weight) rendering it unavailable for use in the judging the weight of the box observed in the video. Variability of the weights simulated (and consequently, variability in the modules used in the judgment task) reduces the correlation between judged weight and observed weight. Because the modules used in simulating the light sentences are unlikely to be used in judging the heavy weights (and vice versa), the correlation is most reduced when the sentence is about lifting objects similar to those observed.

There is other experimental evidence that seems to demonstrate that visual stimuli automatically activate the motor system, but the results are not as straightforward. Hamilton, Joyce, Flanagan, Frith and Wolpert (2007) tried to define the kinematic variables used in the perceptual weight judgment task and to test whether observers are sensitive to the variables. The authors decomposed the lifting movement into four phases: reach, grasp, lift and place. They found that participants tended to judge the objects' weight relying on the early lift phase, whereas the more reliable predictor of the objects' weight is the duration of the grasp phase. This discrepancy does not support a strong simulation hypothesis for weight evaluation. These data, much like ours, suggest some degree of motor involvement in the perceptual task, but a weaker version of the motor simulation hypothesis, compatible with the Theory of Event Coding (Hommel et al. 2001).

In theses two experiments we did not obtain straightforward results. It could be due to the complexity of the weight evaluation task. Another possibility concerns the timing: participants simulate while reading but this simulation doesn't last long enough to influence the comparative judgments. In order to disentangle these two possibilities and to better understand if comprehending sentences referring to differently weighted objects affects the motor system, we decided to study if the processing of the same kind of sentences has an effect on kinematic parameters (action system) as well as on weight judgments (perception system). The study is discussed in *Chapter 6*.

6 The specificity of the simulation with respect to the external world. An intrinsic object property - weight - and the production of action

Language comprehension requires a simulation process that taps perception and action systems. How specific is this simulation? To address this question, participants listened to sentences referring to the lifting of light or heavy objects (e.g., pillow or chest, respectively). Then they lifted one of two boxes that were visually identical, but one was light and the other heavy. We focused on the kinematics of the initial lift (rather than reaching) because it is mostly shaped by proprioceptive features derived from weight that cannot be visually determined. Participants were slower when the weight suggested by the sentence and the weight of the box corresponded. This effect indicates that language can activate a simulation which is sensitive to intrinsic properties such as weight.

6.1 Introduction

The simulation theory of language (e.g., Barsalou, 1999a; Glenberg & Kaschak, 2002; Gallese, 2007; Gallese & Goldman, 1998; Jeannerod, 2007) proposes that language comprehension requires a simulation of the situation described using the same neural systems that contribute to perception, action, and emotion within that situation. In the last fifteen years, many studies have shown that simulating implies recruiting these systems without necessity of a transduction process from the sensorimotor experience to an amodal and astract representation (Pecher et al., 2003; Saffran, Coslett, Martin & Boronat, 2003; for recent reviews see Barsalou, 2008a, 2008b; Fischer & Zwaan, 2008; Gallese, 2008; Martin, 2007). An important question within this framework concerns the detail of the simulation. For example, must the simulation match the temporal course of the situation? Are lifting forces simulated? We investigate these questions by examining the effects of language comprehension on the kinematics of bimanual lifting. We begin with a brief review of the literature relating language and kinematics, and we develop the case for focusing on the interaction of language and actual weight being lifted. We then present the results of an experiment demonstrating that interaction.

Many recent studies provide evidence of language-induced effects in motor areas of the brain (Wise, Chollet, Hadar, Frison, Hoffner & Frackowiak, 1991; Martin et al., 1996; de Lafuente & Romo, 2004; Hauk, Johnsrude & Pulvermüller, 2004; Kemmerer, 2006; Kemmerer, Gonzalez Castillo, Talavage, Patterson & Wiley, 2008) and also on overt motor behavior (Glover, Rosenbaum, Graham & Dixon, 2004; Gentilucci, Benuzzi, Bertolani, Daprati & Gangitano, 2000; Gentilucci & Gangitano, 1998). In particular, kinematics studies have examined the effect of different syntactic (adjectives, adverbs and verbs) and semantic (e.g., 'long' vs. 'short') categories of words on the mono-manual reaching and grasping movements (Gentilucci et al., 2000; Glover and Dixon, 2002; Boulanger, Roy, Paulignan, Deprez, Jeannerod & Nazir, 2006). The experiments have demonstrated interactions of language and both intrinsic properties, i.e. invariant object features, such as size and shape, and extrinsic (visual) object properties, such as orientation (Gentilucci et al., 2000; Glover & Dixon, 2002). Given that the point of these studies was to test whether language affects the visuo-motor transformations during the programming of movement, kinematics analyses focused on mono-manual object grasping. In particular, analyses concentrated on the prehension movement, from the beginning of the reaching until object grasping. The parameters which are typically considered are the thumb-index finger distance and the wrist velocity, both relying on object visual analysis. The thumb-index finger distance in shaping the suitable grasp depends on the object intrinsic properties. The wrist velocity in reaching the object is mostly a function of object extrinsic properties, such as orientation, thus it is sensitive to subject's observation conditions. Evidence reveals that both the reach and the grasp components of the movement are modulated by words. For example, linguistic labels such as "far" and "near" printed on a target object affect the reach kinematics, whereas labels such as "large" and "small" influence the initial grasp kinematics (Gentilucci & Gangitano, 1998; Gentilucci et al., 2000; Glover & Dixon, 2002). Evidence shows that not only the meaning but also the class of word has a different influence on kinematics: for example, verbs influence the action kinematics more than adjectives (e.g., "lift" vs. "high") (Gentilucci, 2003a). The class of words has an influence on timing as well: for example, adverbs (e.g. "up" vs. "down") influence more the grasping action, whereas semantically equivalent adjectives (e.g. "high" and "low") affect more the movement planning phases (Gentilucci et al., 2000).

After grasping an object, the movement is shaped more by proprioceptive than by visual features. Object weight is a kind of proprioceptive feature, as it cannot be visually predicted. In summary, even though an increasing number of kinematics studies deal with language, to our knowledge all of them focus on object properties that can be visually detected. None of these studies focuses on the influence of language on properties that cannot be visually detected, such as object weight.

The panorama is similar if we consider, more generally, kinematics evidence concerning prehension. The majority of the studies have shown that the manipulation of intrinsic object properties influences the grasp component of the movement, and that manipulation of extrinsic object properties mainly affects the reaching component of the movement (Jeannerod, 1981; Gentilucci, Chieffi, Scarpa & Castiello, 1992; Jeannerod, Arbib, Rizzolatti & Sakata, 1995). As previously noted, size and shape are properties that can be visually detected, so the studied movement phase is the one that precedes the interaction with the object.

Studies focusing on the effects on movement of object mass[1] are scarce. Nonetheless, it is clear that the heavier the weight, the more lifting time increases, due to the applications of larger lifting forces (Brouwer, Georgiou, Glover & Castiello, 2006; Johansson & Westling, 1984, 1988; Westling & Johansson, 1984).

Most of the studies of weight manipulate both visual cues for the estimation of weight (e.g., size, illusory size, color, object identity), and/or learning and participants' expectancies – for example by presenting participants with a heavy object in a 'light block' of trials, or, vice versa, by presenting a light object in a 'heavy block' of trials. For example, Eastough and Edwards (2007) recently found that the weight of the object significantly influences prior-to-contact grasp kinematics. The effect of participants' expectations about weight is detectable not only in the lifting phase of the movement, but also during the reaching phase. In particular, some studies provide evidence of longer lifting time for objects that were unexpectedly heavy, and shorter lifting time for objects that were unexpectedly light (Brouwer et al., 2006; Johansson & Westling, 1988; Weir, MacKenzie, Marteniuk, Cargoe & Frazer, 1991; Jenlman, Schmitz, Forssberg & Ehrsson, 2006). Some of the issues addressed by these studies is whether online control of movement is specialized for features such as size and shape, and whether it can be extended to non-visual features such as weight. Different studies addressed the mono-manual lifting movement to directly investigate whether people can adjust their movement plan to visually indicated sudden changes in weight. In contrast with previous evidence (Glover, 2004; Goodale, 1998; Milner & Goodale, 1993), recent results argue against visual online control specialized only for low-level features, such as size and shape. Instead, there is some evidence that visual online control is also extended to weight (Brouwer et al., 2006).

Compared with previous studies, our work is novel in at least two respects. First, we examine the effects of language on a property that cannot be visually detected

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[1] Objects mass is an intrinsic object property that does not depend on the object spatial position, whereas object weight is the gravitational field effect on this mass. However, from here on, we will refer to mass as 'weight', following the literature mainstream.

(in our experiment), namely, object weight. Whereas the effects of language on visually detectable properties such as size and shape have been demonstrated in a variety of experiments, this is not the case for a property such as weight. Finding a result with weight would contribute to enhancing the role of simulation by showing that it takes into account more than visuo-motor transformations. As shown in our review, participants' expectations about weight can be influenced both by visual features such as object size (size-weight illusion, see, for example, Brenner & Smeets, 1996) and shape, and by memory and learning. But in the current experiment, we ruled out possible influences of object size and shape by keeping them constant, and we randomly changed object weight in order to analyse the effects on kinematics parameters of sentences referring to different weighted objects.

To investigate the effect of language on an intrinsic proprioceptive feature such as weight, it is necessary to focus on the placing phase, i.e. on the movement phase in which participants interact with the object. Therefore, the second novel aspect of our work is investigating effects of language on the motor system after grasping, in the early phase of the placing movement. During this phase, participants interact with the object, and their movement is shaped by the proprioceptive information which constrains the movement very quickly. Our analysis focused mainly on lift delay defined as the time immediately after the object is grasped. It has been demonstrated that this parameter is the most sensitive to weight manipulation (Weir et al., 1991; Johansson & Westling, 1988).

Thus the aim of the present study is to test whether the simulation activated by language takes into account weight, and thereby influences action production. To investigate this issue, we presented participants with sentences describing the lifting of differently-weighted objects (e.g., light objects such as pillows, and heavy objects such as tool chests). After listening to the sentence, participants were required to lift with both hands (bimanual lifting) a heavy or a light box placed in front of them.

We can derive predictions based on two contrasting hypotheses. The first hypothesis begins with the assertion that language comprehension does not involve a simulation. However, people may use the content of the language to control their behaviour. Thus, when participants hear a sentence describing the lift of a light object, they may take that as a hint that the box they are about to lift is in fact light, and the converse for sentences describing heavy objects. This hypothesis predicts a main effect of sentence content on lift kinematics: hearing about heavy objects will result in the application of more force, and hence faster lifting times, than hearing about light objects. Here and henceforth, we define faster lifting times in terms of the early occurrence of the first peak velocity, rather than in terms of an overall faster movement. As noted by an anonymous reviewer, this hypothesis makes predictions substantially similar to a priming hypothesis in which language inputs prime motor outputs.

The second hypothesis is based on the MOSAIC model of action control discussed by Hamilton et al. (2004). According to MOSAIC, the force used in an action arises from integrating the force parameters from several modules that might apply in the situation (e.g., modules for lifting a light box and modules for lifting a heavy box). The integration is based on the estimated probability that a module applies in the situation. Furthermore, Hamilton et al (2004) demonstrated that modules may be rendered temporarily unavailable by simultaneous use in another task, and that this produces a type of repulsion effect. That is, when a module for producing a light force is being used in Task 1 and hence it is unavailable for Task 2, the integration of forces from the remaining modules produce too much force in Task 2; similarly, when a module for producing a heavy force is being used in Task 1, the integration of forces from the remaining modules produce too little force in Task 2. As discussed in *Chapter 5*, Scorolli, Glenberg, and Borghi (2007) demonstrated that language comprehension could serve as Task 1 and render modules unavailable when Task 2 consists of judging the weight lifted by another.

Consider how such a repulsion effect would be revealed in the current experiment. (One caveat is important, however: movements are complex, and thus the MOSAIC for actually generating and controlling such a movement would need to be complex. Here we consider just one parameter, namely, the amount of force used in lifting a box.) The upper section of Table 1 illustrates the force parameters for six

MOSAIC modules. For illustrative purposed, we suppose that the force required to lift the Light Box (force = 2) is generated by Module 2 and the force required to lift the Heavy Box (force = 5) is generated by Module 5.

	Light Box & Sentence			**Heavy Box & Sentence**		
	Mod1	**Mod2**	**Mod3**	**Mod4**	**Mod5**	**Mod6**
Force	**1**	**2**	**3**	**4**	**5**	**6**
Prob.	**.1**	**.3**	**.1**	**.1**	**.3**	**.1**

Force No Sentence = (1 x .1 + 2 x .3 + 3 x .1 + 4 x .1 + 5 x .3 + 6 x .1) / 1 = 3.5

Force Light Sentence = (1 x .1 + 3 x .1 + 4 x .1 + 5 x .3 + 6 x .1) / .7 = 4.14

Force Heavy Sentence = (1 x .1 + 2 x .3 + 3 x .1 + 4 x .1 + 6 x .1) / .7 = 2.86

Table 1. Computation of forces according to the MOSAIC model.

In our experiment, participants experience only two boxes, and thus these modules are weighted more than the others. Nonetheless, in the absence of any visual information about which box is the one that will be lifted on the current trial, the average force (3.5) is generated for every lift (middle section of Table 1). We will also assume that simulating a light sentence requires (most often) Module 2 and simulating a heavy sentence requires (most often) Module 5. When these modules are removed from consideration (because of the simulation) and the contributions of the remaining modules renormed, the force generated after comprehending a light sentence is 4.14 and the force generated after comprehending a heavy sentence is 2.86 (note the repulsion effect).

Table 2 illustrates the relation between the force generated after listening to a sentence relative to the force required to lift the boxes. For the Light Box, the force generated after the light sentence is further from the required force than the force generated after reading a heavy sentence. Just the opposite obtains for the Heavy Box. That is, the force generated after the heavy sentence is further from the required force than the force generated after a light sentence.

	Generated force relative to required force	
	Light Box Req. (2)	**Heavy Box Req. (5)**
Force after Light Sent. (4.14)	**Further from required**	**Closer to required**
Force after Heavy Sent. (2.86)	**Closer to required**	**Further from required**

Table 2. Predictions for the MOSAIC model.

Once the participant begins to lift a box, she will receive feedback from proprioception. Thus the bottom section of Table 1 can also be read as the discrepancy between generated force and the required force revealed by feedback. When the discrepancy is large, we presume that more time will be needed to recompute and apply the new force. Hence, based on the bottom section of Table 1, we derive the following prediction: when lifting a Light Box, listening to a Light Sentence will slow attainment of some kinematics benchmarks (such as latency to peak velocity) compared to listening to a heavy sentence. In contrast, when lifting a Heavy Box, listening to a Heavy Sentence will slow attainment of the benchmarks relative to listening to a light sentence.

6.2 Method

6.2.1 Participants

Eighteen students of the University of Bologna (mean age 20 years) were recruited and were given credit for research participation. Their height ranged from 1,62 to 1,80 m and their hand spans[2] ranged from 17 to 19 cm. All the participants were right handed and were free from pathologies that could affect their motor behavior. All subjects gave informed consent to participate in the study and were naïve as to the purpose of the experiment.

6.2.2 Stimuli

6.2.2.1 Linguistic Materials

An independent group of 12 participants evaluated a set of 18 object words on a seven-point scale in order to assess whether their weights better matched the weight of a box with polystyrene (3 kg weighted box) or a box with gold ingots (12 kg weighted box). All words referred to bi-manually graspable objects, with about the same size and shape. From the original set, 12 words were selected. We chose words whose average weight ratings were less than 3.5 points for Light Sentences and words whose average weight ratings were greater than 4.5 for Heavy Sentences. Then we built 12 sentences using the selected object words and embedded them in the same context, "Move xxx from the ground to the table". Thus the linguistic stimuli were constituted by 6 sentences referring to the lifting of 'light' objects (e.g. "Move the pillow from the ground to the table") and by 6 sentences referring to the lifting of 'heavy' objects (e.g. "Move the tool chest from the ground to the table"). Each sentence was presented only

[2] Span: the distance between the tip of the thumb and the tip of the little finger, when the hand is fully extended.

once. For each sentence we constructed a comprehension question (e.g., "Is the object on the table edible?"; "Does the object that was on the ground contain drinks?"). To make the experimental purpose opaque to subjects, we selected comprehension questions that did not explicitly refer to weight. Unlike other studies of language effects on kinematics, this semantic task allowed us to be sure that the sentence had been comprehended (see Boulanger, et al., 2006).

6.2.2.2 Object Materials

Two boxes, one 'heavy' (mass of 12 Kg) and one 'light' (mass of 3 Kg) were created. Both boxes had exactly the same rectangular shape (40 cm wide X 30 cm high X 24 cm deep), were white coloured, and smooth textured. Each box had two handles, to allow an easy grasp of the object and to constrain the movement both across subjects and across experimental conditions. We examined bimanual rather than mono-manual object placing. Using large boxes that required bimanual lifting enabled us to introduce a large difference between object weights, thus allowing for easy detection of differences in overt motor behavior.

6.2.3 Procedure

At the beginning of the experiment, the experimenter showed the lifting movement to the participants. Participants stood with their feet on a fixed point 40 cm from the box they would lift. Participants were encouraged to execute the movement in a relaxed and natural way. Each trial began with an acoustically presented sentence referring to the lifting of a light object or of a heavy object. After listening to the sentence, participants were required to lift the box and place it on a pedestal (high 30 cm; 100 cm far from the starting point) (see Figure 1). After the execution of the motor task, participants were required to return in the erect starting position. Finally, they were asked a yes/no question about the sentence to verify that they had comprehended it. The 12 experimental trials were preceded by two practice trials which allowed subjects to familiarize themselves with the procedure. To minimize possible effects in weight estimating due to the involvement of memory, learning processes (Brouwer et al., 2006), or expectations, the presentation order of both linguistic and object stimuli was randomised.

6.2.4 Movement Recordings

A BTS Smart system, constituted by a vision system, three cameras, and a control unit, was used in recording the movements. Capture and Tracker software were used to record and to track the spatial positions of five markers (infrared light-emitting diodes), at a frequency of 60 Hz and with a spatial resolution of 768 x 576 pixel. Markers were taped on the hand (third metacarpal bone), on the external wrist (carpus), on the elbow (humeral lateral epicondyle), on the shoulder (scapular acromion) and on the ankle (talus bone).

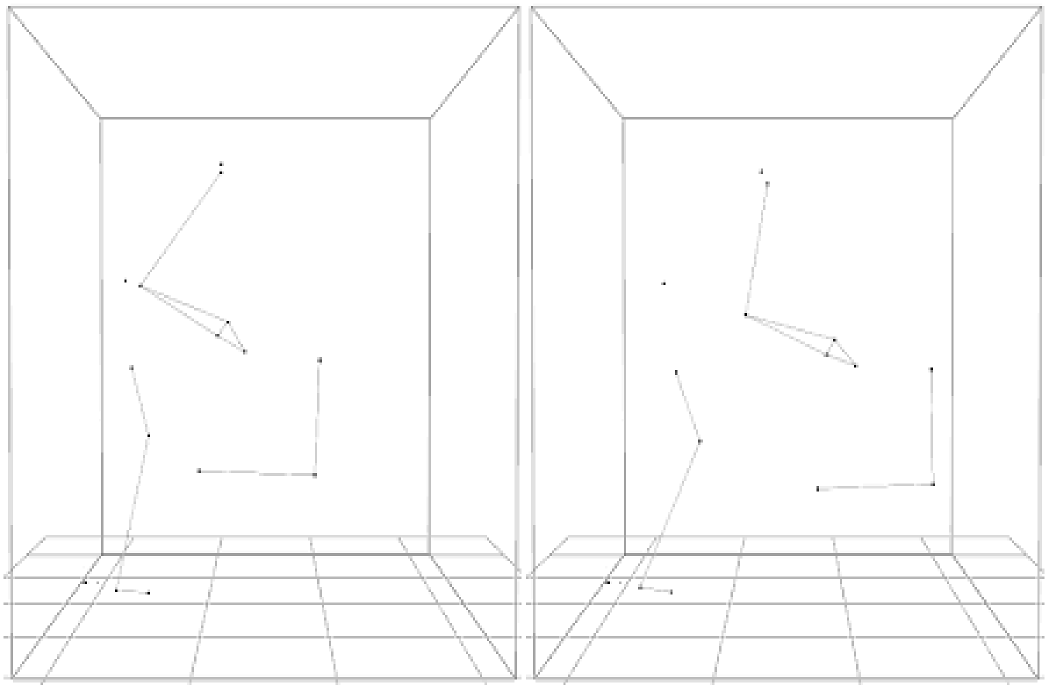

Figure 1. (left) subject bimanually grasps the handles of the box; (right) subject rests the box on the pedestal.

6.2.5 Data Analysis

Movements were visualized and analyzed using Smart Analyzer software. Raw data were smoothed using a rectangular window filter. Kinematics parameters were assessed for each individual movement. The choice to use kinematics parameters as dependent variables is based on evidence showing that using force metrics (dynamics) confirms results obtained with kinematics measures on lifting movement (Jackson and Shadow, 2000).

Our major concern is with the *lifting phase* (Brenner and Smith, 1996; Brouwer et al., 2006), as it reflects the time in which the grasp and the lift forces are accumulating. The *lifting phase* onset was calculated as the end of the reaching movement, that is as the last value of a sequence of 9 decreasing points on the basis of ankle and wrist velocity profile (both ankle and wrist velocity at zero-crossings). The end of the lifting phase, when the object is placed on the pedestal, was defined as the last value of a sequence of 9 decreasing points on the basis of wrist velocity (starting from wrist velocity zero-crossing). We did not consider the latency of the object motion per se because this measure was included in the duration of the *lifting phase*.

Within the *lifting phase*, we analysed latencies of hand velocity peak and elbow angular velocity peak. The elbow angle is formed by wrist-elbow ray and shoulder-elbow ray. Positive velocity values determine the extension movement, whereas negative ones define the muscular contraction, i.e. the bending movement. As outlined in the introduction, we considered only the *first* velocity peaks recorded in the *lifting phase* of the movement. Velocity peak latencies were defined as the time elapsed between *lifting phase* onset and the first maximum value of the hand velocity and the elbow angular velocity. We decided to focus on hand and arm movement as they are the first body parts that interact with the object. Our choice to focus on velocity rather than on acceleration, as in other studies (Gentilucci, 2003a, 2003b; Glover et al., 2004; Lindemann, Stenneken, van Schie & Bekkering, 2006; Zoia, Pezzetta, Blason, Scabra, Carrozzi, Bulgheroni & Castiello, 2006), is based on the fact we are interested in the change of position in time. In addition, in our study we focused on the *first* velocity peak, which is correlated with acceleration.

Moreover, we focused on the latencies of velocity peaks rather than on the velocity values. The latter measure is sometimes used to study mono-manual grasping. Nonetheless, latencies of velocity peaks appear to be a more reliable measure in a motor performance characterized (as in our task) by strong individual differences between participants as far as force and various bodily characteristics are concerned. All kinematics parameters were determined for each individual trial and were averaged for each participant as a function of (light / heavy) sentence category.

6.3 Results

We excluded from the analysis trials when a) the marker movement was not captured correctly, and b) the comprehension question was not answered correctly. Removed items accounted for 9.53% (1.17% for wrong answers to the comprehension questions) of kinematics recordings. All analyses were performed with both kind of Sentence and kind of Box as within-subject factors.

6.3.1 Analyses of 'lifting'

To specifically investigate if the simulation activated by sentences influences movement production, we performed analyses on latencies of hand velocity peak and elbow angular velocity peak during the *'lifting'* phase. For both the parameters we considered the first peak immediately after having grasped the box to move it onto the pedestal. From this point forward, we will discuss only significant results, taking .05 as our level of significance.

6.3.1.1 Hand

We analyzed the hand movement focusing on the absolute value of the third metacarpal bone velocity. Data from two participants were removed as the hand marker was not accurately captured in more than 50% of the trials. We performed a 2 (kind of Sentence: Heavy vs. Light) X 2 (kind of Box: Heavy vs. Light) analysis of variance on velocity latencies with both variables as within participants variables. Results showed a main effect of the kind of box, as participants achieved velocity peaks earlier during lifting of Light Boxes (M = 0.43 s) than during lifting of Heavy ones (M = 0.58 s), F (1, 15) = 19.68, MSe = 0.02, p < .001. This is consistent with previous evidence on mono-manual lifting movement showing that the lifting time increases with the application of larger lifting forces required for larger weights

(Johansson, and Westling, 1984, 1988; Westling and Johansson, 1984; Smeets, and Brenner, 1999).

Crucially, we found a significant interaction between the kind of Sentence and the kind of Box, F (1, 15) = 4.35, MSe = 0.01, $p < .05$ (see Figure 2 top): while lifting a light box participants reached the velocity peak later (M = 0.44 s) after listening to a light sentence than after listening to a heavy one (M = 0.42 s). Symmetrically, during lifting of a heavy box, participants were slower in reaching the hand velocity peak after a heavy sentence (M = 0.61 s) than after a light one (M = 0.55 s). Newman-Keuls post-hoc analysis indicates that this effect is mainly due to the effect of the Light *vs.* Heavy Sentences during lifting of the Heavy Boxes ($p < .04$). These results indicate that the simulation activated by the sentence affects the lifting movement, and they are substantially in agreement with the predictions derived from Hypothesis 2: when a MOSAIC module is occupied by an ancillary task (in this case, simulation in the service of language comprehension), integration of force across the remaining relevant modules will be biased.

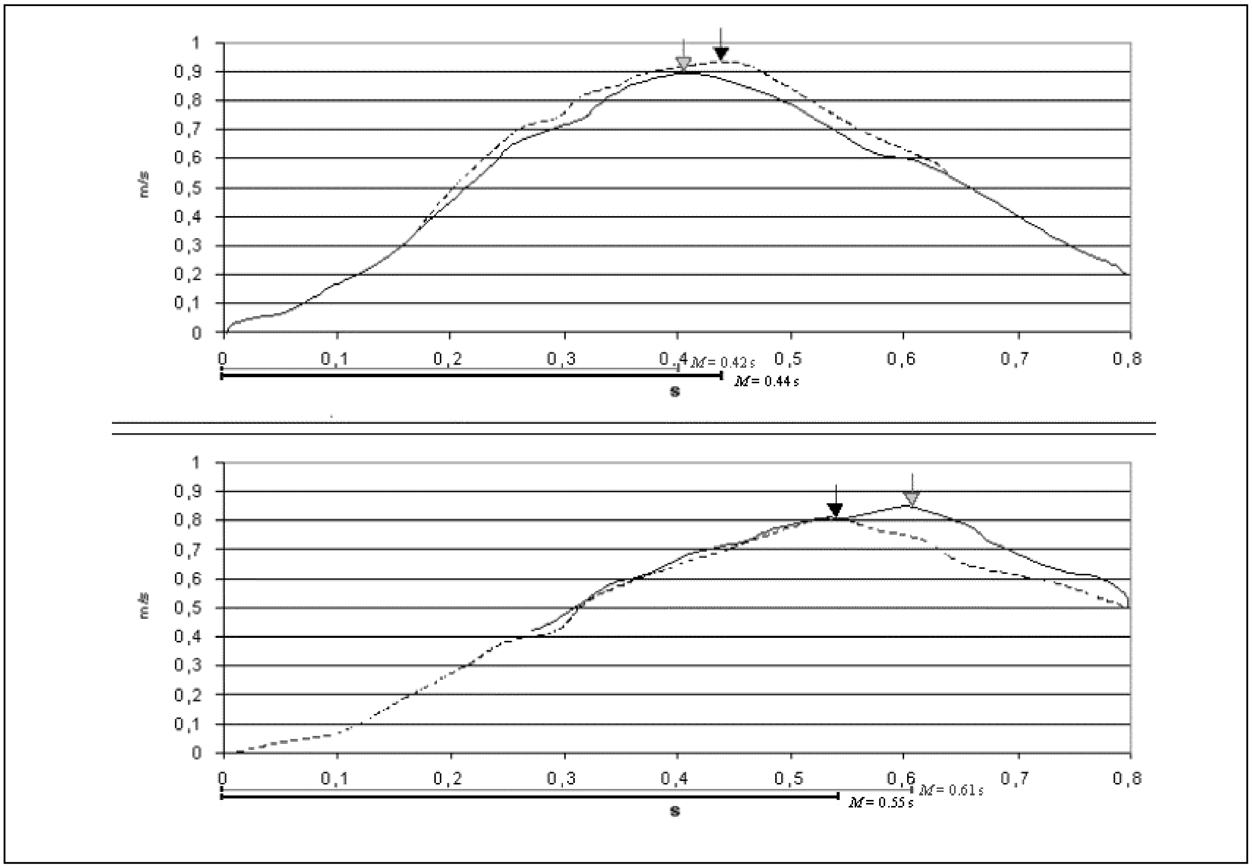

Figure 2. [diagrams] Examples of hand velocity profiles during the *lifting phase*. Single movements are represented. Latencies of velocity peak are defined as the time elapsed between *lifting phase* onset and the first maximum value of the hand velocity. (top) Light Box lifting; (bottom) Heavy Box lifting. *Continuous lines* refer to the movement after listening to a Heavy Sentence; *grey arrows* refer to the first velocity peaks; *grey segments* (below the X axis) refer to the first velocity peaks latencies. *Dashed lines* refer to the movement after listening to a Light Sentence; *black arrows* refer to the first velocity peaks; *black segments* refer to the first velocity peaks latencies. From the figure it might appear that the latencies are measured from the moment in which the object starts to move rather than when the hand velocity is at zero-crossing. However, this is not the case: the erroneous impression is due to the

very brief delay occurring between hand velocity zero-crossings and hand movement onset.

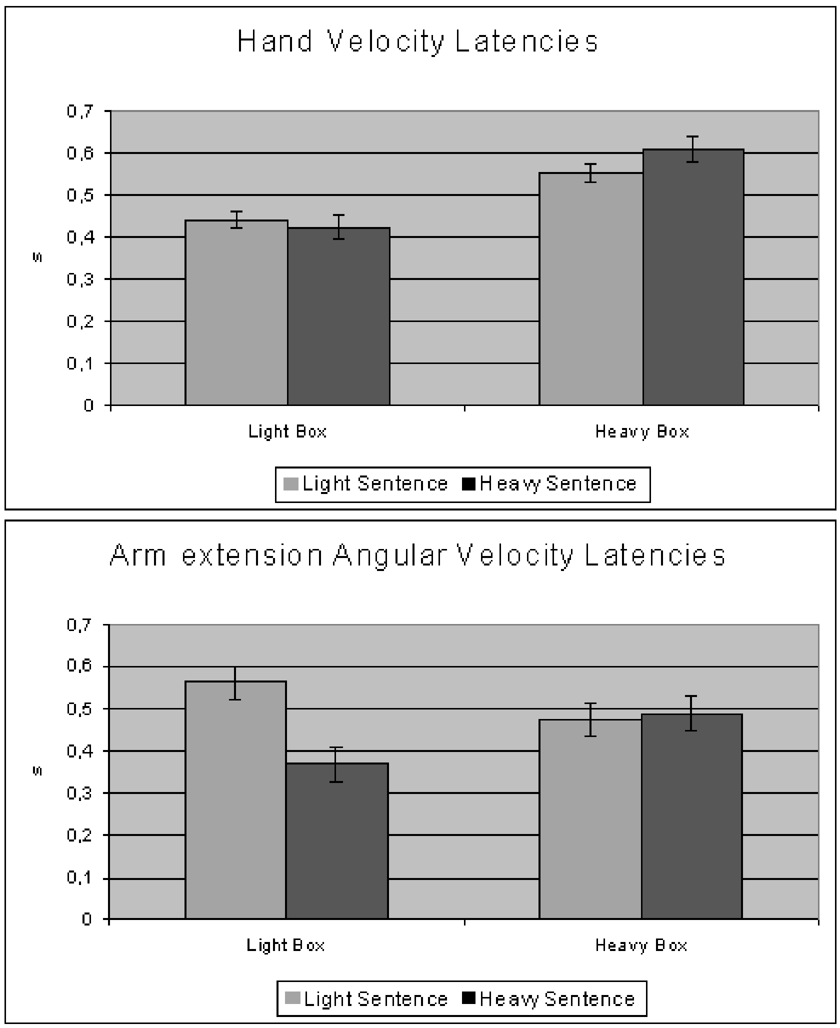

Figure 3. (top) Hand: the interaction between the kind of Sentence and the kind of Box; (bottom) Arm extension: the interaction between the kind of Sentence and the kind of Box. Bars indicate standard error.

6.3.1.2 Arm extension

We analysed the arm extension and bending focusing on the elbow angular velocity. We used the velocity vector, instead of the scalar absolute value of velocity, as it maintains the information on the specific kind of performed movement: the positive sign of the angular velocity vector accounts for the arm extension movement, and the negative sign accounts for the arm bending movement. We analysed the two kinds of movements separately.

We submitted the latency to the elbow positive velocity peaks to a 2 (kind of Sentence: Heavy vs. Light) X 2 (kind of Box: Heavy vs. Light) ANOVA, with both factors as within subjects variables. Neither of the main effects was statistically significant. Crucially, the interactions between kind of Sentence and kind of Box was significant, F (1, 17) = 4.74, MSe = 0.04, $p < .04$ (see Figure 2 bottom). When lifting Light Boxes participants were significantly slower in reaching the velocity peak when they previously listened to Light Sentences (M = 0.56 s) than Heavy Sentences (M = 0.37 s). Symmetrically, after listening to Light Sentences they were faster (M = 0.47 s) in extending the arm to lift the Heavy Box than after listening with Heavy Sentences (M = 0.49 s). Newman-Keuls post-hoc analysis indicates that the interaction is mainly due to angular velocity peak differences between the Light Sentence and Heavy Sentence conditions during the Light Boxes lifting ($p < .04$). Once again, these results indicate that the simulation activated by the sentence affects the lifting movement, and they are substantially in agreement with the predictions derived from Hypothesis 2, that is, when the weight implied by the sentence and the weight of the box to be lifted are similar the time delay is larger compared to when they do not match at all.

6.3.1.3 Arm bending

The latency to negative velocity peaks were submitted to the same ANOVA. The factor kind of Box was significant, as the velocity peaks were faster when lifting the Light Boxes (M = 0.26 s) compared to the Heavy ones (M = 0.37 s), F (1, 17) = 46.93, MSe = 0.01, $p < .001$. Results showed also a significant main effect of the kind of Sentence: participants were slower with the Light Sentences (*M* = 0.33 s) than with the Heavy ones (*M* = 0.30 s), F (1, 17) = 7.41, *MSe* = 0.04, $p < .01$. The two factors did not interact, however.

6.3.1.4 Analyses by halves of the experiment

To understand why the effect of language did not emerge as clearly as for the other two parameters, we analyzed the elbow negative velocity peaks separately for trials from first half (see Figure 4 top) and second half (see Figure 4 bottom) of the experiment. In the first half of the experiment, the participants may have taken the sentences as providing information about the weights of the boxes, as suggested by Hypothesis 1. After experiencing the lack of correlation between the weight of the object mentioned in the sentence and the weight of the box that was lifted, it is less likely that the participants would consider the sentences as providing information about the boxes.

In the analysis performed in the first half of trials, the factor kind of Box was significant, as the velocity peaks were faster when lifting the Light Boxes (*M* = 0.30 s) compared to the Heavy ones (*M* = 0.39 s), F (1, 14) = 7.50, *MSe* = 0.02, $p < .02$. Results showed also a significant main effect of the kind of Sentence: participants were slower with the Light Sentences (*M* = 0.37 s) than with the Heavy ones (*M* = 0.32 s), F (1, 14) = 7.38, *MSe* = 0.007, $p < .02$. The two factors did not interact (see Figure 3 top). Nevertheless, the pattern was interesting, as participants were slower to lift a Heavy box after listening to a Light sentence (*M* = 0.43 s) than after a Heavy one (*M* = 0.35 s). In contrast, they were faster to lift a Light box after listening to a Heavy sentence (*M* = 0.28 s) than after a Light one (*M* = 0.32 s).

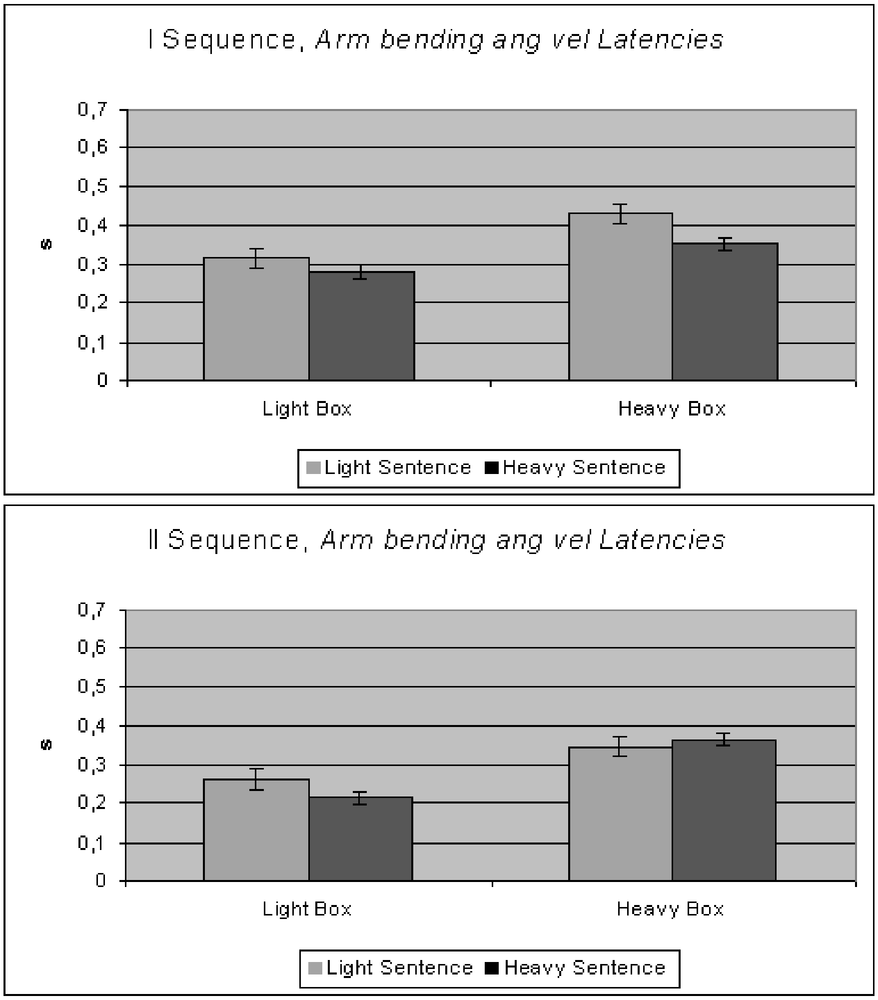

Figure 4. (top) Arm bending: first half of trials; (bottom) Arm bending: second half of trials. Bars indicate standard error.

These results are similar to expectation effects about weight (Johansson and Westling, 1988; Jenmalm, Schmitz, Forssberg, and Ehrsson, 2006). For example, if one expects to lift a light object and instead one lifts a heavy object, the loading phase requires more time. These results are consistent with Hypothesis 1.

In the analysis performed on the second half of the trials the factor kind of Box was significant, as the velocity peaks were faster when lifting the Light Boxes (M = 0.24 s) compared to the Heavy ones (M = 0.36 s), F (1, 13) = 15.98, MSe = 0.01, p < .02. The main effect of kind of Sentence was not significant. The interaction between the kind of Sentence and the kind of Box almost reached significance, F (1, 13) = 2.79, MSe = 0.01, p < .11 (see Figure 3 bottom). Most interestingly, the pattern is changed: participants were faster to lift a Light box after listening to a Heavy sentence (M = 0.21 s) than after a Light one (M = 0.26 s), but they were faster to lift a Heavy box after listening to a Light sentence (M = 0.35 s) than after a Heavy one (M = 0.37 s).

Dividing the experiment into two halves greatly reduced statistical power, which is the likely reason for the interaction failing to reach statistical significance. Nonetheless, the pattern of the means in the second half is similar to the patterns obtained for Hand and Arm extension movement, and all of those patterns are consistent with Hypothesis 2.

To understand if the same change of pattern found in the arm bending parameter for the lifting of Heavy boxes occurred also for the other kinematics parameters, we also performed analyses by halves of the experiment on hand and arm extension movement.

Concerning the hand movement, in the analysis performed in the first half of trials, the factor kind of Box was significant, as the velocity peaks were faster when lifting the Light Boxes (M = 0.45 s) compared to the Heavy ones (M = 0.67 s), F (1, 12) = 61.56, MSe = 0.01, p < .02. The factors kind of Box and kind of Sentence did not interact. In the analysis performed in the second half of trials, the factor kind of Box was significant, as the velocity peaks were faster when lifting the Light Boxes (M = 0.43 s) compared to the Heavy ones (M = 0.59 s), F (1, 13) = 38.92, MSe = 0.01, p < .02. Crucially, the interaction between the kind of Sentence and the kind of Box almost reached significance, F (1, 13) = 3.83, MSe = 0.02, p < .07, and the pattern of the means was consistent with Hypothesis 3: in the second half of the experiment participants were faster to lift a Heavy box after listening to a Light sentence (M = 0.50 s) than after a listening to a Heavy one (M = 0.67 s).

As to the arm extension movement, in the analysis performed in the first half of trials we did not find significant effects. Also in the analysis performed in the second half of trials we did not find the interaction, but again the pattern switched over. In fact, while in the first half of the experiment participants were faster to lift a Heavy box after listening to a Heavy sentence (M = 0.39 s) than after a Light one (M = 0.46 s), in the analyses performed on the second half of trials we found that participants were faster to lift a Heavy box after listening to a Light sentence (M = 0.55 s) than after a Heavy one (M = 0.57 s).

These results of these analyses, although only tentative given the reduced statistical power, are consistent with the following summary: in the first half of the experiment, participants may have been using the sentences to form conscious expectancies about the weights of the boxes, and then they used those expectancies to modify their lifting. After experiencing the independence of the weights of objects mentioned in the sentences and the weights of the boxes, these expectancies were weakened. At this point, effects of language simulation, as described by Hypothesis 2, were more evident.

6.4 Discussion

We have shown that the comprehension of sentences referring to the lifting of differently weighted objects effects the production of action. We asked participants to lift heavy or light boxes after listening to sentences referring to the lifting of heavy objects (e.g, a tool chest) or light objects (e.g, a pillow). Unlike other kinematics studies of language, we used a bimanual rather than a mono-manual lifting task. In addition, we focused on sentences rather than on single word processing. Finally, we added a semantic comprehension task to make sure that participants comprehended the sentences. Most importantly, we focused on an object property that cannot (in our experiment) be visually inferred, namely weight.

The data provide support to our primary hypothesis that language affects the motor system. Importantly, the data speak in favour of the embodied view, according to which during sentence comprehension we internally simulate the actions and situations described by the sentence (Jeannerod, 2007; Gallese & Goldman, 2008; Zwaan, 2004). In addition, the data suggest that simulations can, in at least some situations, consider aspects such as object weights.

There are at least three results that could be offered in support of the claim that simulation can be quite specific. The two most important results are based on analyses of hand and arm delay (latencies of first peak velocities) immediately after grasping the box. We found that participants' time delay was larger when the weight implied by the sentence and the weight of the box they lifted were similar compared to when they were dissimilar. These results are consistent with the operation of the MOSAIC model as outlined in Hypothesis 2.

Third, the effects obtained in the current experiment are consistent with the findings shown in *Chapter 5*. In that study, some participants first practiced lifting boxes of various sizes, shapes, and weights to familiarize themselves with the kinematics appropriate for those boxes; other participants did not have this practice. Then, for all participants, on each trial they read a sentence describing the lift of a Heavy Weight or a Light Weight, and the sentence was followed by a video (Bosbach et al., 2005) depicting the lift of a Large Box or a Small Box. Finally, the participant estimated the weight of the box observed in the video. When observers were required to practice lifting large and small boxes before the reading and judgment tasks, there was a dramatic increase in the correlation between judged and observed weight. Crucially, for the Light Videos (depicting lifts of light objects), the Light Sentences (describing the lifting of light objects) produced the lowest correlations between judged and observed weight, whereas for the Heavy Videos, Heavy Sentences produced the lowest correlations.

The results just described can also be accommodated by the MOSAIC model described as part of Hypothesis 2. First, comprehending the sentence describing a lift requires a simulation using the motor system. This simulation temporarily occupies a particular module (e.g., the module for lifting a 250 g weight) rendering it unavailable for use in the judging the weight of the box observed in the video. Variability of the weights simulated (and consequently, variability in the modules used in the judgment task) reduces the correlation between judged weight and observed weight. Because the modules used in simulating the light sentences are unlikely to be used in judging the heavy weights (and vice versa), the correlation is most reduced when the sentence is about lifting objects similar to those observed.

Evidence is rapidly accumulating that simulations during language comprehension are rather specific (e.g. Buccino et al., 2005; Glenberg & Kashak, 2002; Scorolli & Borghi, 2007). The novelty of our study is that it shows for the first time that the simulation activated during language comprehension can entail information on object weight. As noted in the introduction, weight information cannot be inferred from visual stimuli in our experiment; instead it must be based on proprioceptive and kinaesthetic information. Thus, we have demonstrated through observations of kinematics parameters how language can have another type of specific effect on the motor system.

It can be objected that our results, which are in keeping with the MOSAIC model, conflict with results of other studies examining language effects on action. The reason why this difference appears might lie in the design of the studies. Namely, our study was explicitly designed to produce a contrast effect between the modules used during the ancillary task, the language processing task, and the modules used during the task directly involving the motor system, that is the lifting task. That is, detecting the effect requires that the ancillary task uses a MOSAIC module that is likely to be needed during the motor task, and that this ancillary task be compared to one that does not use that MOSAIC. Consider, for example, evidence by Gentilucci et al. (2000) showing that the kinematics of the initial reaching/grasping phase was modulated by the labels "LARGE" and "SMALL" written on a cube to be grasped. It is possible that in these experiments the MOSAIC required to process a word is not required to set reach kinematics. So, these experiments probably reflect a type of priming (e.g., Hypothesis 1).

One last issue is worth discussion and further exploration. It seems that language can have a different effect than expectations. As outlined in the introduction, it has been demonstrated with mono-manual lifting (Johansson & Westling, 1988; Jenmalm et al., 2006) that when an unexpected heavy weight is lifted after a light weight, then the duration of the loading phase is longer than when a heavy weight is lifted after another heavy object. Differently, the lifting of an unpredictable light weight after a heavy weight results in an early lift off.

Our results partially differ from those obtained in studies on expectations. Namely, we found that participants were faster in the case of heavy box lifting preceded by light sentences. Similar to those studies, however, we found that the time delay of a light box lifting preceded by a heavy box was shorter. Even though these discrepancies might be accounted for by differences in method (e.g., mono- vs. bi-manual lifting), they raise the interesting possibility that language and expectations might tap different mechanisms. In keeping with these speculations, in an fMRI study, Jenmalm et al. (2006) found activity in the right inferior parietal cortex regardless of whether the weight was heavier or lighter than predicted, as well as differences in brain activity (left primary sensory motor cortex and right cerebellum) specific to the direction of the weight change. Unfortunately, research on differences between language effects and expectancy effects are likely to be complicated because language can also be used to change expectancies. Indeed, our analyses of arm bending latencies are consistent with the claim that language can produce both expectancy effects (as in the first half of the experiment) as well as more subtle effects on action control (as in the second half of the experiment). Further research should be conducted to investigate whether language affects different brain circuitries than the ones activated by an unpredictable weight change, and whether module/modules engaged in the comparison between the predicted and the actual sensory feedback are different from that ones engaged during language comprehension.

III part

'THE MEANING OF ABSTRACT WORDS': THE LINGUISTIC EXPERIENCE

7 The meaning of abstract words and the impact of different languages on cognition

One of the main challenges of embodied theories is to account for meanings of abstract words. The traditional explanation of embodied theories is that abstract words, as concrete ones, are grounded in the sensorimotor system and activate situations and introspection; alternatively, they are explained through metaphoric mapping. However, evidence provided so far pertains specific domains and such a theory is not able to account for abstract words in their variety. It could be necessary to take into account not only the fact that language is grounded in the sensorimotor system, but also the fact that language represents a linguistic-social experience. Namely, this experience might be particularly crucial for abstract words compared to concrete ones. Using cross-linguistic comparisons is a possible way to investigate the role played by linguistic experience in abstract words. We examined different combinations of transitive verbs (abstract and concrete ones) and nouns (abstract and concrete ones), focusing on two languages that are syntactically different: German and Italian. Compatible combinations (concrete-concrete and abstract-abstract) required faster times to be processed compared to the mixed combinations. Interestingly, the processing of mixed combinations was modulated by the specific language, as when the concrete word primed the abstract one participants were faster, regardless of the specific grammatical class. Results are discussed in the framework of current views on abstract words; they confirm theories assigning a crucial role of both sensorimotor and linguistic experience for abstract words.

7.1 Introduction

One of the most serious challenges that embodied theories need to cope with is the explanation of how we understand abstract words. The first problem we find facing this issue is that we do not have a *good* definition of abstractness. Curiously, we understand each other when we refer to "abstract entities", nevertheless we notice a high level of disagreement when we try to categorize a specific noun, and even more a specific verb, as "abstract". We all agree that the noun "kiwi" refers to a concrete entity as we can touch it, perceive its ruggedness, see its colour, grasp it, peel it off, proprioceptively feel it while bringing it to the mouth and, of course, taste it. We also agree about the abstractness of the noun "cleverness" as we cannot touch the entity it refers to, neither see it, neither perceive it with other senses. So it could seem that our exteroceptive senses (that is sight, taste, smell, touch, hearing and balance) allow us to discriminate objects and entities in accordance with our dychotomic division. Coherently with this claim, nouns like "pain" or "sorrow" should be unambiguously categorized as abstract, as we cannot perceive their referents, but we can only represent them by introspection. Instead there is a high disagreement in rating them, maybe because we can *feel* them, also physically, by our interoceptive senses: for example, a deep sorrow can cause pain in our internal organs (Altarriba, Bauer & Benvenuto, 1999; Altarriba & Bauer 2004 proposed that emotions constitute a special group of entities, distinct from both concrete and abstract ones). In the same way, the noun "race" should be considered as concrete, primarily for the high imageability of its referent: we can see, as easily imagine, a race, and also hear the noise caused by, for example, a horses race. However, even if there is an high level of agreement in judging the verb "to run" as concrete (maybe because it explicitly involves our motor system), the corresponding noun "race" leads to uncertainty. This last instance arises another issue: not all of our senses are equally critical in characterizing a concept as "abstract". The "smell" or the "scent", for example, are typically categorized as abstract (*see*, for example, Dunabeitia, Avilés, Afonso, Scheepers & Carreiras, 2009), consistently with the assumption that what allow us to discriminate abstract from concrete entities is mostly the imageability, the sense of touch and the proprioception. Nevertheless cooks classify “smell” as concrete with a high level of agreement, consistently with the fact that the meaning is linked to our own perceptive and motor experience, as well as to our specific culture. And what about “stink”? It seems to be more concrete than “scent”, maybe because its intensity seems to be stronger, or because of its negative connotation, that is strongly associated with an avoidance behaviour.

These few examples referring to single words give us an idea of how much is blur the boundary that splits concrete from abstract concepts. Things are even more complicated as typically to communicate we do not use single words, but words combined in a meaningful sentence. Most of us would agree in judging the very simple sentence “to grasp an apple” as concrete, or the sentence “to think about the meaning” as abstract. What about the verb-noun pairs “to grasp the meaning”, or “to think about an apple”? It’s not easy to judge them. Even more tricky is to rate and to understand how we represent sentences like “biting off more than you can chew”, or “chewing over the details”, “kicking off the year”, or “time is running” (Aziz-Zadeh, Wilson, Rizzolatti & Iacoboni, 2006). To know the meanings of single words and to be able to combine them is not enough to fully understand these sentences. The meaning is often related to a specific culture, and it does not work (or it works differently) for other ones. Maybe most of us would judge the aforementioned four sentences as abstract, because of they are not taken literally. These sentences are considered as metaphorical, since there is one domain of knowledge that is applied to another (Lakoff & Johnson, 1980), that is: we can distinguish a target (the subject to which attributes are ascribed) and a source (the subject from which the attributes are borrowed). Concerning metaphoricity, we can individuate different levels, depending on the ease and the immediacy by which we can map one domain on the other one: for example “to grasp a concept” could be considered as a metaphor, even if less metaphorical than “biting off more than you can chew”. In the first case just the verb refers to the source, and the noun refers to the target; in the second case the whole sentence refers to the source, and we have to do a further step to link it to the target. Apart from this difference, actually both source domains refer to a concrete sensori-motor experience in the world, nevertheless our feeling is that these sentences are not concrete. The "sense of abstractness" is probably given by "the abstract link" with the referent/target. This link can be culturally determined, and more or less strong (let's think to some very bizarre poetic licenses), in any case it does not directly match the external referent (differently from what happens with sentences like "to grasp an apple").

Looking at the literature on language grounding in action we find also sentences like "Tom gives you a good suggestion", "Mary tells you the news", contrasted to sentences as "John gives you the cake" (Glenberg & Kaschak, 2002; Glenberg, Sato, Cattaneo, Riggio, Palumbo & Buccino, 2008). Actually the first two sentences could be categorized as "not-concrete", but at the same time they cannot be considered as abstract, since we have directly or indirectly experienced the content expressed by the sentences, that is the referent-situation. There is still a *mapping* on our previous sensori-motor experiences ("to give something to someone"), as probably we firstly learn sentences that refer to a concrete transfer and only later those ones that refer to an abstract one. Even so, there isn't any kind of *mental operation* that we have to do to understand them. The comprehension of these kinds of sentences does not depend on the linguistic community we belong to: they are universally and unambiguously understandable. In fact to test if they activate the same action schema authors manipulate the semantics of the sentences but maintaining a fixed syntactical structure.

7.1.1 Differences between "abstract" and "concrete" words

By showing the reported examples we intended to emphasize that a definition of abstract words and sentences is missing and that we badly need it, as the first step to experimentally study a phenomenon is to unambiguously circumscribe the object of the research. Actually the definition of abstractness using just an exclusion criterion – "all that is not concrete" – is not a good starting point. The dychotomic division between concrete and abstract words is an oversimplification, as the “abstract-concrete dimension” reflects a continuum. This hypothesis was tested and confirmed by Nelson and Schreiber (1992) and successively by Wiemer-Hastings, Krug and Xu (2001). Asking people to judge the concreteness of big sets of words (2172 and1660 words, respectively) they found a bimodal distribution (according to particular features, as tangibility or visibility): this result is in contrast with the view that concreteness is one dimension, and all entities vary along this dimension. Obviously they also found *variance* in concreteness within both clusters of entities.

Different theories tried to explain this variance. One of the older ones is the Dual Code theory (Paivio, 1971; Paivio, 1986), according to which we use two codes to represent and process concepts: a language-like code and an imagery-like one. While concrete entities can be represented by using both codes, the abstract ones fit only the first one. This single coding results in a disadvantage of abstract concepts in different tasks, such as comprehension and recall. While according to the Dual Code theory the difference between concrete and abstract words rests on imagery ratings, the Context Availability theory (Schwanenflugel & Shoben, 1983) points to the ease to think about a context (in terms of faster times) as discriminating feature. More recently, another theory, the Contextual Constraints theory (Wiemer-Hastings et al., 2001) also underlines the fact that abstract entities are associated with contexts (Schwanenflugel, 1991; Wiemer-Hastings & Graesser, 1998). Authors point out that an entity that is not strongly constrained is more abstract than an entity that is contingent on a fairly extensive set of constraints. So they maintain that entities are abstract or concrete depending on whether they are physical in nature (that is perceivable through vision, touch, etc.), nonetheless they highlight that abstractness varies as well, according to more specific types of information (*two-factor model of abstractness*). That is, oppositely to common sense, Wiemer-Hastings et al. (2001) suggest that the higher/lower degree of abstractness could rest on factors different from the ones that determine different degrees of concreteness. This implies a qualitative rather than a quantitative distinction.

Another interesting proposal was advanced by Barr and Caplan (1989). They suggested that abstract concepts differ from concrete ones as they are characterized only by "extrinsic features" (that is "connections" between the conceptual referent and other entities). On the contrary, concrete concepts are characterized also by "intrinsic features", that is features pertaining to the referent characteristics.

An additional line of research focusing on qualitative differences tries to identify which specific pattern of information is activated by abstract vs. concrete words. Studies conducted both with children (Borghi & Caramelli, 2003) and adults (Barsalou & Wiemer-Hastings, 2005) show that words referring to natural and artefact objects activate perceptual and functional information. On the contrary, words referring to abstract entities mainly activate thematic information (that is information related to space, time, place, agent, action, event) and instantiations (when participants produces an example instead of definitions). The *qualitative different representational framework* (QDR), proposed by Crutch and Warrington (2005), also assumes a qualitative distinction, since according to this framework concrete and abstract words are differently organized. Namely abstract words are mainly organized by their associations with other words ("associative neural network"), which correspond approximately to the thematic relations. Concrete words organization is more categorical, based on "semantic similarity" between objects and entities (Dunabeitia et al., 2009), that roughly corresponds to a taxonomic organization, resting on superordinates, coordinates, subordinates.

7.2 Perceptual versus amodal representations: some weaknesses of the "Embodied Theories" framework

The investigation of the way we represent abstract nouns/verbs is crucial as test-bed for "embodied theories". Recently some authors highlighted that the empirical evidence cited in support of embodied theories is compelling with respect to concrete or highly imageable words but has limited reach with respect to abstract ones (Pezzulo & Castelfranchi, 2007; Louwerse & Jeuniaux, in press; Borghi & Cimatti, submitted a, submitted b; Dove, in press). Starting from different perspectives, they proposed to draw attention not only to "grounding" but also to semantic relations.

We'll briefly outline the work conducted in the embodied theory framework, its strength and its weaknesses. Then we'll summarize some new proposals that address the issue of abstractness in a systematic way.

The embodied-situated theories have stressed the continuity between perception, action and cognition. In opposition to the classical-cognitivist views, concepts and words are no more considered as separate from perception and action but rather as grounded in sensorimotor activity. Nowadays lots of evidence supports this view (just to give some examples, Stanfield & Zwaan, 2001; Pecher et al., 2003; Borghi, Glenberg & Kaschak, 2004, Zwaan & Taylor, 2006). The majority of these experimental investigations focus on concepts referring to 'concrete entities'. Concerning the method, in these studies participants are typically shown a specific object, or an action performed on the object, or words or sentences that refer to an object concept or to an action performed on it. This kind of approach arises directly from the assumption that concepts reactivate the same perceptual and motor experience we had with their referents. This "direct" link with the body (as well with an action schema, or with a specific external referents) makes the hypothesis "easily testable". The experimental procedure is intrinsically suggested by the hypotheses. Focusing on language, for example, many studies manipulate the kind of movements suggested by the sentences and the kind of movement required to respond (for example, Glenberg & Kaschak, 2002), looking for "some kind" of modulation of the dependent variable, that we generally define as *motor system.*

The study of abstract concepts is completely different, given their high variability. As drawn above, typically they are thought as "all concepts that are not concrete", so they are more difficult to categorize. Concerning sentences, it's not straightforward what an "abstract sentence" is (think of idiomatic sentences);

moreover, the judgment is hardly generalizable, given the amount of inter-languages subtle differences.

By definition it is clear that there is not an external referent with which we previously interacted. There is not a “clear trace” in our sensori-motor system that can be easily looked for by partial re-activation, as the acquisition process for abstract words is completely different: it rests on linguistic-social experiences (Borghi & Cimatti, submitted a). This suggests that some sort of theoretical reframing/adjustment is necessary.

Nevertheless inside the embodied framework we can find some studies demonstrating that also the comprehension of language about abstract sentences may be embodied (for a review see, Glenberg, et al., 2008). There are basically three approaches to the embodiment of abstract language. The first one, strongly associated with Lakoff (1987) and Gibbs (e.g., Gibbs & Steen, 1999), is based on metaphor. Lakoff proposes that bodily structure induces a consistent structure to experiences, and these experiences become represented as image schemas. A second approach was developed by Barsalou (1999a; Barsalou & Wiemer-Hastings, 2005). On this approach, at least some abstract concepts arise from simulation processes, that is, in order to understand and correctly use a word, one needs to recruit the same senorimotor systems involved while experiencing the referent of the word. A third approach relates abstract events to actions. For example, the indexical hypothesis (Glenberg & Robertson, 1999) asserts that sentences are understood by creating a simulation of the actions that underlie them. So, for example, judging the sensibility of sentences describing the transfer of concrete objects or abstract information requires less time when the action implied by the sentence matches the action required to make the response (action-sentence compatibility effect, or ACE, Glenberg & Kaschak, 2002). This approach can be subdivided into two versions. The first version states that comprehension of transfer might involve a simulation process in which the motor system is used to simulate the specific actions used to accomplish the transfer. The second one assumes that the linguistic material is grounded in motor processes, but not necessarily by direct simulation (action schema approach). As highlighted by Glenberg et al. (2008), these various approaches may all be emphasizing different aspects of the same phenomenon. Simulation of action is the simulation of an event (Barsalou & Wiemer-Hastings, 2005), and events generally are extended in time and space (Boroditsky & Ramscar, 2002; Richardson et al., 2003). Furthermore, to the extent that transfer of information is understood primarily as physical transfer (Glenberg & Kaschak, 2002; Glenberg et al. 2008; Glenberg, Sato, & Cattaneo, 2008), its understanding is metaphorical (Lakoff, 1987).

Even if these approaches to the embodiment of abstract language are not mutually exclusive, they would need a unique framework in which to be integrated. As highlighted above, the heterogeneity of abstract sentences partially justifies the proposal of these “ad-hoc solutions”, which are adequate for specific kinds of abstract words. Nonetheless the multiplicity of the approaches to some extent points out a very specific problem of the embodied theories. One of the main limitations of these experimental approaches can be found in their attempt to overlap with the ones designed to investigate the embodiment of concrete concept. Borrowing these methods can be useful, but it should be taken into account that they fit only the investigation of some kinds of abstract concepts, the ones that can be easily (culturally) mapped on external referents, or action schemas. Accordingly, these findings, even if interesting, are hardly to generalize, as they work only for particular kinds of abstract concepts.

7.2.1 Some theoretical proposals

Providing an overview on the main theories on concrete and abstract concepts, Dove (in press) identifies three major approaches: one proposes that concepts are generally couched in perceptual or motor representations (Barsalou, 1999a; Damasio, 1989; Glenberg 1997; Prinz, 2002). A second one reaffirms the orthodox view that concepts are couched solely in amodal representations (Caramazza, Hillis, Rapp, & Romani, 1990; Pylyshyn, 1973; Pylyshyn, 1981). A third proposal posits the existence of both amodal and modal conceptual representations in conceptual processing (Goldstone & Barsalou, 1998). According to the author, while the first approach is not sufficient to explain the representation of abstract concepts, the one proposed by Pylyshyn (1973) is well suitable to account for it, but it has the limit to explain away the increasing body of research that implicates the use of perceptual representation in cognitive tasks. Finally, the third approach recognizes the qualitative difference between abstract and concrete concepts. In support of the third approach, Dove (*in press*) shows that the empirical evidence for perceptually based conception is fundamentally circumscribed: he claims that the general arguments offered in support of perceptual symbols are much stronger with respect to concrete or highly imageable concepts. Thus the author addresses empirical and theoretical reasons to think that some abstract concepts employ amodal representations. At last he proposes a "representational pluralism", that is a "multiple semantic code" approach, holding that perceptual simulations play an important role in highly imageable concepts while amodal linguistic representations play a crucial role in abstract concepts (independent levels of semantic representation).

In a similar attempt to argue that not just a single type of representation underlies knowledge, Barsalou, Santos, Simmons and Wilson (2008) review linguistic and modal approaches to the representation of knowledge. They propose the LASS (Language and Situated Simulation) Theory as as a preliminary framework for integrating them. The authors focus on two sources of knowledge: the linguistic forms in the brain's language systems, and the situated simulations in the brain's modal systems. They assume that linguistic forms and situated simulations interact continuously in varying mixtures to produce conceptual processing: different mixtures of the two systems underlie a wide variety of tasks. "When superficial linguistic processing is sufficient to support adequate task performance, processing may rely mostly on the linguistic system and little on simulation […]. Conversely, when linguistic processing is unable to support adequate performance, the simulation system must be consulted for the required conceptual information. Depending on task conditions, conceptual processing may mostly consist of linguistic processing or simulation." (Barsalou et al., 2008, p. 4). So, according to them, previous neuroimaging experiments had only found evidence for linguistic representations of abstract concepts because they used tasks that allowed and encouraged superficial linguistic processing (e.g., lexical decision, synonym judgments). LASS claims that the linguistic and simulation systems play different roles in different concepts and in different task contexts. Linguistic forms provide a powerful means of indexing simulations, and for manipulating simulations in language and thought. As the two systems interact, one may dominate momentarily. However, a deeper conceptual processing necessarily requires the simulation system.

Borghi and Cimatti (submitted a, submitted b) propose to extend the embodied view of cognition in order to consider not only language grounding but also the social and normative aspects of cognition. In this framework they claim that words cannot be conceived of as mere signals of something but also as *tools* that allow us to operate in the world. Their theoretical proposal assumes two simultaneous cognitive sources for word meanings. The first one is "individual", that is circumscribed to the embodied individual experience; the second one is "social". This proposal has important direct implications for the abstract words meaning. As drawn above, actually it is almost impossible to come up with a general explanation of abstract concepts as grounded in the motor system. There are some abstract sentences for which we could reasonably predict an activation of the motor system (e.g., "grasping a concept"), but for some others we could mainly expect an activation of perceptual areas. Besides, there might be abstract concepts that simply involve introspection. As pointed out by the authors, in general abstract word meanings rely more than concrete word meanings on language and conventions/norms (Borghi & Cimatti, submitted b). This might lead to a different acquisition mechanism for concrete and abstract words (Borghi & Cimatti, submitted a, submitted b): in the first case the sensorimotor experience "precedes" the linguistic one. That is, with concrete words firstly we experience the concrete entities (e.g., book) and then we tag their referents using linguist labels (we learn the name "book"). In the case of abstract word meaning, instead, we initially learn a word (the label) and then we "tag" it with our sensori-motor experience, that is we use the word to assemble a set of experiences (e.g., probably I assemble different experiences of freedom once I have learned the word “freedom”). Thus, in some sense abstract word meanings would activate more linguistic areas compared to concrete ones.

The best way to disambiguate these hypotheses would be investigating the neural correlates of abstract and concrete words processing with a functional magnetic resonance study. The first step in this systematic path should be the selection of a good paradigm that allows us to contrast abstract and concrete words combined in sentences. Thus far, as shown above, there is a huge amount of evidence on abstract single words. As we thought that embodied views should consider the social aspects of languages, we’ll focus on full sentences, in two kinds of languages. Testing also the specific languages modulation on the way in which we organize categories would allow us to understand the variable and cultural dependency of our word use (Borghi & Cimatti, submitted b).

7.2.2 An attempt to experimentally disentangle the proposals

The aim of the present study is to investigate the comprehension of abstract language using very simple sentences, where concrete nouns and concrete verbs are contrasted with abstract nouns and abstract verbs. One of the advantages of this design is the possibility to study abstractness in a continuum, that is studying combinations in which abstract and concrete verbs and nouns are put together.

We examined different combinations of nouns (abstract and concrete ones) and verbs (abstract and concrete ones), in German and in Italian, given that the two languages are syntactically different (in German the noun precedes the verb, in Italian it is the opposite). Coherently with previous literature, we defined as “concrete” only nouns that refer to manipulable objects and only verbs referring to manual actions (e.g., “an apple” / “to grasp”). We decided to define as “abstract” only nouns that do not refer to an object, rather to an entity that cannot be grasped, neither touched; and "abstract" only verbs that refer to an action[1] that cannot be performed with any parts of the body, that is an action that do not explicitly require any movement neither any activation of the motor system (e.g., "a concept" / "to think"). We balanced the materials for familiarity and probability of use. Participants' task was to judge the sensibility of the sentences.

We'll briefly outline the predictions advanced by different approaches: a strictly modal theory, an amodal theory, a theory based on representational pluralism (Dove, *in press*), a theory resting on language and situated simulation (Barsalou et al., 2008) and finally our prediction, which assumes two simultaneous cognitive source, an individual one and a socially embodied one (Borghi & Cimatti, submitted a, submitted b).

According to a strictly modal theory, there should be no difference in processing concrete and abstract words (Barsalou, 1999a). Namely, the difference between concrete and abstract words relies in the fact that, whereas concrete words activate more perceptual features, abstract words should activate a different set of relations, that is situational and introspective features. Therefore, we should expect no difference between the four conditions. Amodal theories of concepts claim that both concrete and abstract concepts are represented in the same format, so there should be no difference in processing between the two. Therefore no difference between the four conditions is predicted. According to a theory based on representational pluralism (Dove, in press), processing abstract words should require a different strategy than that used to process concrete words. Namely, the latter would be represented in a perceptual format, the first in a propositional format. Given that the task is a linguistic one, processing of abstract words should require less effort than processing of concrete words. The LASS theory (Barsalou et al., 2008) maintains that in abstract concepts language plays a more relevant role with respect to concrete ones and that the process of simulation occurs at a deep level, whereas linguistic processing is more superficial.

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[1] Action thought in a more general way, as to include also cognitive processes, or mental operations.

If this is the case, as our task is a linguistic one, abstract concepts should be processed faster than concrete ones. Thus, we should predict that the pairs abstract-abstract are processed faster than the pairs concrete-concrete.

According to the theory proposed by Borghi and Cimatti (submitted a, submitted b), both concrete and abstract concepts are modal, and both refer to experiences, which do not differ in depth but have the same status. Therefore there should not be a difference between abstract and concrete concepts in processing. However, given that there might be costs passing from one perceptual modality to another, there might be costs in shifting from abstract words to concrete ones. This theory does not specify the direction of these costs, however. As this proposal also stresses the cultural dependency of our words use, we also predict that in the mixed conditions (concrete verb - abstract noun, and vice versa) the response times would be modulated depending on the specific language, as the chosen languages have a different syntactical structure.

7.3 Experimental paradigm

7.3.1 Method

7.3.1.1 Participants

38 students of the University of Hamburg (I group) and 38 students of the University of Bologna (II group) took part in the study. All were native German speakers (I group) and native Italian speakers (II group), right-handed according to the Edinburgh Handedness Questionnaire (Oldfield, 1971), and all had normal or corrected-to-normal vision. They all gave their informed consent to the experimental procedure. Their ages ranged from 18 to 32 years old.

7.3.1.2 Materials

Materials consisted of word pairs (sentences) composed by a transitive verb and a concept noun. We invented 192 sentences (48 quadruples) in German language and 192 sentences in Italian language. Each quadruple was constructed by pairing a concrete verb (e.g. *to grasp*) both with a concrete noun (e.g. *an apple*) and an abstract noun (e.g. *a concept*); and by pairing an abstract verb (e.g. *to think*) both with the same concrete and abstract noun previously used. The majority of these sentences meanings matched in both the languages; few of them slightly differ between the two groups as some pairs (above all the mixed combinations) did not allow for a literal translation.

Thus, we built an experimental paradigm that could allow us to study different kinds of abstract sentences: we contrasted two kinds of Nouns (Concrete *vs.* Abstract) with 2 kind of Verbs (Concrete *vs.* Abstract). We defined Concrete Nouns as nouns referring to graspable objects; Concrete Verbs as verbs referring to hand actions; Abstract Nouns as nouns that do not refer to manipulable objects; Abstract Verbs as verbs that do not refer to motor actions. Therefore the quadruples had to contain every possible combinations for motor/non-motor verbs and for graspable/non-graspable objects: e.g., 1. to grasp/an apple; 2. to think/an apple; 3. to grasp/a concept; 4. to think/a concept. We decided to use sentences with a very simple grammatical structure (a verb plus a noun) as it was not possible to develop full sentences in a similar grammatical structure that fulfilled the criteria of the quadruples.

Due to the different syntax of German and Italian language, the German sentences were composed by a noun followed by a verb; instead the Italian ones were composed by a verb followed by a noun. We chose to compare these two languages as the specific differences in the syntactical structure allowed us to speculate on the different effects caused by a verb preceded by a noun (German sample) versus a noun preceded by a verb (Italian sample).

To select 30 critical quadruples among the 48 ones we asked 20 German students and 20 Italian students to judge how familiar each sentence sounded and how probably would they use each sentence. They had to rate on a continuous scale (Not familiar - Very Familiar; Not probably - Very probably), by making a cross on a line. We selected the quadruples with higher scores for both familiarity and probability of use, and, among these ones, we finally chose those quadruples with lower scores' standard deviations. Thus we obtained 120 verb-noun pairs (balanced for familiarity and probability of use).

In addition to the 30 critical quadruples, 30 filler quadruples were constructed. We used the same criteria adopted for the critical ones, that is we combined concrete verb both with a concrete noun and with an abstract noun; and we combined an abstract verb both with the same concrete noun and abstract noun, leading to sentences which didn't make sense (e.g. "to switch off the shoe"). Each quadruple was presented only once.

7.3.1.3 Procedure

Both German and Italian participants were randomly assigned to one of two groups. Members of both groups were tested individually in a quiet library room. They sat on a comfortable chair in front of a computer screen and were instructed to look at a fixation cross that remained on the screen for 1000 ms. Then a sentence appeared on the screen for 2600 ms. The German sentences were composed by a determinative or not determinative article plus a noun plus a verb, while the Italian ones were composed by a verb plus a determinative or not determinative article plus a noun.

The timer started operating when the sentence appeared on the screen. For each verb-noun pair, participants were instructed to press a key if the combination made sense, and to press another key if the combination did not make sense.

Participants in the first group (both German and Italian) were asked to respond "yes" with their left hand and "no" with their right hand; participants in the other group (both German and Italian) were required to do the opposite. All participants were informed that their response times would be recorded and invited to respond as quickly as possible while still maintaining accuracy. Stimuli were presented in a random order. The 240 experimental trials were preceded by 8 training trials, in order to allow the participants to familiarize with the procedure.

7.4 Results

We considered only the sensible sentences. Participants were accurate in responding as nobody's responses included errors over 10%.

All incorrect responses were eliminated. As the error analysis revealed that there was no speed-for-accuracy trade-off, we focused on the RTs analysis. To screen for outliers, scores 2 standard deviations higher or lower than the mean participant score were removed for each participant. Removed outliers accounted for 2.6% of response trials.

The remaining response times were submitted to a 2 (kind of Noun: Concrete *vs.* Abstract) X 2 (kind of Verb: Concrete *vs.* Abstract) X 2 (Mapping: yes-right / no-left vs. yes-left / no-right) X 2 (Language: German vs. Italian) mixed factor ANOVA, with Mapping and Language as a between participants variables. We conducted the analyses with participants as a random factor.

We did not find a main effect of the kind of Mapping, neither a main effect of the kind of Language.

Crucially we found a significant interaction between the kind of Noun and the kind of Verb: German and Italian participants responded faster to both kinds of congruent pairs, that is to pairs composed by an Abstract Verb plus an Abstract Noun (M = 1172.56) and to pairs composed by a Concrete Verb plus a Concrete Noun (M = 1168.83). Instead they were slower with the mixed pairs, that is with pairs composed by an Abstract Verb plus a Concrete Noun (M = 1211.95) and pairs composed by a Concrete Verb plus an Abstract Noun (M = 1206.81) (F (1, 72) = 48.83, MSe = 2328.79, p < .0001). Interestingly, Abstract Verbs combined with Abstract Nouns did not require a longer time to be processed than Concrete Verbs – Concrete Nouns pairs.

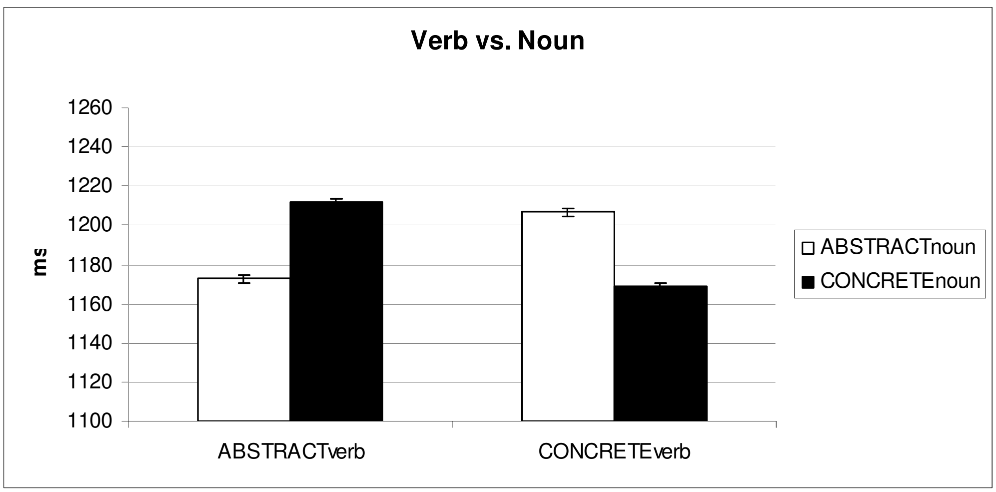

Figure 1. The interaction between the kind of Noun and the kind of Verb. Bars represent standard error.

We found also a significant three ways interaction between the kind of Language, the kind of Noun and the kind of Verb, F (1, 72) = 5.07, MSe = 2328.79, p < .03. Crucially the post-hoc analyses showed that German participants were 13.25 ms faster with Abstract Verb plus Concrete Noun pairs than with Concrete Verb plus Abstract Noun pairs; on the contrary Italian participants were 23.51 ms faster with Concrete verb plus Abstract Noun pairs than with Abstract Verb plus Concrete Noun pairs, also if this difference reached the significance only for the Italian participants, $p < .04$.

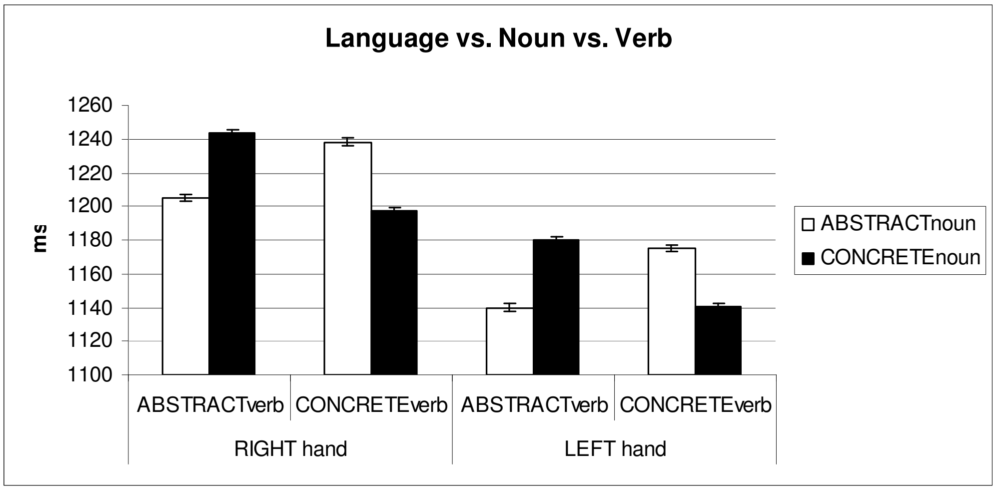

Figure 2. The three ways interaction between the kind of Language, the kind of Noun and the kind of Verb. Bars represent standard error.

As the syntactic construction of German and Italian is different for pairs containing a transitive verb plus an object, German participants firstly saw the noun and then the verb, oppositely of the Italian ones. Results with mixed pairs indicate that when the first word is a "concrete" one, that is when it refers to an *object* on which we could perform an hand action (German pairs), or to an *action* to perform with the hands (Italian pairs), participants are faster than in the case in which the first word refers to a no-manipulable object or to an action that does not involve the hand. This suggests a stronger effect of semantic features compared to the syntactic ones.

Coherently, we also found an interaction between the kind of Language and the kind of Verb, that almost reached significance, F (1, 72) = 3.68, MSe = 3490.70, $p <$ .06. German participants were 8.57 ms faster with pairs containing Abstract Verbs than with pairs containing Concrete Verbs. On the contrary, Italian participants were 17.42 ms slower with pairs containing Abstract Verbs than with the ones containing Concrete Verbs. Integrating these results with the previous ones allows us to speculate that the order of the words in the pairs strongly determines the time necessary to process the sentence, but also that the verb has a stronger effect than the noun.

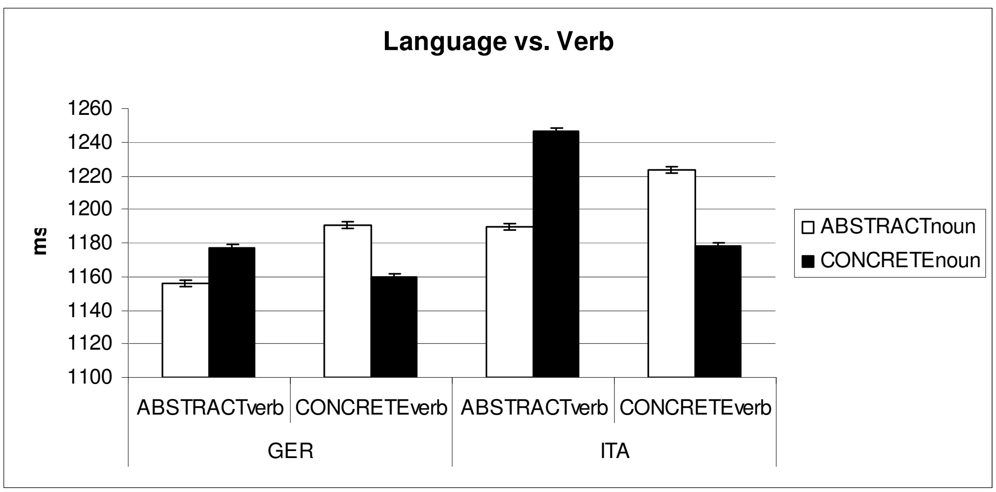

Figure 3. The interaction between the kind of Language and the kind of Verb. Bars represent standard error.

7.5 German and Italian pairs' assessment

To check for our materials, 30 students of the University of Hamburg and 30 students of the University of Bologna were asked to rate on a continuous scale (scores ranging from 0 to 100) the ease or difficulty with which each pair evoked mental images (imageability: Low imagery rate - High Imagery rate); how literally would they take each pair (literality: Literal - No Literal); whether and to what extent each pair elicited movement information (quantity of motion: Not much movement - Much movement). Finally 10 German students and 10 Italian students were also asked to rate at which age they approximately had learned to use each pair (age of acquisition ratings). For each rating, we calculated the scores' averages and the scores' standard deviations for each condition.

7.5.1 Imageability

Both German and Italian participants judged the Concrete Verb – Concrete Noun pairs as the easiest to imagine (Germans: *M* = 69.10; *SD* = 12.76; Italians: *M* = 77.74; *SD* = 8.49), followed by the Abstract Verb – Concrete Noun pairs (Germans: *M* = 52.72; *SD* = 15.80; Italians: *M* = 51.33; *SD* = 18.65), by the Concrete Verb – Abstract Noun pairs (Germans: *M* = 48.53; *SD* = 12.92; Italians: *M* = 46.33; *SD* = 12.36), and finally by Abstract Verb – Abstract Noun pairs (Germans: *M* = 45.56; *SD* = 14.51; Italians: *M* = 44.88; *SD* = 15.23).

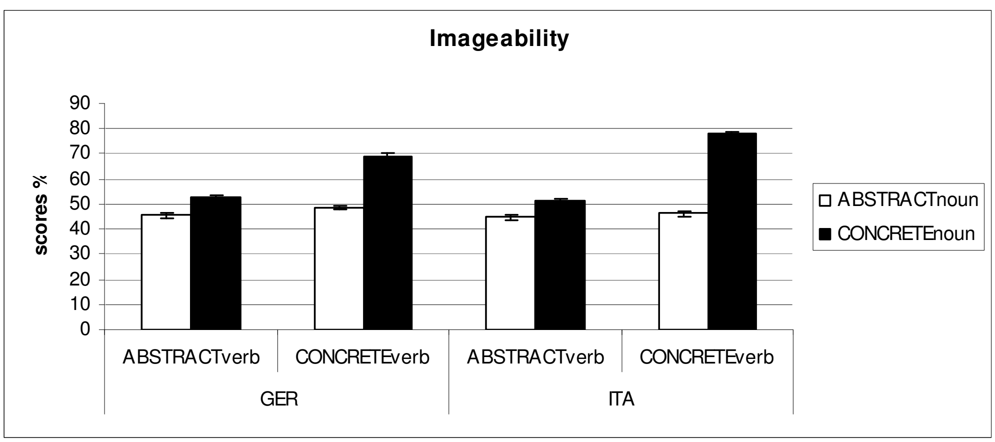

Figure 4. Imagebility ratings, scores' averages. Bars represent standard error.

So for imageability ratings German and Italian participants have the same pattern: the pair containing both words concrete was judged as the easiest to imagine. Moreover the noun is stronger than the verb in determining the imageability of the sentence.

7.5.2 Literality

Concerning literality, we found that German participants rated the Abstract verb – Concrete noun pairs as the ones that they would take most literally (*M* = 18.89; *SD* = 13.72), followed by the Concrete Verb – Concrete Noun pairs (*M* = 20.22; *SD* = 18.12), by the Abstract Verb – Abstract Noun pairs (*M* = 31.23; *SD* = 19.59), and finally by Concrete Verb – Abstract Noun pairs (*M* = 56.95; *SD* = 19.01).

Italian participants rated the Concrete Verb – Concrete Noun pairs as the sentences that they would take most literally (*M* = 11.42; *SD* = 4.57), followed by the Abstract Verb – Concrete Noun pairs (*M* = 31.33; *SD* = 13.11), by the Abstract Verb – Abstract Noun pairs (*M* = 59.42; *SD* = 13.63), and finally by Concrete Verb – Abstract Noun pairs (*M* = 69.50; *SD* = 11.78).

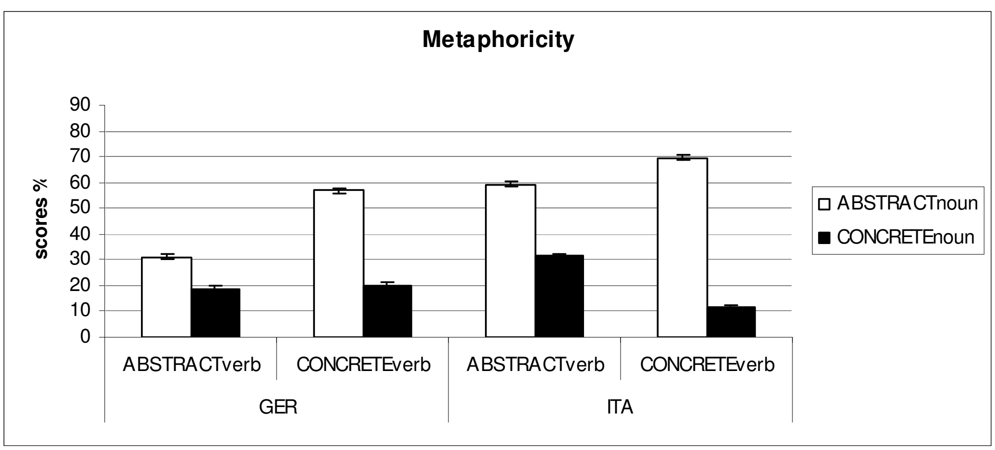

Figure 5. Literality ratings, scores' averages. Bars represent standard error.

The sentences rated as more literal are the ones which contained a Concrete Verb plus a Concrete Noun (Italian participants) and the ones containing an Abstract Verb plus a Concrete Noun (German participants). Moreover both groups judged the combination Concrete Verb – Abstract Noun as the most metaphorical one. It's worth noting that while the concrete noun meaning remains the same through the quadruples, the concrete verb meaning, as well as its concreteness/abstractness, changes through the quadruples, depending on the context. Just to give an example, the meaning of the verb "to grasp" is not the same in "grasping an apple" and in "grasping a concept (Parisi, *personal communication*).

7.5.3 Quantity of Motion

German participants rated the Concrete Verb – Concrete Noun pairs as the ones that mainly elicited movement information (M = 34.29; SD = 13.95), followed by the Concrete Verb – Abstract Noun pairs (M = 27.22; SD = 12.82), by the Abstract Verb – Abstract Noun pairs (M = 17.98; SD = 13.87) and finally by Abstract Verb – Concrete Noun pairs (M = 13.99; *standard deviation* = 7.39).

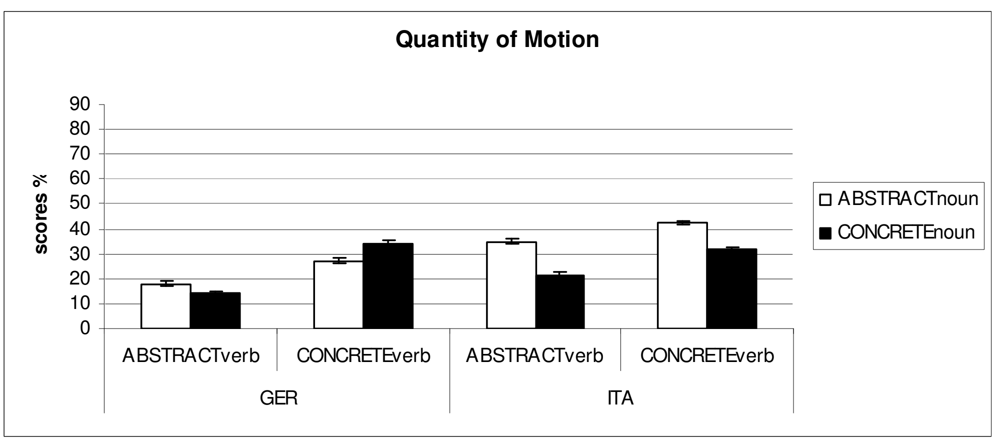

Figure 6. Motion ratings, scores' averages. Bars represent standard error.

Interestingly, Italian participants' pattern was different, as they rated the Concrete Verb – Abstract Noun pairs as the ones that mainly elicited movement information (*M* = 42.56; *SD* = 13.28), followed by the Abstract Verb – Abstract Noun pairs (*M* = 35.05; *SD* = 12.24), by the Concrete Verb – Concrete Noun pairs (*M* = 31.93; *SD* = 10.58) and finally by the Abstract Verb – Concrete Noun pairs (*M* = 21.56; *SD* = 11.25).

So both the groups judged the Abstract Verb – Concrete Noun combination as the one that elicits less movement. The main difference concerns the combinations Abstract Verb – Abstract Noun vs. Concrete Verb – Concrete Noun combination, as while the former suggested the biggest amount of movement for Italian participants, the latter evoked the huger quantity of motion in German participants.

7.5.4 Age of acquisition

A number of studies (Gilhooly & Gilhooly, 1980; Zevin & Seidenberg, 2002) have demonstrated the validity of age of acquisition ratings, by showing that age rated by adults is the major independent predictor of the objective age-of-acquisition indices.

In our study German participants rated the Concrete Verb – Concrete Noun pairs as the firstly learnt ones (*M* = 7.82 years old; *SD* = 2.21), followed by the Abstract Verb – Concrete Noun pairs (*M* = 8.64 years old; *SD* = 2.55), and finally by both Abstract Verb – Abstract Noun pairs and Concrete Verb – Abstract Noun pairs (*M* = 10.24 years old; *SD* = 2.35; *M* = 10.74 years old; *SD* = 1.95).

In the same way, Italian participants rated the Concrete Verb – Concrete Noun pairs as the earliest learnt ones (*M* = 6.63 years old; *SD* = 1.97), followed by the Abstract Verb – Concrete Noun pairs (*M* = 8.33 years old; *SD* = 2.34), and finally by both Abstract Verb – Abstract Noun pairs and Concrete Verb – Abstract Noun pairs (*M* = 10.45 years old; *SD* = 2.09; *M* = 10.74 years old; *SD* = 2.25).

It seems that the different age of acquisition is explained by the noun: as shown in the literature on single word age of acquisition, the concrete noun is learned before than the abstract one. Consistently, we found that also sentences containing a concrete noun, even if in combination with an abstract verb, are acquired earlier than sentences containing an abstract noun.

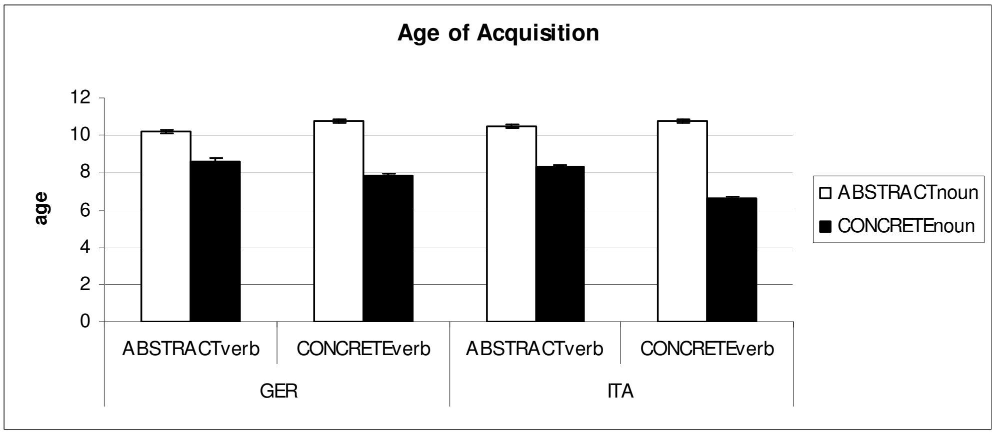

Figure 7. Age of Acquisition ratings, scores' averages. Bars represent standard error.

7.5.5 Integrating behavioral results with pairs' assessment

Integrating the results on response times with the ones on ratings, it seems that the advantage for the Concrete Verb – Concrete Noun combination can be mainly explained resting on its high imageability, low metaphoricity rate and precocious age of acquisition. But the same evaluations cannot account for the advantage of Abstract Verb – Abstract Noun combination.

Going back to the predictions, according to a strictly modal theory results on response times should be explained by imageability rating. An approach more based on metaphors (Lakoff, 1987) should account for the behavioral results resting on literality ratings. Both the hypotheses are not verified by our results on Abstract Verb – Abstract Noun condition. Finally, an approach proposing that concepts are generally couched in perceptual as well as in motor representations (Glenberg, 1997) would predict a relation between the behavioral data and the quantity of motion scores. This is not the case, as the results of the two groups are pretty different, and the faster/smaller amount of movement suggested by the sentence does not modulate the time to execute the semantic-motor task.

An amodal theory would account for response times resting on age acquisition ratings but above all on association rate between verbs and nouns combinations. Therefore, the amodal hypothesis would account the advantage of both Concrete Verb plus Concrete Noun and Abstract Verb plus Abstract Noun on the basis of the higher association rate of these pairs compared to the one of the mixed combinations. To check for this possibility, we calculated the familiarity scores averages for each conditions, for the 120 pairs selected for the behavioral experiment. German participants rated the Concrete Verb – Concrete Noun pairs as the most familiar (M = 75.58; SD = 21.42), followed by the Concrete Verb – Abstract Noun pairs (M = 73.50; SD = 20.64), by the Abstract Verb – Abstract Noun pairs (M = 69.06; SD = 20.17) and by the Abstract Verb – Concrete Noun pairs (M = 66.24; SD = 17.24).

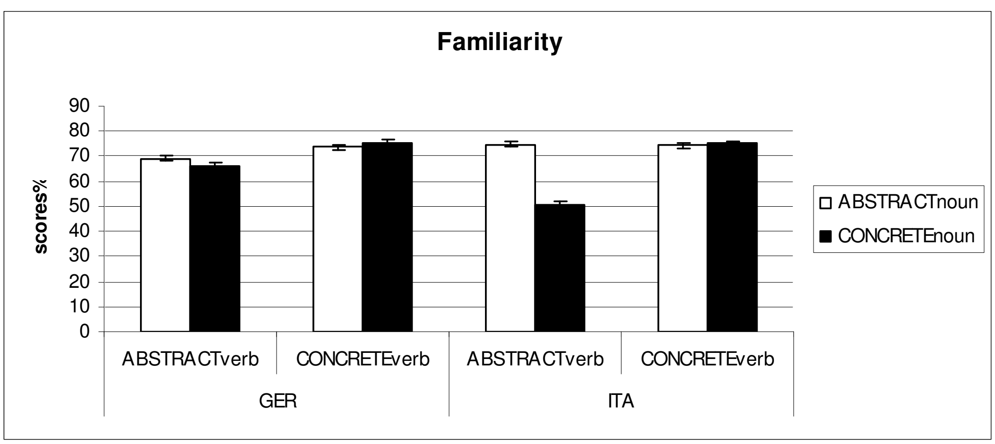

Figure 8. Familiarity ratings, scores' averages. Bars represent standard error.

As clearly shown by the data, the advantage of both Concrete Verb plus Concrete Noun and Abstract Verb plus Abstract Noun pairs is not explained by familiarity. Besides, the low familiarity of Abstract Verb – Concrete Noun combination cannot account for its advantage on Concrete Verb – Abstract Noun condition. Focusing on Italian participants, they judged the Concrete Verb – Concrete Noun pairs as the most familiar (M = 75.02; SD = 16.51), followed by the Abstract Verb – Abstract Noun pairs (M = 74.77; SD = 14.99), by Concrete Verb – Abstract Noun (M = 74.43; SD = 15.07), and by Abstract Verb – Concrete Noun pairs (M = 50.73; SD = 19.70). Again, the advantage of both the Concrete Verb – Concrete Noun and the Abstract Verb –Abstract Noun combinations on the mixed pairs is not explained by a supposed higher familiarity.

The representational pluralism theory as well as the LASS theory would rest on imageability ratings to explain a generically faster processing of pairs containing both noun and verb as concrete (even if the same account doesn't work for the abstract verb – abstract noun combination). However, since the task used in the present study is a linguistic one, they would predict fastest processing for the trials containing two abstract terms, because the Abstract Verb plus Abstract Noun condition shares the same format with the task. The LASS would predict the same result because abstract sentence and the task are founded on the same coding, that is a linguistic one.

Finally a theory based on an individual plus a social source for word meanings (Borghi & Cimatti, submitted a, submitted b) would account for response times results chiefly resting on age of acquisition ratings, as well as on the use of "social words". Learning of both the concrete and abstract words is based on the same experiential modality, that is the systematic association with something else (Parisi, *submitted*). In the first case the earliest association experienced is that one with the referents of the word; in the case of abstract words, we firstly make experience of the association between the word and particular social-linguistic situations, that finally we'll be able to tag with the word. Importantly these two learning mechanisms do not have a different status, and both are active over the time. Even if both kinds of words are experienced-used in association with both sensori-motor and linguistic experiences (contexts, circumstances), the very first learning, and "the most powerful" use, of concrete nouns-verbs and abstract nouns-verbs occur in associations with different contexts. This implies a sort of "experiential switch" occurring in the mixed conditions, that does not occur in the congruent ones. The cost of this "experiential switch" is mirrored by the data.

7.6 Discussion

As outlined in the introduction, different studies in the framework of embodied cognition tried to investigate abstractness, but they often focus on very specific cases: metaphorical-idiomatic sentences (Aziz-Zadeh et al., 2006), whose grammatical structure cannot be strong controlled in an experimental paradigm; sentences that can be mapped in a specific action schema, as abstract transfer sentences (Glenberg & Kaschak, 2002; Glenberg et al., 2008); sentences referring to very specific categories, such as time (Boroditsky & Ramscar, 2002); sentences whose meaning can be directly mapped on concrete objects (Lakoff, 1987). This heterogeneity makes it very tricky to compare and integrate the results of these study, as well as to generalize the findings to all abstract words.

Compared to other studies, our study has the advantage of comparing not only abstract and concrete sentences, but also sentences which result from a mixture of abstract and concrete nouns and verbs. We believe this can represent an important step for a systematic investigation of abstraction. We used the quadruples as we intended to reason on different levels of abstractness: in our experimental design, in fact, we have every possible combination for motor verbs/non-motor verbs and graspable/non-graspable objects. Finally, we used simple "transitive verb plus noun" pairs as firstly it was not possible to develop full sentences in a similar grammatical structure that fulfilled the criteria of the quadruples, and secondly since it allowed us to maintain a fixed and mirrored structure for German and Italian pairs.

1. Our study basically showed three main new results. Firstly we found an interaction between the kind of verb and the kind of noun. Both the abstract verb - abstract noun combinations and the concrete verb - concrete noun combinations were processed faster than the mixed combinations. This effect does not allow to favour a modal rather than an amodal symbols theory. Nevertheless, as shown in the previous paragraph, results on imageability ratings do not support a strictly modal theory, and familiarity scores analyses do not match the predictions made by an amodal theory. The verb-noun interaction (essentially the similar timing between the two congruent conditions) goes against the predictions of a representational pluralism theory (Dove, in press): given that the task is a linguistic ones, processing of abstract words should require less effort than processing of concrete words, as the latter are represented with a perceptual rather than with a propositional format. Similarly to the multiple semantic code approach, the LASS theory would predict that abstract words coding should be linguistic, and would not require a deep simulation. As the task is a linguistic one, the processing of abstract verb – abstract noun combination should be faster that the processing of concrete verb – concrete noun combination, contrarily to what we found. Finally Borghi and Cimatti (submitted a, submitted b), resting on the two different acquisition mechanisms, would predict an "experiential switch" in the mixed but not in the congruent conditions. As drawn in the previous paragraph, the very first learning and the strongest use of concrete nouns and concrete verbs take place in associations with the same experiences (that are different from the ones more powerfully associated with abstract nouns and abstract verbs), so when they occur together there is a facilitation on sentence processing.

2. The second major results we found is the three ways interaction among the kind of language, the kind of verb and the kind of noun. Italian participants were generally slower than German ones, due to the specific inter-linguistic differences, but in neither of the two groups there was any significant difference between the no-mixed conditions. Consistently with our predictions of a cultural dependency of words use (achievable to test due to the different languages grammatical structure), the post-hoc analyses showed that the interaction was mainly due to the modulation of German and

Italian languages on mixed combinations. Curiously German and Italian students' results on mixed combinations seem to be opposite: with abstract verbs and concrete nouns combinations German participants were faster than with the concrete verbs and abstract nouns combinations. Italian participants showed a mirror pattern.

All the above mentioned theories would expect a slower processing for the mixed conditions rather than for the congruent ones, even if due to different reasons: to different associative rates between the linguistic symbols combined in a pair (amodal theory), or to different ease to simulate the word referent (modal theory), or to different kinds of formats (Dove, in press), or to a linguistic versus a deeper coding (LASS). They would also predict a similar time of processing for both the abstract verb-concrete noun and for the concrete verb- abstract noun pairs. On the contrary, we found different timings for the mixed combinations, depending on the first world appearing in the sentence.

It's difficult to account for this result if we do not consider that German participants firstly saw the noun and then the verb, while Italian ones saw the same combination in a reverse order. Thus, participants were faster when the *first word* shown in the sentence was a concrete one, regardless of its grammatical class (verb *vs.* noun) and of the spoken language (German vs. Italian). We think this is the most plausible explanation as the abstractness *vs.* concreteness of the first word is the only variable that changed between the two mixed samples. In fact, even if we did not use literal translations across languages, the pairs were balanced for familiarity and probability of use. Of course, we are not arguing that the processing of the words on a sentence is "only" serial, but that the specific task (that is, judging the sensibility of the sentence as soon as possible) in a certain sense obliged participants to a sequential processing of the words in the sentence. Response times were shorter both when a concrete noun (referring to a manipulable object) preceded an abstract verb, as when a concrete verb (referring to an action performed by the hand) preceded an abstract noun.

We think that there are two possible explanations of this advantage. The first relies on language acquisition data: the effect could depend on the fact that concrete words are learnt earlier than the abstract ones, thus they result more familiar than abstract ones. The other possible explanation rests on the idea that two different acquisition mechanisms underlie concrete and abstract words (Borghi & Cimatti, submitted a): as drawn above, with concrete words firstly we experience the concrete entities and then we tag their referents using linguist labels. In the case of abstract words, instead, we initially learn the labels, afterward we "tag" them with our sensori-motor experience, assembling a set of experiences. Moreover, there are more or less complicated and socially constructed ways of using the words: learning to use a word such as "lipstick" is simpler then learning to use a word as "justice". The difference between "lipstick" and "justice" could be paraphrased as less or more difficult to learn. So it's more difficult to process a sentence where abstract words are mixed together with concrete ones (as shown by the first result we found), and *even more* difficult to process the same mixed combination if *a)* the first word to process was difficult to learn and *b)* it's *now* part of a complex net of situations, objects, human activities and so on: this is the case of the abstract word.

3. The third crucial result is the interaction we found between the kind of language and the kind of verb. German participants were faster with abstract verbs while Italian ones were slower with the same kind of verbs, regardless of the kind of noun that preceded or followed the verb. Integrating the two last findings, it seems that the structure of the sentence modulates its processing more strongly than the linguistic category (noun vs. verb). Nevertheless there is also an effect of the linguistic category (verb *vs.* noun), as verbs are more powerful than nouns in influencing subjects responses. Fascinatingly this result could be in keeping with the idea that the grammatical structure of a language shapes to some extent its speakers' perception of the world (Boroditsky, 2003; Gentner, 2003, Mirolli & Parisi, in press).

7.7 Future Work

The general aim of the project is to assess whether processing abstract words modulates the activity of the motor system as processing concrete words does. To investigate further this issue we are planning to use also fMRI technique. We'll use the selected quadruples. We expect to find a large activation in motor and premotor areas for motor acts containing graspable objects, but also some lighter effects in the mixed conditions. For fMRI analyses we'll use the non-motor (verbs)/non-graspable (objects) combinations as a baseline condition for the estimation of contrasts. We are going to specifically investigate the change of signal in the individual motor areas (as opposed to a whole brain analysis). This will be facilitated by a preceding localizer task, that can be used to identify the individual site of the motor areas (primary motor area, M1; ventral premotor cortex, vPMC; dorsal premotor cortex, dPMC; supplementary motor area, SMA).

Besides we predict that, given that abstract words acquisition occurs with the mediation of other words, abstract words activate more than concrete ones linguistic areas, as they should evoke more phonoarticulatory movements. As far as meaning is concerned, we hypothesize that abstract words meanings would activate more areas in a diffuse and multimodal way (Rüschemeyer, Brass & Friederici, 2007). Thus far, the predictions of the LASS theory (Barsalou et al., 2008), of the theory that words are tools (Borghi & Cimatti, submitted b) and of the representational pluralism theory (Dove, in press) are similar. However, the latter would assume a differential activation of the frontal areas, given that in order to use propositional symbols inferencing and reasoning are implied.

We believe the brain imaging study, together with the behavioral study we have conducted, will contribute to shed a new light on the fascinating issue of the relationship between concrete and abstract words.

8 General discussion

The results found in the first two studies are in line with the predictions of the embodied theory. Namely, they suggest that the comprehension of the meaning of verb-noun pairs implies a mental simulation. This simulation is quite detailed, as it is modulated by the kind of effector the sentence refers to (hand, foot, mouth), by the specific hand (dominant, non-dominant) the action expressed by the sentence typically involves, and by the kind of effector used for responding.

In the first study we found that "mouth sentences" were processed faster than "hand sentences" when participants were responding with the microphone rather than with the pedal. The same facilitation effect was obtained with "foot sentences" compared to "hand sentences" when participants were responding with the pedal rather than with the microphone. Importantly, this modulation occurred even with a task in which the information related to the involved effector was really irrelevant, such as the evaluation of the sensibility of sentences.

In the second study we found an advantage of the dominant hand restricted to sensible sentences related both to hand and to mouth. Significantly, the facilitation of the dominant hand with "hand" and with "mouth sentences" was present only with sensible sentences, thus confirming the hypothesis that it was due to a simulation process, and not to a general advantage of the right over the left hand. Finally, in the first experiment of the second study, in which sensible sentences referred to actions involving both hand and foot, we found slower response times with the right than with the left hand.

Thus these studies show that during sentence comprehension we are sensitive not just to the effector involved, but also to the goal expressed by the sentence, consistently with the idea of motor resonance and with ideomotor theories (e.g., Prinz, 1997). As a matter of fact, in both the studies we found a wider difference between hand related sentences and foot related sentences than between hand related sentences and mouth related sentences. Evidence indicating that foot-verbs have wider cortical distributions compared to mouth- and hand-verbs also accounts for these results (Pulvermüller et al., 2001). These findings confirm that we simulate the action not only at a proximal level, i.e. at the level of effector, but also at a distal level; that is, that we are sensitive both to the effector referred to by the sentence and to the goal the sentence expresses. To clarify: a mouth-action, such as "licking an ice cream", typically implies / follows a manual action such as, for example, "grasping the ice cream". Moreover, these studies support the hypothesis of the existence of a strict interrelationship between hand and mouth actions and it is in keeping with recent studies showing that language evolves from gestures and manual actions (e.g., Corballis, 2002).

The results found across the third and the forth studies demonstrate a reciprocal effect of comprehension on the use of the motor system both in action understanding and action production (*see* MOSAIC model, Hamilton et al., 2004). They reveal that the simulation activated by language is sensitive to different objects' weight; they show as well that language comprehension requires a simulation process that taps perception and action systems.

These two studies were explicitly designed to produce a contrast effect between the modules used during the ancillary task, the language processing task, and the modules used during the tasks directly involving the motor system, that is the weight judgment task and the lifting task. That is, detecting the effect requires that the ancillary task uses a MOSAIC module (that is likely to be needed during the weight judgment as well the motor task), and that this ancillary task be compared to one that does not use that MOSAIC module.

In the first study we specifically investigated if the mere act of comprehending language could affect perception in a weight judgment task. We found that when observers were required to practice lifting large and small boxes before the reading and judgment task, there was a dramatic increase in the correlation between judged and observed weight. Crucially, for the “light videos” (depicting lifts of light objects), the “light sentences” (describing the lifting of light objects) produced the lowest correlations, whereas for the “heavy videos”, “heavy sentences” produced the lowest correlations. This interference effect suggests that language comprehension calls upon and thereby affects perception system.

In the second study we asked if the mere act of comprehending language affects also the production of action. If language comprehension affects the motor system, then the comprehension task should affect kinematics parameters in bimanual boxes lifting. Participants listened to sentences describing the lifting of a “heavy” or “light weight”. Then they were required to lift and place different weighted boxes. We analyzed kinematics parameters detected immediately after having grasped the box. The interaction found on times analyses demonstrates an interference effect between the kind of sentence and the kind of box to be lifted. This effect is analogous to the one obtained in the previous study and corroborates the hypothesis that language can activate a simulation which is sensitive to intrinsic object properties such as weight.

Moreover, both the results can be accommodated by the MOSAIC model. Concerning the study on effects of language in weight perception, we found that comprehending the sentence describing a lift requires a simulation using the motor system. This simulation temporarily occupies a particular module (e.g., the module for lifting a 250 g weight) rendering it unavailable for use in the judging the weight of the box observed in the video. Variability of the simulated weights (and consequently, variability in the modules used in the judgment task) reduces the correlation between judged weight and observed weight. Because the modules used in simulating the light sentences are unlikely to be used in judging the heavy weights (and vice versa), the correlation is most reduced when the sentence is about lifting objects similar to those observed. Analogously, as to the study on the effects of language in lifting movement, our results are consistent with the operation of the MOSAIC model since we found that participants’ time delay was larger when the weight implied by the sentence and the weight of the box they lifted were similar compared to when they were dissimilar. Namely, when a MOSAIC module is occupied by an ancillary task (in this case, simulation in the service of language comprehension), integration of force across the remaining relevant modules will be biased.

All these findings favour a fully embodied theory of cognition and language. The basic tenet of this theory is that all forms of cognition are grounded in our sensorimotor system and are constrained by the kind of body we have and by its relationship with the particular environment in which our species has evolved and in which we currently inhabit. But, what about words that do not correspond to any things in the material world? The well known problem of the meanings of abstract words is one of the main challenges of embodied theories (Mahon & Caramazza, 2008). So far, evidence has shown that abstract words refer metaphorically to concrete referents (Lakoff & Johnson, 1999; Casasanto & Boroditsky, 2008), that abstract sentences recruit the motor system (Glenberg et al., 2008), that abstract concepts elicit situations and simulations of internal states (Barsalou & Wiemer-Hastings, 2005). This evidence, though compelling, refers only to a subset of phenomena, so its findings are hardly generalizable.

The aim of the fifth study was to use a paradigm suitable to reason on different levels of abstractness. We examined combinations of transitive verbs (abstract, concrete) and nouns (abstract, concrete), focusing on two syntactically different languages (German, Italian). We found that compatible combinations were processed similarly and faster than mixed combinations. Instead, processing of mixed pairs was modulated by the specific language: when concrete words preceded abstract ones responses were faster, regardless of grammatical class. Finally, materials were rated on familiarity, imageability, literality, age of acquisition. A strictly modal theory doesn't explain the data, as imageability did not correlate with response times. An amodal theory was also disconfirmed since familiarity did not explain the results. Two further recent proposals, representational pluralism (Dove, in press) and LASS theory (Barsalou et al., 2008), don't account for the data, as for a linguistic task they would predict faster processing for abstract compatible pairs than for concrete compatible pairs. An alternative explanation is that linguistic modal experience plays a more relevant role for abstract than for concrete words (Borghi & Cimatti, submitted a). Therefore the higher difficulty of abstract *first* words reflects the way they are acquired: differently from concrete words, with abstract ones we first learn linguistic labels, then we "tag" them with sparse sensorimotor experiences.

Summing up, the results found across the five studies suggest that in order to explain words comprehension it's necessary to consider language grounding in the sensorimotor system, but also the role played by the linguistic experience. As proposed by Borghi and Cimatti (submitted a), to account also for the comprehension of abstract words its is necessary an extension of classical embodied theory. Such an extension could take place without assuming neither a non embodied source of cognition nor the existence of amodal mental entities.

In order to solve problem of so called abstract concepts the authors suggest that we basically need three notions: concept, word/tool and meaning. A *concept* is an entity (the re-enhancement of the neural pattern activated when we perceive or interact with objects and entities) which is formed through individual bodily and modal experience. A *word/tool* is a thing that one can use to do something in the world according to a social rule. The *meaning* of a word/tool is the set of rules that regulates its use in the language.

Accordingly, Borghi and Cimatti (submitted a) highlight that words are not "simple signals for expressing internal and private concepts; words are the unique and external things that allow us to entertain apparently amodal forms of cognition. […] the uneasiness that any embodied theory of cognition feels when explaining abstract words can be mitigated (and perhaps solved) by stressing the social nature of language and its impact on cognitive activity" (p. 28). Thus this proposal "is still an embodied theory of cognition, that is, a theory of human cognitive activity based on body experience" but with also a particular attention to "social experience […] as a typical human embodied experience. Embodied experience is not closed inside the boundaries of our body. The social linguistic experience is an embodied experience too" (Borghi & Cimatti, submitted a, p. 28).

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Appendix - materials

3 The specificity of the simulation with respect to the body. Different effectors: the hand, the mouth and the foot.

HAND PAIRS		**MOUTH PAIRS**	
cogliere	l'albicocca	mordicchiare	l'albicocca
spremere	l'arancia	divorare	l'arancia
accarezzare	il bambino	baciare	il bambino
versare	bevanda	sorseggiare	la bevanda
tagliare	la bistecca	masticare	la bistecca
scartare	la caramella	succhiare	la caramella
porgere	il gelato	leccare	il gelato
spezzare	il grissino	mangiucchiare	il grissino
pelare	la mela	mordere	la mela
schiacciare	la nocciola	sgranocchiare	la nocciola
mescolare	la pasta	assaggiare	la pasta
afferrare	la pillola	inghiottire	la pillola

HAND PAIRS		**FOOT PAIRS**	
potare	l'aiuola	calpestare	l'aiuola
ricucire	la ciabatta	calzare	la ciabatta
annodare	la corda	saltare	la corda
tirare	il freno	premere	il freno
sfogliare	la margherita	pestare	la margherita
lanciare	la palla	calciare	la palla
avvitare	il pedale	schiacciare	il pedale
accendere	la sigaretta	pestare	la sigaretta
aggiustare	il tacco	battere	il tacco
afferrare	la trave	saltare	la trave
raccogliere	l'uva	pigiare	l'uva
tirare	lo zoccolo	calzare	lo zoccolo

Linguistic materials 1. Block Hand – Mouth and block Hand – Foot.

4 The specificity of the simulation with respect to the body and to the goal. The hand: dominant vs. non-dominant hand

ITA			ENG		
tipo di verbo	**verbi**	**nomi**	***kind of verb***	**verbs**	**nouns**
mano dominante	brandire	accetta	dominant hand	to brandish	hatchet
entrame le mani	deporre	accetta	both hands	to depose	hatchet
mano dominante	tendere	arco	dominant hand	to stretch	arc
entrame le mani	appendere	arco	both hands	to hang	arc
mano dominante	suonare	arpa	dominant hand	to play	harp
entrame le mani	sfiorare	arpa	both hands	to touch	harp
mano dominante	stringere	cacciavite	dominant hand	to hold	screwdriver
entrame le mani	riporre	cacciavite	both hands	to put back	screwdriver
mano dominante	infilarsi	calzino	dominant hand	to put	sock
entrame le mani	piegare	calzino	both hands	to fold	sock
mano dominante	aprire	chiave	dominant hand	to open	key
entrame le mani	posare	chiave	both hands	to lay	key
mano dominante	tagliare	coltello	dominant hand	to cut	knife
entrame le mani	lavare	coltello	both hands	to wash	knife
mano dominante	girare	corda	dominant hand	to turn	rope
entrame le mani	annodare	corda	both hands	to knot	rope
mano dominante	mangiare	cucchiaio	dominant hand	to eat	spoon
entrame le mani	asciugare	cucchiaio	both hands	to dry	spoon
mano dominante	tirare	fionda	dominant hand	to throw	slingshot
entrame le mani	porgere	fionda	both hands	to hand	slingshot
mano dominante	strappare	foglio	dominant hand	to ripe	sheet
entrame le mani	accartocciare	foglio	both hands	to curl up	sheet
mano dominante	sparare	fucile	dominant hand	to shoot	gun
entrame le mani	spolverare	fucile	both hands	to dust	gun

ITA			ENG		
tipo di verbo	**verbi**	**nomi**	***kind of verb***	**verbs**	**nouns**
mano dominante	battere	martello	dominant hand	to hammer	hammer
entrame le mani	posare	martello	both hands	to place/lie	hammer
mano dominante	sollevare	martello	dominant hand	to lift	hammer
entrame le mani	disegnare	matita	both hands	to draw	pencil
mano dominante	giocherellare	matita	dominant hand	to play with	pencil
entrame le mani	impugnare	mazza baseball	both hands	to hold	baseball bat
mano dominante	lasciare	mazza baseball	dominant hand	to release	baseball bat
entrame le mani	muovere	mouse	both hands	to move	mouse
mano dominante	pulire	mouse	dominant hand	to clean	mouse
entrame le mani	pulire	mouse	both hands	to clean	mouse
mano dominante	scrivere	penna	dominant hand	to write	pen
entrame le mani	spostare	penna	both hands	to move	pen
mano dominante	dipingere	quadro	dominant hand	to paint	picture
entrame le mani	staccare	quadro	both hands	to take off	picture
mano dominante	pulire	rastrello	dominant hand	to clean	rake
entrame le mani	trascinare	rastrello	both hands	to drag	rake
mano dominante	allacciarsi	scarpa	dominant hand	to tie	shoe
entrame le mani	lustrare	scarpa	both hands	to shine	shoe
mano dominante	pettinarsi	spazzola	dominant hand	to brush	brush
entrame le mani	afferrare	spazzola	both hands	to grasp	brush
mano dominante	lavarsi	spazzolino	dominant hand	to wash	toothbrush
entrame le mani	bagnare	spazzolino	both hands	to wet	toothbrush
mano dominante	spalare	vanga	dominant hand	to shovel	spade
entrame le mani	appoggiare	vanga	both hands	to place	spade
mano dominante	scavare	zappa	dominant hand	to dig	hoe
entrame le mani	conficcare	zappa	both hands	to hoe	hoe

Linguistic materials 1. Experiment 1.a.

ITA		ENG	
verbi	**nomi**	**verbs**	**nouns**
pensare	soluzione	to think	solution
spiegare	inchiesta	to explain	enquiry
riflettere	mercato	to reflect	market
considerare	possibilità	to consider	possibility
meditare	decisione	to meditate	decision
vincere	mandato	to win	mandate
giudicare	operato	to judge	work
concentrare	potere	to concentrate	power
ponderare	voto	to think over	vote
credere	divinità	to believe	divinity
decidere	luogo	to decide	location
deliberare	spesa	to deliberate	expense
inventare	futuro	to invent	future
progettare	casa	to plan	house
opinare	operato	doubt on	work
giustificare	violenza	to justify	violence
stimare	probabilità	to estimate	probability
addurre	scusa	furnish	excuse
apprendere	nozione	to learn	notion
ammettere	colpa	to admit	guilt
acquisire	concetto	to acquire	concept
analizzare	dati	to analyse	data
misurare	tempo	to measure	time
scovare	evasori	to discover	evaders
affrontare	problema	to face	problem
valutare	colore	to evaluate	color
commentare	articolo	to comment	article
scoprire	causa	to discover	cause
criticare	progetto	to critique	project
discutere	programma	to discuss	program
notare	errore	to notice	error
prevedere	pioggia	to forecast	rain

ITA		ENG	
verbi	**nomi**	**verbs**	**nouns**
assumere	incarico	to accept	assignment
rispettare	regola	to respect	rule
suggerire	argomento	to suggest	topic
organizzare	conoscenza	to organize	knowledge
ipotizzare	intervento	to hypothesize	event
ripensare	accaduto	to rethink	incident
sviluppare	applicazione	to develop	application
interpretare	analisi	to interpret	analysis
memorizzare	evento	to memorize	event
ricordare	password	to remember	password
suggerire	titolo	to suggest	title
ripensare	impresa	to rethink	enterprise
calcolare	integrale	to compute	integral number
controllare	meccanismo	to control	mechanism
sospettare	influenza	to suspect	flu
capire	procedura	to understand	procedure

Linguistic materials 2. Experiment 1.b.

ITA		ENG	
verbi	**nomi**	**verbs**	**nouns**
calpestare	aiuola	to keep off	flower-bed
potare	aiuola	to prune	flower-bed
annodare	corda	to knot	rope
saltare	corda	to jump	rope
calpestare	erba	to keep off	grass
strappare	erba	to rip	grass
cogliere	fiore	to pick	flower
pestare	fiore	to crush	flower
scavare	fosso	to dig	ditch
saltare	fosso	to jump	ditch
tirare	freno	to pull	brake
premere	freno	to press	brake
pestare	margherita	to stomp	daisy
piantare	margherita	to plant	daisy
calciare	palla	to kick	ball
lanciare	palla	to throw	ball
calzare	scarpa	to put on	shoe
allacciare	scarpa	to tie	shoe
pestare	sigaretta	to crush	sigarette
accendere	sigaretta	to light	sigarette
pigiare	uva	to press	grapes
raccogliere	uva	to pick	grapes
tirare	zoccolo	to throw	socket
calzare	zoccolo	to wear	socket

Linguistic materials 3. Experiment 2.

ITA		ENG	
verbi	**nomi**	**verbs**	**nouns**
cogliere	albicocca	to pick	apricot
mordicchiare	albicocca	to bite	apricot
assaporare	bevanda	to taste	drink
versare	bevanda	to pour	drink
masticare	bistecca	to chew	steak
tagliare	bistecca	to cut	steak
succhiare	caramella	to suck	sweet
scartare	caramella	to unwrap	sweet
rompere	cioccolata	to break	chocolate
gustare	cioccolata	to taste	chocolate
porgere	gelato	to hand	ice-cream
leccare	gelato	to lick	ice-cream
spezzare	grissino	to break	breadstick
mangiucchiare	grissino	to nibble	breadstick
mordere	mela	to bite	apple
pelare	mela	to peal	apple
sgranocchiare	nocciola	to munch	hazelnut
cogliere	nocciola	to pick	hazelnut
affettare	pane	to slice	bread
sbocconcellare	pane	to nibble	bread
mescolare	pasta	to mix	pasta
assaggiare	pasta	to taste	pasta
inghiottire	pillola	to swallow	pill
afferrare	pillola	to grasp	pill
preparare	spremuta	to prepare	juice
sorseggiare	spremuta	to sip	juice
divorare	torta	to devour	cake
dividere	torta	to divide	cake

Linguistic materials 4. Experiment 3.

5 The specificity of the simulation with respect to the external world. An intrinsic object property - weight - and the perception of action

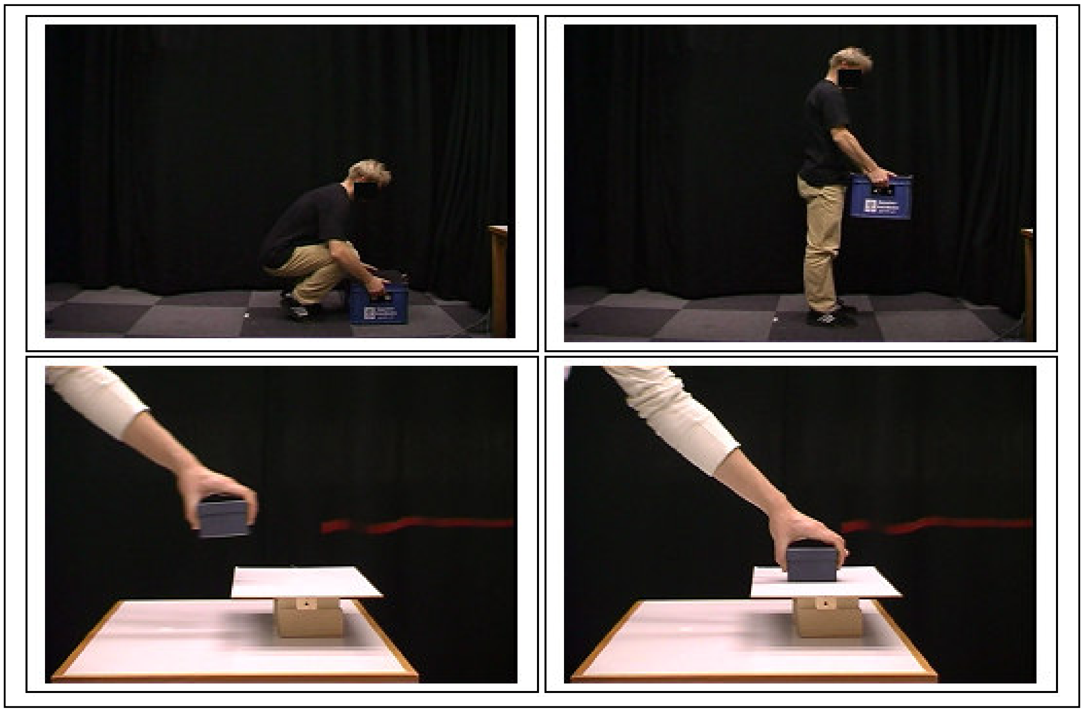
Kind of Sentence	Sentence
Heavy	Solleva il baule di biancheria dal carrello e mettilo sul camion
Heavy	Solleva il bidone dell'olio dalla cantina e mettilo nell'appartamento
Heavy	Solleva il bilanciere da palestra dalla panca e mettilo sul piedistallo
Heavy	Solleva il comodino dalla pedana e mettilo sul soppalco
Heavy	Solleva il computer dall'imballaggio e mettilo sul tavolo
Heavy	Solleva il materasso dal parquet e mettilo sulla rete
Heavy	Solleva il motore della barca dalla spiaggia e mettilo in garage
Heavy	Solleva il passeggino dall'ingresso e mettilo in aula
Heavy	Solleva il pentolone del brodo da terra e mettilo nella scansia
Heavy	Solleva il sacco di patate dalla cantina e mettilo in soffitta
Heavy	Solleva il secchio di mattoni dal prato e mettilo sul ponteggio
Heavy	Solleva il televisore dalla scatola e mettilo in bancone
Heavy	Solleva la cassapanca dalla cantina e mettila sulla soffitta
Heavy	Solleva la cassetta degli attrezzi dal selciato e mettila sul bancone
Heavy	Solleva la cassetta di bevande dallo scantinato e mettila nella mansarda
Heavy	Solleva la cassetta di frutta dalla strada e mettila nel furgone
Heavy	Solleva la culla da terra e mettila in ascensore
Heavy	Solleva la damigiana di vino dal primo piano e mettila al secondo
Heavy	Solleva la fascina di legno dallo scantinato e mettila sulla mansarda
Heavy	Solleva la gomma del camion dalla strada e mettila sul furgone
Heavy	Solleva la palla da bowling dal suolo e mettila sulla scansia
Heavy	Solleva la pila di libri dalla cassa e mettila sul ripiano
Heavy	Solleva la pila di piatti dall'imballo e mettila sulla vetrinetta
Heavy	Solleva la sedia da ufficio dal tappeto e mettila sul palco
Heavy	Solleva la tanica di benzina dal carrello e mettila sullo scaffale
Heavy	Solleva la tanica di gasolio dal marciapiede e mettila sul motorino
Heavy	Solleva la tinozza d'acqua dalla cassa e mettila nel ripiano
Heavy	Solleva la valigia piena da terra e mettila sul portabagagli
Heavy	Solleva l'arpa dal piano terra e mettila al primo piano
Heavy	Solleva l'estintore dal pavimento e mettilo sul gancio

Kind of Sentence	Sentence
Heavy	Solleva lo scatolone di mattoni dal carrello e mettilo sullo scaffale
Heavy	Solleva lo zaino pieno dal garage e mettilo nel portapacchi
Heavy	Sposta il baule di biancheria dal camion alla casa
Heavy	Sposta il bidone d'olio dal magazzino alla cucina
Heavy	Sposta il bilanciere da palestra dal baule della macchina al camion
Heavy	Sposta il comodino dalla cantina all'appartamento
Heavy	Sposta il computer dal parquet al bancone
Heavy	Sposta il materasso da terra sul letto
Heavy	Sposta il motore delle barca dal baule della macchina al camion
Heavy	Sposta il passeggino dal piano terra al primo piano
Heavy	Sposta il pentolone di brodo dal pavimento al fornello
Heavy	Sposta il sacco di patate dalla stuoia alla mensola
Heavy	Sposta il secchio di mattoni dal marciapiedi al motorino
Heavy	Sposta il televisore dall'imballo al comò
Heavy	Sposta la cassapanca da terra al portabagagli
Heavy	Sposta la cassetta degli attrezzi dal piano di lavoro alla mensola
Heavy	Sposta la cassetta di bevande dal terreno alla scaffalatura
Heavy	Sposta la cassetta di frutta dal carrello allo scaffale
Heavy	Sposta la culla dal piano terra alla soffitta
Heavy	Sposta la damigiana di vino dallo scantinato al sottotetto
Heavy	Sposta la fascina di legna dal giardino al balcone
Heavy	Sposta la gomma del camion dal giardino al garage
Heavy	Sposta la palla da bowling dallo scantinato al sottotetto
Heavy	Sposta la pila di libri dal piano di lavoro alla mensola
Heavy	Sposta la pila di piatti dalla camera al salotto
Heavy	Sposta la sedia da ufficio dal primo piano al secondo piano
Heavy	Sposta la tanica di benzina dal garage al portapacchi
Heavy	Sposta la tanica di gasolio dal piano terra alla soffitta
Heavy	Sposta la tinozza d'acqua dal selciato al bancone
Heavy	Sposta la valigia piena dalla pedana al soppalco
Heavy	Sposta l'arpa dal tappeto al palco
Heavy	Sposta l'estintore dal carrello al camion
Heavy	Sposta lo scatolone di mattoni da terra alla libreria
Heavy	Sposta lo zaino dal sedile al portaoggetti

Kind of Sentence	Sentence
Light	Solleva l'oliera dal piano di cottura e mettila sulla vetrinetta
Light	Sposta il barattolo di caffè dallo scatolone al ripiano del frigo
Light	Sposta il bicchiere da vino dal carrello al tavolo
Light	Sposta il birillo da terra sul tavolo
Light	Sposta il cacciavite dal piano di lavoro alla scaffalatura
Light	Sposta il cellulare dal parquet al tavolino
Light	Sposta il cestino della carta dal pavimento al balcone
Light	Sposta il cucchiaio di legno dal piano cottura alla vetrinetta
Light	Sposta il fazzoletto dal cassetto all'attaccapanni
Light	Sposta il piatto dalla tovaglia al pensile
Light	Sposta il portafoglio dal banco alla cattedra
Light	Sposta il portapenne dal pavimento alla scrivania
Light	Sposta il sacchetto di zucchero dal parquet al tavolino
Light	Sposta il sandalo dal tappeto al portascarpe
Light	Sposta il tamburello dalla moquette al gancio in alto
Light	Sposta il telecomando dalla borsa allo scaffale dei libri
Light	Sposta il telefono da ufficio dalla scrivania alla libreria
Light	Sposta il vasetto di pomodori dal carrello al tavolo
Light	Sposta la bambola dal letto al pianoforte
Light	Sposta la borsetta di tela dal divano all'appendiabiti
Light	Sposta la bottiglia vuota dal ripiano allo scaffale
Light	Sposta la candela dal cassetto al ripiano in alto
Light	Sposta la lampadina dal cassetto al lampadario
Light	Sposta la lattina di aranciata dalla borsa della spesa alla scansia in alto
Light	Sposta la palla di gomma dal tappeto al cassetto
Light	Sposta la pallina da tennis dal selciato al mobiletto
Light	Sposta la saliera dalla tovaglia al pensile
Light	Sposta la scarpa di cuoio dal pavimento alla scarpiera
Light	Sposta la scatola di fiammiferi dal fornello al ripiano della cappa
Light	Sposta la scatoletta di tonno dal carrello alla cassa
Light	Sposta la tazza da colazione dal ripiano allo scaffale
Light	Sposta l'agenda di pelle dalla tasca alla mensola
Light	Sposta l'oliera dal lavandino allo scolapiatti

Kind of Sentence	Sentence
Light	Solleva il barattolo di caffè dal carrello e mettilo sulla cassa
Light	Solleva il bicchiere da vino da terra e mettilo sul bancone
Light	Solleva il birillo dal pavimento e mettilo sul balcone
Light	Solleva il cacciavite dallo sgabello e mettilo sul bancone
Light	Solleva il cellulare dalla stanza e mettilo nel corridoio
Light	Solleva il cestino della carta dalla stanza e mettilo nel corridoio
Light	Solleva il cucchiaio di legno dal lavandino e mettilo sullo scolapiatti
Light	Solleva il fazzoletto dal suolo e mettilo nel corridoio
Light	Solleva il piatto dalla stuoia e mettilo sulla bacheca in alto
Light	Solleva il portafoglio dalla tasca e mettilo sulla mensola
Light	Solleva il portapenne dal banco e mettilo sulla cattedra
Light	Solleva il sacchetto di zucchero dalla borsa e mettilo sulla scansia
Light	Solleva il sandalo dalla stuoia e mettilo sulla scarpiera
Light	Solleva il tamburello dal divano e mettilo sulla scansia
Light	Solleva il telecomando dalla moquette e mettilo sulla mensola
Light	Solleva il telefono da ufficio dal tavolo e mettilo sullo scaffale
Light	Solleva il vasetto di pomodori dalla dispensa e mettilo in basso al davanzale
Light	Solleva la bambola dal letto e mettila sull'armadio
Light	Solleva la borsetta di tela dal letto e mettila sul pianoforte
Light	Solleva la bottiglia vuota da terra e mettila sul bancone
Light	Solleva la candela dal piano di lavoro e mettila sulla scaffalatura
Light	Solleva la lampadina dallo stuoino e mettila sul lavandino
Light	Solleva la lattina di aranciata dallo sgabello e mettila sul bancone
Light	Solleva la palla di gomma dal suolo e mettila sulla scansia
Light	Solleva la pallina da tennis dal tappeto e mettila sulla mensola
Light	Solleva la saliera dal suolo e mettila sulla scansia
Light	Solleva la scarpa di cuoio dal selciato e mettila nel mobiletto
Light	Solleva la scatola di fiammiferi dalla pedana e mettila sul comodino
Light	Solleva la scatoletta di tonno dal tavolo e mettila sullo scaffale
Light	Solleva la tazza da colazione dallo scatolone e mettila sul ripiano del frigo
Light	Solleva l'agenda di pelle dalla scrivania e mettila sulla libreria

Linguistic materials 1. Experiment 1 and 2.



Videos. Experiment 1 and 2. We used 4 Heavy Videos - 3 Kg, 6 Kg, 12 Kg, 18 Kg - and 4 Light Videos - 50 g, 300 g, 600 g, 900 g - (the same used by Bosbach, Cole, Prinz, & Knoblich, 2005).

6 The specificity of the simulation with respect to the external world. An intrinsic object property - weight - and the production of action

	Kind of Sent.	Sentences
1	Heavy	Solleva il bilanciere da palestra da terra mettilo sul tavolo
2	Heavy	Sposta la damigiana di vino da terra e mettila sul tavolo
3	Heavy	Solleva la cassetta di mele da terra e mettila sul tavolo
4	Heavy	Sposta la cassetta di mattoni da terra e mettila sul tavolo
5	Heavy	Solleva la pila di libri da terra e mettila sul tavolo
6	Heavy	Sposta la tanica di benzina da terra e mettila sul tavolo
7	Light	Sposta il cuscino da terra e mettilo sul tavolo
8	Light	Sposta il sacco a pelo da terra e mettilo sul tavolo
9	Light	Solleva la scatola con le matite da terra e mettilo sul tavolo
10	Light	Solleva lo scatolone con i tovaglioli da terra e mettilo sul tavolo
11	Light	Solleva lo scatolone con i peluche da terra e mettilo sul tavolo
12	Light	Sposta il piumino da terra e mettilo sul tavolo
	Kind of Box	**Boxes**
a	Heavy	12 Kg
b	Light	3 Kg

Linguistic materials and boxes. The Heavy and Light Sentences and the Boxes' weights. An example of the box to lift immediately after the sentence acoustic presentation.

		Comprehension Questions	Right Answers
1	Heavy	L'oggetto sul tavolo serve per allenarsi?	SI
2	Heavy	Il liquido nella damigiana si può bere?	SI
3	Heavy	Il contenitore sul tavolo contiene cibo?	SI
4	Heavy	Gli oggetti sul tavolo servono per suonare?	NO
5	Heavy	Gli oggetti sul tavolo sono commestibili?	NO
6	Heavy	L'oggetto sul tavolo è un arredo?	NO
7	Light	L'oggetto sul tavolo è morbido?	SI
8	Light	L'oggetto sul tavolo è infiammabile?	SI
9	Light	La scatola sul tavolo contiene oggetti per scrivere?	SI
10	Light	L'oggetto sul tavolo è uno strumento?	NO
11	Light	Gli oggetti sul tavolo hanno dei tasti?	NO
12	Light	L'oggetto sul tavolo si può cucinare?	NO

Comprehension questions. The comprehension questions and the right answers.

7 The meaning of abstract words and the impact of different languages on cognition

GERMAN SENTENCES							
N.	**Quadr.**	**NOUNS**	**VERBS**	**NOUNS**	**VERBS**	**Kind of N.**	**Kind of V.**
1	**1a**	***einen Kuchen***	***anschneiden***	una torta	tagliare	Conctete	Conctete
2	**1b**	***einen Kuchen***	***wählen***	una torta	scegliere	Conctete	Abstract
3	**1c**	***ein Thema***	***anschneiden***	un tema	tagliare	Abstract	Conctete
4	**1d**	***ein Thema***	***wählen***	un tema	scegliere	Abstract	Abstract
5	**2a**	***einen Ring***	***schmieden***	un anello	forgiare	Conctete	Conctete
6	**2b**	***einen Ring***	***aussuchen***	un anello	selezionare	Conctete	Abstract
7	**2c**	***einen Plan***	***schmieden***	un progetto	forgiare	Abstract	Conctete
8	**2d**	***einen Plan***	***aussuchen***	un progetto	selezionare	Abstract	Abstract
9	**3a**	***den Gegenstand***	***aufnehmen***	un oggetto	sostenere	Conctete	Conctete
10	**3b**	***den Gegenstand***	***überwachen***	un oggetto	sorvegliare	Conctete	Abstract
11	**3c**	***die Untersuchung***	***aufnehmen***	un'indagine	sostenere	Abstract	Conctete
12	**3d**	***die Untersuchung***	***überwachen***	un'indagine	sorvegliare	Abstract	Abstract
13	**4a**	***die Schlagsahne***	***schlagen***	una panna	battere	Conctete	Conctete
14	**4b**	***die Schlagsahne***	***verabscheuen***	una panna	detestare	Conctete	Abstract
15	**4c**	***den Gegner***	***schlagen***	un avversario	battere	Abstract	Conctete
16	**4d**	***den Gegner***	***verabscheuen***	un avversario	detestare	Abstract	Abstract
17	**5a**	***einen Flummi***	***werfen***	una palla	buttare	Conctete	Conctete
18	**5b**	***einen Flummi***	***bemerken***	una palla	notare	Conctete	Abstract
19	**5c**	***einen Schatten***	***werfen***	un'ombra	buttare	Abstract	Conctete
20	**5d**	***einen Schatten***	***bemerken***	un'ombra	notare	Abstract	Abstract
21	**6a**	***den Stuhl***	***verschieben***	una sedia	spostare	Conctete	Conctete
22	**6b**	***den Stuhl***	***überblicken***	una sedia	osservare	Conctete	Abstract
23	**6c**	***die Perspektive***	***verschieben***	una prospettiva	spostare	Abstract	Conctete
24	**6d**	***die Perspektive***	***überblicken***	una prospettiva	osservare	Abstract	Abstract
25	**7a**	***die CD***	***anheben***	un cd	levare	Conctete	Conctete
26	**7b**	***die CD***	***hören***	un cd	ascoltare	Conctete	Abstract
27	**7c**	***die Stimme***	***anheben***	una voce	levare	Abstract	Conctete
28	**7d**	***die Stimme***	***hören***	una voce	ascoltare	Abstract	Abstract
29	**8a**	***die Hand***	***ergreifen***	una mano	prendere	Conctete	Conctete

GERMAN SENTENCES							
	N.	NOUNS	VERBS	NOUNS	VERBS	Kind of N.	Kind of V.
30	**8b**	***die Hand***	***lesen***	una mano	leggere	Conctete	Abstract
31	**8c**	***das Wort***	***ergreifen***	una parola	prendere	Abstract	Conctete
32	**8d**	***das Wort***	***lesen***	una parola	leggere	Abstract	Abstract
33	**9a**	***die Karten***	***vermischen***	una carta	mescolare	Conctete	Conctete
34	**9b**	***die Karten***	***verstehen***	una carta	apprendere	Conctete	Abstract
35	**9c**	***die Standpunkte***	***vermischen***	un punto di vista	mescolare	Abstract	Conctete
36	**9d**	***die Standpunkte***	***verstehen***	un punto di vista	apprendere	Abstract	Abstract
37	**10a**	***die Tür***	***öffnen***	una porta	aprire	Conctete	Conctete
38	**10b**	***die Tür***	***sehen***	una porta	vedere	Conctete	Abstract
39	**10c**	***einen Freiraum***	***öffnen***	uno spazio	aprire	Abstract	Conctete
40	**10d**	***einen Freiraum***	***sehen***	uno spazio	vedere	Abstract	Abstract
41	**11a**	***ein Buch***	***vorbringen***	un libro	accampare	Conctete	Conctete
42	**11b**	***ein Buch***	***anerkennen***	un libro	riconoscere	Conctete	Abstract
43	**11c**	***einen Einspruch***	***vorbringen***	un veto	accampare	Abstract	Conctete
44	**11d**	***einen Einspruch***	***anerkennen***	un veto	riconoscere	Abstract	Abstract
45	**12a**	***den Kuli***	***ergreifen***	una biro	prendere	Conctete	Conctete
46	**12b**	***den Kuli***	***benutzen***	una biro	impiegare	Conctete	Abstract
47	**12c**	***eine Gelegenheit***	***ergreifen***	un'occasione	prendere	Abstract	Conctete
48	**12d**	***eine Gelegenheit***	***benutzen***	un'occasione	impiegare	Abstract	Abstract
49	**13a**	***einen Baum***	***fällen***	un albero	tagliare	Conctete	Conctete
50	**13b**	***einen Baum***	***finden***	un albero	trovare	Conctete	Abstract
51	**13c**	***ein Urteil***	***fällen***	un giudizio	tagliare	Abstract	Conctete
52	**13d**	***ein Urteil***	***finden***	un giudizio	trovare	Abstract	Abstract
53	**14a**	***ein Zahnrad***	***manipulieren***	un ingranaggio	manipolare	Conctete	Conctete
54	**14b**	***ein Zahnrad***	***erfinden***	un ingranaggio	congegnare	Conctete	Abstract
55	**14c**	***eine Meinung***	***manipulieren***	un'opinione	manipolare	Abstract	Conctete
56	**14d**	***eine Meinung***	***erfinden***	un'opinione	congegnare	Abstract	Abstract
57	**15a**	***ein Paket***	***schließen***	un pacco	chiudere	Conctete	Conctete
58	**15b**	***ein Paket***	***haben***	un pacco	avere	Conctete	Abstract
59	**15c**	***ein Fazit***	***schließen***	un risultato	chiudere	Abstract	Conctete
60	**15d**	***ein Fazit***	***haben***	un risultato	avere	Abstract	Abstract
61	**16a**	***einen Zahn***	***ziehen***	un dente	tirare	Conctete	Conctete
62	**16b**	***einen Zahn***	***untersuchen***	un dente	esplorare	Conctete	Abstract
63	**16c**	***einen Schluss***	***ziehen***	un ragionamento	tirare	Abstract	Conctete
64	**16d**	***einen Schluss***	***untersuchen***	un ragionamento	esplorare	Abstract	Abstract
65	**17a**	***ein Bild***	***ausmalen***	un quadro	dipingere	Conctete	Conctete
66	**17b**	***ein Bild***	***verkaufen***	un quadro	vendere	Conctete	Abstract
67	**17c**	***eine Erzählung***	***ausmalen***	un racconto	dipingere	Abstract	Conctete
68	**17d**	***eine Erzählung***	***verkaufen***	un racconto	vendere	Abstract	Abstract
69	**18a**	***einen Strumpf***	***stricken***	una calza	lavorare a maglia	Conctete	Conctete

GERMAN SENTENCES							
	N.	**NOUNS**	**VERBS**	**NOUNS**	**VERBS**	**Kind of N.**	**Kind of V.**
70	**18b**	***einen Strumpf***	***ansehen***	una calza	visionare	Conctete	Abstract
71	**18c**	***einen Vortrag***	***stricken***	una lettura	lavorare a maglia	Abstract	Conctete
72	**18d**	***einen Vortrag***	***ansehen***	una lettura	visionare	Abstract	Abstract
73	**19a**	***die Zeitung***	***bringen***	un giornale	portare	Conctete	Conctete
74	**19b**	***die Zeitung***	***erwarten***	un giornale	aspettare	Conctete	Abstract
75	**19c**	***einen Gruß***	***bringen***	un saluto	portare	Abstract	Conctete
76	**19d**	***einen Gruß***	***erwarten***	un saluto	aspettare	Abstract	Abstract
77	**20a**	***eine Apfel***	***hinwerfen***	una mela	buttare	Conctete	Conctete
78	**20b**	***eine Apfel***	***verweigern***	una mela	rifiutare	Conctete	Abstract
79	**20c**	***die Chancen***	***hinwerfen***	un'occasione	buttare	Abstract	Conctete
80	**20d**	***die Chancen***	***verweigern***	un'occasione	rifiutare	Abstract	Abstract
81	**21a**	***eine Tasche***	***anheben***	una borsa	sollevare	Conctete	Conctete
82	**21b**	***eine Tasche***	***verlieren***	una borsa	perdere	Conctete	Abstract
83	**21c**	***die Zuversicht***	***anheben***	una fiducia	sollevare	Abstract	Conctete
84	**21d**	***die Zuversicht***	***verlieren***	una fiducia	perdere	Abstract	Abstract
85	**22a**	***einen Pokal***	***annehmen***	una coppa	gradire	Conctete	Conctete
86	**22b**	***einen Pokal***	***gewinnen***	una coppa	vincere	Conctete	Abstract
87	**22c**	***eine Herausforderung***	***annehmen***	una sfida	gradire	Abstract	Conctete
88	**22d**	***eine Herausforderung***	***gewinnen***	una sfida	vincere	Abstract	Abstract
89	**23a**	***eine Praline***	***anbieten***	una pralina	offrire	Conctete	Conctete
90	**23b**	***eine Praline***	***empfehlen***	una pralina	raccomandare	Conctete	Abstract
91	**23c**	***den Unterricht***	***anbieten***	un insegnamento	offrire	Abstract	Conctete
92	**23d**	***den Unterricht***	***empfehlen***	un insegnamento	raccomandare	Abstract	Abstract
93	**24a**	***das Menu***	***zusammenstellen***	un menu	compilare	Conctete	Conctete
94	**24b**	***das Menu***	***anfordern***	un menu	ordinare	Conctete	Abstract
95	**24c**	***eine Mannschaft***	***zusammenstellen***	una squadra	compilare	Abstract	Conctete
96	**24d**	***eine Mannschaft***	***anfordern***	una squadra	ordinare	Abstract	Abstract
97	**25a**	***den Pfeiler***	***stützen***	una pila	sostenere	Conctete	Conctete
98	**25b**	***den Pfeiler***	***sehen***	una pila	vedere	Conctete	Abstract
99	**25c**	***den Kandidaten***	***stützen***	un candidato	sostenere	Abstract	Conctete
100	**25d**	***den Kandidaten***	***sehen***	un candidato	vedere	Abstract	Abstract
101	**26a**	***die Patrone***	***reinstecken***	una cartuccia	inserire	Conctete	Conctete
102	**26b**	***die Patrone***	***verbrauchen***	una cartuccia	consumare	Conctete	Abstract
103	**26c**	***die Energie***	***reinstecken***	un'energia	inserire	Abstract	Conctete
104	**26d**	***die Energie***	***verbrauchen***	un'energia	consumare	Abstract	Abstract
105	**27a**	***einen Keks***	***abbrechen***	un biscotto	rompere	Conctete	Conctete
106	**27b**	***einen Keks***	***haben***	un biscotto	avere	Conctete	Abstract
107	**27c**	***eine Beziehung***	***abbrechen***	un legame	rompere	Abstract	Conctete
108	**27d**	***eine Beziehung***	***haben***	un legame	avere	Abstract	Abstract
109	**28a**	***eine Karte***	***aufdecken***	una carta	voltare	Conctete	Conctete

GERMAN SENTENCES							
	N.	**NOUNS**	**VERBS**	**NOUNS**	**VERBS**	**Kind of N.**	**Kind of V.**
110	**28b**	***eine Karte***	***entdecken***	una carta	scoprire	Conctete	Abstract
111	**28c**	***ein Geheimnis***	***aufdecken***	un segreto	voltare	Abstract	Conctete
112	**28d**	***ein Geheimnis***	***entdecken***	un segreto	scoprire	Abstract	Abstract
113	**29a**	***das Portemonnaie***	***aufheben***	un portafoglio	raccogliere	Conctete	Conctete
114	**29b**	***das Portemonnaie***	***finden***	un portafoglio	trovare	Conctete	Abstract
115	**29c**	***ein Urteil***	***aufheben***	una stima	raccogliere	Abstract	Conctete
116	**29d**	***ein Urteil***	***finden***	una stima	trovare	Abstract	Abstract
117	**30a**	***ein Streichholz***	***entzünden***	un fiammifero	accendere	Conctete	Conctete
118	**30b**	***ein Streichholz***	***verlieren***	un fiammifero	perdere	Conctete	Abstract
119	**30c**	***die Fantasie***	***entzünden***	una fantasia	accendere	Abstract	Conctete
120	**30d**	***die Fantasie***	***verlieren***	una fantasia	perdere	Abstract	Abstract
121	**31a**	***eine Zitrone***	***ausquetschen***	un limone	spremere	Conctete	Conctete
122	**31b**	***eine Zitrone***	***entdecken***	un limone	rinvenire	Conctete	Abstract
123	**31c**	***einen Spion***	***ausquetschen***	una spia	spremere	Abstract	Conctete
124	**31d**	***einen Spion***	***entdecken***	una spia	rinvenire	Abstract	Abstract
125	**32a**	***das Schwert***	***tragen***	una spada	portare	Conctete	Conctete
126	**32b**	***das Schwert***	***fürchten***	una spada	temere	Conctete	Abstract
127	**32c**	***das Risiko***	***tragen***	un rischio	portare	Abstract	Conctete
128	**32d**	***das Risiko***	***fürchten***	un rischio	temere	Abstract	Abstract
129	**33a**	***einen Bolzen***	***lockern***	una vite	allentare	Conctete	Conctete
130	**33b**	***einen Bolzen***	***bestellen***	una vite	far venire	Conctete	Abstract
131	**33c**	***die Überwachung***	***lockern***	una sorveglianza	allentare	Abstract	Conctete
132	**33d**	***die Überwachung***	***bestellen***	una sorveglianza	far venire	Abstract	Abstract
133	**34a**	***das Band***	***entwirren***	una corda	ingarbugliare	Conctete	Conctete
134	**34b**	***das Band***	***vergessen***	una corda	dimenticare	Conctete	Abstract
135	**34c**	***eine Geschichte***	***entwirren***	un racconto	ingarbugliare	Abstract	Conctete
136	**34d**	***eine Geschichte***	***vergessen***	un racconto	dimenticare	Abstract	Abstract
137	**35a**	***das Geld***	***hineinstecken***	i soldi	insinuare,inserire	Conctete	Conctete
138	**35b**	***das Geld***	***aufwenden***	i soldi	prodigare	Conctete	Abstract
139	**35c**	***die Mühe***	***hineinstecken***	uno sforzo	insinuare,inserire	Abstract	Conctete
140	**35d**	***die Mühe***	***aufwenden***	uno sforzo	prodigare	Abstract	Abstract
141	**36a**	***einen Hund***	***ergreifen***	un cane	afferrare	Conctete	Conctete
142	**36b**	***einen Hund***	***scheuen***	un cane	temere	Conctete	Abstract
143	**36c**	***die Gelegenheit***	***ergreifen***	un'occasione	afferrare	Abstract	Conctete
144	**36d**	***die Gelegenheit***	***scheuen***	un'occasione	temere	Abstract	Abstract
145	**37a**	***den Faden***	***einfädeln***	un fibra	infilare	Conctete	Conctete
146	**37b**	***den Faden***	***verlieren***	un fibra	perdere	Conctete	Abstract
147	**37c**	***eine Situation***	***einfädeln***	una situazione	infilare	Abstract	Conctete
148	**37d**	***eine Situation***	***verlieren***	una situazione	perdere	Abstract	Abstract
149	**38a**	***ein Bild***	***schießen***	un foto	attaccare	Conctete	Conctete

GERMAN SENTENCES							
	N.	**NOUNS**	**VERBS**	**NOUNS**	**VERBS**	**Kind of N.**	**Kind of V.**
150	**38b**	***ein Bild***	***würdigen***	un foto	apprezzare	Conctete	Abstract
151	**38c**	***einen Gewinn***	***schießen***	una vincita	attaccare	Abstract	Conctete
152	**38d**	***einen Gewinn***	***würdigen***	una vincita	apprezzare	Abstract	Abstract
153	**39a**	***den Stoff***	***schenken***	una stoffa	donare	Conctete	Conctete
154	**39b**	***den Stoff***	***wertschätzen***	una stoffa	ammirare	Conctete	Abstract
155	**39c**	***die Aufmerksamkeit***	***schenken***	un'attenzione	donare	Abstract	Conctete
156	**39d**	***die Aufmerksamkeit***	***wertschätzen***	un'attenzione	ammirare	Abstract	Abstract
157	**40a**	***einen Schrank***	***wegschieben***	un armadio	scostare	Conctete	Conctete
158	**40b**	***einen Schrank***	***behalten***	un armadio	conservare	Conctete	Abstract
159	**40c**	***einen Vorbehalt***	***wegschieben***	una riserva	scostare	Abstract	Conctete
160	**40d**	***einen Vorbehalt***	***behalten***	una riserva	conservare	Abstract	Abstract
161	**41a**	***eine Tafel***	***verwischen***	un lavagna	cancellare	Conctete	Conctete
162	**41b**	***eine Tafel***	***lesen***	un lavagna	leggere	Conctete	Abstract
163	**41c**	***eine Spur***	***verwischen***	una traccia	cancellare	Abstract	Conctete
164	**41d**	***eine Spur***	***lesen***	una traccia	leggere	Abstract	Abstract
165	**42a**	***ein Schmuckstück***	***bringen***	un gioiello	portare(portare a)	Conctete	Conctete
166	**42b**	***ein Schmuckstück***	***präsentieren***	un gioiello	presentare	Conctete	Abstract
167	**42c**	***einen Nachweis***	***bringen***	una prova	portare(portare a)	Abstract	Conctete
168	**42d**	***einen Nachweis***	***präsentieren***	una prova	presentare	Abstract	Abstract
169	**43a**	***eine Kartoffel***	***durchdrücken***	una patata	schacciare	Conctete	Conctete
170	**43b**	***eine Kartoffel***	***verwenden***	una patata	usare	Conctete	Abstract
171	**43c**	***eine Aussage***	***durchdrücken***	un'asserzione	schacciare	Abstract	Conctete
172	**43d**	***eine Aussage***	***verwenden***	un'asserzione	usare	Abstract	Abstract
173	**44a**	***einen Schmetterling***	***malen***	un farfalla	pitturare	Conctete	Conctete
174	**44b**	***einen Schmetterling***	***bestaunen***	un farfalla	ammirare	Conctete	Abstract
175	**44c**	***den Sonnenuntergang***	***malen***	un tramonto	pitturare	Abstract	Conctete
176	**44d**	***den Sonnenuntergang***	***bestaunen***	un tramonto	ammirare	Abstract	Abstract
177	**45a**	***einen Cocktail***	***schütteln***	un cocktail	scrollare	Conctete	Conctete
178	**45b**	***einen Cocktail***	***verschmähen***	un cocktail	disprezzare	Conctete	Abstract
179	**45c**	***einen Feind***	***schütteln***	un nemico	scrollare	Abstract	Conctete
180	**45d**	***einen Feind***	***verschmähen***	un nemico	disprezzare	Abstract	Abstract
181	**46a**	***eine Scheibe***	***abschneiden***	una fetta	mozzare	Conctete	Conctete
182	**46b**	***eine Scheibe***	***bekommen***	una fetta	ottenere	Conctete	Abstract
183	**46c**	***das Wort***	***abschneiden***	una parola	mozzare	Abstract	Conctete
184	**46d**	***das Wort***	***bekommen***	una parola	ottenere	Abstract	Abstract
185	**47a**	***eine Stecknadel***	***fassen***	una spilla	prendere	Conctete	Conctete
186	**47b**	***eine Stecknadel***	***spüren***	una spilla	avvertire	Conctete	Abstract
187	**47c**	***das Vertrauen***	***fassen***	una confidenza	prendere	Abstract	Conctete
188	**47d**	***das Vertrauen***	***spüren***	una confidenza	avvertire	Abstract	Abstract
189	**48a**	***einen Stuhl***	***heben***	una sedia	sollevare	Conctete	Conctete

GERMAN SENTENCES							
	N.	**NOUNS**	**VERBS**	**NOUNS**	**VERBS**	**Kind of N.**	**Kind of V.**
190	**48b**	***einen Stuhl***	***ignorieren***	una sedia	ignorare	Conctete	Abstract
191	**48c**	***die Stimmung***	***heben***	un'atmosfera	sollevare	Abstract	Conctete
192	**48d**	***die Stimmung***	***ignorieren***	un'atmosfera	ignorare	Abstract	Abstract

Linguistic materials. The German quadruples.

ITALIAN SENTENCES				
N.	**Quadr.**	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
1	**1a**	***afferrare una mela***	Conctete	Conctete
2	**1b**	***afferrare un concetto***	Conctete	Abstract
3	**1c**	***pensare una mela***	Abstract	Conctete
4	**1d**	***pensare un concetto***	Abstract	Abstract
5	**2a**	***stringere una spugna***	Conctete	Conctete
6	**2b**	***stringere un'amicizia***	Conctete	Abstract
7	**2c**	***trovare una spugna***	Abstract	Conctete
8	**2d**	***trovare un'amicizia***	Abstract	Abstract
9	**3a**	***sostenere la scala***	Conctete	Conctete
10	**3b**	***sostenere l'esame***	Conctete	Abstract
11	**3c**	***osservare la scala***	Abstract	Conctete
12	**3d**	***osservare l'esame***	Abstract	Abstract
13	**4a**	***battere i panni***	Conctete	Conctete
14	**4b**	***battere l'avversario***	Conctete	Abstract
15	**4c**	***scegliere i panni***	Abstract	Conctete
16	**4d**	***scegliere l'avversario***	Abstract	Abstract
17	**5a**	***ricucire una gonna***	Conctete	Conctete
18	**5b**	***ricucire un rapporto***	Conctete	Abstract
19	**5c**	***ricordare una gonna***	Abstract	Conctete
20	**5d**	***ricordare un rapporto***	Abstract	Abstract
21	**6a**	***spostare la sedia***	Conctete	Conctete
22	**6b**	***spostare la prospettiva***	Conctete	Abstract
23	**6c**	***valutare la sedia***	Abstract	Conctete
24	**6d**	***valutare la prospettiva***	Abstract	Abstract
25	**7a**	***sollevare un tavolo***	Conctete	Conctete
26	**7b**	***sollevare una critica***	Conctete	Abstract
27	**7c**	***ricevere un tavolo***	Abstract	Conctete
28	**7d**	***ricevere una critica***	Abstract	Abstract
29	**8a**	***impugnare il martello***	Conctete	Conctete

ITALIAN SENTENCES				
	N.	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
30	**8b**	***impugnare la sentenza***	Conctete	Abstract
31	**8c**	***esaminare il martello***	Abstract	Conctete
32	**8d**	***esaminare la sentenza***	Abstract	Abstract
33	**9a**	***accarezzare un cane***	Conctete	Conctete
34	**9b**	***accarezzare un'idea***	Conctete	Abstract
35	**9c**	***aspettare un cane***	Abstract	Conctete
36	**9d**	***aspettare un'idea***	Abstract	Abstract
37	**10a**	***mescolare le carte***	Conctete	Conctete
38	**10b**	***mescolare i destini***	Conctete	Abstract
39	**10c**	***leggere le carte***	Abstract	Conctete
40	**10d**	***leggere i destini***	Abstract	Abstract
41	**11a**	***aprire una porta***	Conctete	Conctete
42	**11b**	***aprire degli spazi***	Conctete	Abstract
43	**11c**	***vedere una porta***	Abstract	Conctete
44	**11d**	***vedere degli spazi***	Abstract	Abstract
45	**12a**	***spingere una bici***	Conctete	Conctete
46	**12b**	***spingere una protesta***	Conctete	Abstract
47	**12c**	***ammirare una bici***	Abstract	Conctete
48	**12d**	***ammirare una protesta***	Abstract	Abstract
49	**13a**	***cogliere un fiore***	Conctete	Conctete
50	**13b**	***cogliere un'occasione***	Conctete	Abstract
51	**13c**	***descrivere un fiore***	Abstract	Conctete
52	**13d**	***descrivere un'occasione***	Abstract	Abstract
53	**14a**	***tagliare una quercia***	Conctete	Conctete
54	**14b**	***tagliare una relazione***	Conctete	Abstract
55	**14c**	***rimpiangere una quercia***	Abstract	Conctete
56	**14d**	***rimpiangere una relazione***	Abstract	Abstract
57	**15a**	***manipolare un ingranaggio***	Conctete	Conctete
58	**15b**	***manipolare un'opinione***	Conctete	Abstract
59	**15c**	***esplorare un ingranaggio***	Abstract	Conctete
60	**15d**	***esplorare un'opinione***	Abstract	Abstract
61	**16a**	***chiudere il pacco***	Conctete	Conctete
62	**16b**	***chiudere il ragionamento***	Conctete	Abstract
63	**16c**	***apprezzare il pacco***	Abstract	Conctete
64	**16d**	***apprezzare il ragionamento***	Abstract	Abstract
65	**17a**	***scartare la caramella***	Conctete	Conctete
66	**17b**	***scartare l'ipotesi***	Conctete	Abstract
67	**17c**	***respingere la caramella***	Abstract	Conctete
68	**17d**	***respingere l'ipotesi***	Abstract	Abstract
69	**18a**	***dipingere un quadro***	Conctete	Conctete

ITALIAN SENTENCES				
	N.	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
70	**18b**	***dipingere un racconto***	Conctete	Abstract
71	**18c**	***proporre un quadro***	Abstract	Conctete
72	**18d**	***proporre un racconto***	Abstract	Abstract
73	**19a**	***imbastire la giacca***	Conctete	Conctete
74	**19b**	***imbastire il discorso***	Conctete	Abstract
75	**19c**	***rifiutare la giacca***	Abstract	Conctete
76	**19d**	***rifiutare il discorso***	Abstract	Abstract
77	**20a**	***ritagliare un giornale***	Conctete	Conctete
78	**20b**	***ritagliare un momento***	Conctete	Abstract
79	**20c**	***attendere un giornale***	Abstract	Conctete
80	**20d**	***attendere un momento***	Abstract	Abstract
81	**21a**	***gettare dell'acqua***	Conctete	Conctete
82	**21b**	***gettare una possibilità***	Conctete	Abstract
83	**21c**	***negare dell'acqua***	Abstract	Conctete
84	**21d**	***negare una possibilità***	Abstract	Abstract
85	**22a**	***prendere la borsa***	Conctete	Conctete
86	**22b**	***prendere la fiducia***	Conctete	Abstract
87	**22c**	***perdere la borsa***	Abstract	Conctete
88	**22d**	***perdere la fiducia***	Abstract	Abstract
89	**23a**	***lanciare la palla***	Conctete	Conctete
90	**23b**	***lanciare la sfida***	Conctete	Abstract
91	**23c**	***vincere la palla***	Abstract	Conctete
92	**23d**	***vincere la sfida***	Abstract	Abstract
93	**24a**	***offrire il pasticcino***	Conctete	Conctete
94	**24b**	***offrire l'insegnamento***	Conctete	Abstract
95	**24c**	***lodare il pasticcino***	Abstract	Conctete
96	**24d**	***lodare l'insegnamento***	Abstract	Abstract
97	**25a**	***piegare il menù***	Conctete	Conctete
98	**25b**	***piegare la volontà***	Conctete	Abstract
99	**25c**	***rispettare il menù***	Abstract	Conctete
100	**25d**	***rispettare la volontà***	Abstract	Abstract
101	**26a**	***appoggiare un piatto***	Conctete	Conctete
102	**26b**	***appoggiare una candidatura***	Conctete	Abstract
103	**26c**	***elogiare un piatto***	Abstract	Conctete
104	**26d**	***elogiare una candidatura***	Abstract	Abstract
105	**27a**	***dosare il sale***	Conctete	Conctete
106	**27b**	***dosare l'energia***	Conctete	Abstract
107	**27c**	***esaurire il sale***	Abstract	Conctete
108	**27d**	***esaurire l'energia***	Abstract	Abstract
109	**28a**	***spezzare il grissino***	Conctete	Conctete

ITALIAN SENTENCES				
	N.	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
110	**28b**	***spezzare il legame***	Conctete	Abstract
111	**28c**	***notare il grissino***	Abstract	Conctete
112	**28d**	***notare il legame***	Abstract	Abstract
113	**29a**	***rompere la bottiglia***	Conctete	Conctete
114	**29b**	***rompere il segreto***	Conctete	Abstract
115	**29c**	***scoprire la bottiglia***	Abstract	Conctete
116	**29d**	***scoprire il segreto***	Abstract	Abstract
117	**30a**	***raccogliere il portafoglio***	Conctete	Conctete
118	**30b**	***raccogliete la stima***	Conctete	Abstract
119	**30c**	***cercare il portafoglio***	Abstract	Conctete
120	**30d**	***cercare la stima***	Abstract	Abstract
121	**31a**	***accendere il fiammifero***	Conctete	Conctete
122	**31b**	***accendere la fantasia***	Conctete	Abstract
123	**31c**	***perdere il fiammifero***	Abstract	Conctete
124	**31d**	***perdere la fantasia***	Abstract	Abstract
125	**32a**	***rispolverare un mobile***	Conctete	Conctete
126	**32b**	***rispolverare un ricordo***	Conctete	Abstract
127	**32c**	***descrivere un mobile***	Abstract	Conctete
128	**32d**	***descrivere un ricordo***	Abstract	Abstract
129	**33a**	***spremere il limone***	Conctete	Conctete
130	**33b**	***spremere la memoria***	Conctete	Abstract
131	**33c**	***ignorare il limone***	Abstract	Conctete
132	**33d**	***ignorare la memoria***	Abstract	Abstract
133	**34a**	***sfiorare la spada***	Conctete	Conctete
134	**34b**	***sfiorare il pericolo***	Conctete	Abstract
135	**34c**	***temere la spada***	Abstract	Conctete
136	**34d**	***temere il pericolo***	Abstract	Abstract
137	**35a**	***allentare la molla***	Conctete	Conctete
138	**35b**	***allentare la pressione***	Conctete	Abstract
139	**35c**	***considerare la molla***	Abstract	Conctete
140	**35d**	***considerare la pressione***	Abstract	Abstract
141	**36a**	***ingarbugliare la corda***	Conctete	Conctete
142	**36b**	***ingarbugliare l'argomento***	Conctete	Abstract
143	**36c**	***evitare la corda***	Abstract	Conctete
144	**36d**	***evitare l'argomento***	Abstract	Abstract
145	**37a**	***intrecciare una collana***	Conctete	Conctete
146	**37b**	***intrecciare delle idee***	Conctete	Abstract
147	**37c**	***sopravvalutare una collana***	Abstract	Conctete
148	**37d**	***sopravvalutare delle idee***	Abstract	Abstract
149	**38a**	***impugnare il boccale***	Conctete	Conctete

ITALIAN SENTENCES				
	N.	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
150	**38b**	***impugnare la situazione***	Conctete	Abstract
151	**38c**	***schivare il boccale***	Abstract	Conctete
152	**38d**	***schivare la situazione***	Abstract	Abstract
153	**39a**	***sfoderare il cappotto***	Conctete	Conctete
154	**39b**	***sfoderare la grinta***	Conctete	Abstract
155	**39c**	***abbandonare il cappotto***	Abstract	Conctete
156	**39d**	***abbandonare la grinta***	Abstract	Abstract
157	**40a**	***attaccare la foto***	Conctete	Conctete
158	**40b**	***attaccare il nemico***	Conctete	Abstract
159	**40c**	***disdegnare la foto***	Abstract	Conctete
160	**40d**	***disdegnare il nemico***	Abstract	Abstract
161	**41a**	***colpire la tela***	Conctete	Conctete
162	**41b**	***colpire l'attenzione***	Conctete	Abstract
163	**41c**	***criticare la tela***	Abstract	Conctete
164	**41d**	***criticare l'attenzione***	Abstract	Abstract
165	**42a**	***snocciolare le olive***	Conctete	Conctete
166	**42b**	***snocciolare le espressioni***	Conctete	Abstract
167	**42c**	***dimenticare le olive***	Abstract	Conctete
168	**42d**	***dimenticare le espressioni***	Abstract	Abstract
169	**43a**	***pitturare una cornice***	Conctete	Conctete
170	**43b**	***pitturare un tramonto***	Conctete	Abstract
171	**43c**	***ammirare una cornice***	Abstract	Conctete
172	**43d**	***ammirare un tramonto***	Abstract	Abstract
173	**44a**	***mozzare la fetta***	Conctete	Conctete
174	**44b**	***mozzare la parola***	Conctete	Abstract
175	**44c**	***trovare la fetta***	Abstract	Conctete
176	**44d**	***trovare la parola***	Abstract	Abstract
177	**45a**	***sollevare la sedia***	Conctete	Conctete
178	**45b**	***sollevare l'atmosfera***	Conctete	Abstract
179	**45c**	***ignorare la sedia***	Abstract	Conctete
180	**45d**	***ignorare l'atmosfera***	Abstract	Abstract
181	**46a**	***rompere un biscotto***	Conctete	Conctete
182	**46b**	***rompere una storia***	Conctete	Abstract
183	**46c**	***avere un biscotto***	Abstract	Conctete
184	**46d**	***avere una storia***	Abstract	Abstract
185	**47a**	***afferrare la vite***	Conctete	Conctete
186	**47b**	***afferrare il tempo***	Conctete	Abstract
187	**47c**	***smarrire la vite***	Abstract	Conctete
188	**47d**	***smarrire il tempo***	Abstract	Abstract
189	**48a**	***scrivere il documento***	Conctete	Conctete

ITALIAN SENTENCES				
	N.	**VERBS+NOUNS**	**Kind of N.**	**Kind of V.**
190	**48b**	***scrivere la fine***	Conctete	Abstract
191	**48c**	***cercare il documento***	Abstract	Conctete
192	**48d**	***cercare la fine***	Abstract	Abstract

Linguistic materials. The Italian quadruples.