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An embodied and grounded perspective on concepts

Abstract

By the mainstream view in psychology and neuroscience, concepts are informational units, rather stable, and are represented in propositional format. In the view I will outline, instead, concepts correspond to patterns of activation of the perception, action and emotional systems which are typically activated when we interact with the entities they refer to. Starting from this embodied and grounded approach to concepts, I will focus on different research lines and present some experimental evidence concerning concepts of objects, concepts of actions, and abstract concepts. I will argue that, in order to account for abstract concepts, embodied and grounded theories should be extended.

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An embodied and grounded perspective on concepts

Concepts according to embodied and grounded views

In the last years embodied and grounded (from now EG) theories have become more and more popular in a variety of disciplines, ranging from philosophy, to linguistics, to psychology, to cognitive science and neuroscience, to computer science and robotics (for a recent overview, see Borghi and Caruana, in press). There has been a marked increase in the publications on embodied cognition, as noticed by some scholars (e.g., Gentner, 2010), and some recent special issues testify how lively the field is (e.g., Borghi & Pecher, 2011) and start to ask where research on embodiment is going (e.g., Davis & Markman, 2012; Dove, in press). Even if they can be quite different - for example, some of these theories assume the notion of representation, other don't think it is necessary -, these views share the idea that the cognitive processes cannot be studied without referring to the brain and to the body as control system. Furthermore, they propose that perception, action and cognition are deeply interconnected. This is in contrast with classical cognitive science views that posited a linear relationship between perception, cognition and action, implicitly assuming that cognition can be intended as a sandwich, with perception and action considered as the external and less tasty slides compared to the tasty and crucial part of cognition (Hurley, 1998).

From the idea of a strict link between perception, action and cognition derives the way in which EG views intend concepts, i.e. the minimal units of our knowledge on a given object or entity. Concepts would consist in the reactivation of the neural pattern activated during previous experience with the social and physical environment, aimed at facilitating the interaction with objects and entities which are present in the current situation/context (Barsalou, 1999; Borghi, 2005; Gallese & Lakoff, 2005; Prinz, 2002). For example, the concept of telephone would imply the multimodal activation (Gallese & Lakoff, 2005) of the acoustic, visual, tactile etc. properties and corresponding brain areas we typically experience and activate while seeing and using telephones Specifically, Barsalou (1999), one of the most influent proponents of EG views, argued, "In this theory, a concept is equivalent to a simulator. It is the knowledge and accompanying processes that allow an individual to represent some kind of entity or event adequately. A given simulator can produce limitless simulations…Whereas a concept represents a kind generally, a conceptualization provides one specific way of thinking about it."(Barsalou, 1999, p. 587).

The chapter will focus on concepts as simulators. We will discuss of concepts of objects and of actions; then we will turn to how concepts of objects and actions are mediated by language; finally, we will briefly discuss of the so-called "abstract concepts".

Simulation

The notion of simulation is complicated and controversial: as there are many embodied theories, there are also many views of simulation (for discussion, see Borghi & Cimatti, 2010; Gallese, 2009;Jeannerod, 2006; Decety & Grezes, 2006). Here we will intend simulation as composed by two aspects: reenactment and prediction. Simulating would mean reactivating offline the same neural network used while perceiving and interacting with objects and entities, and while experiencing emotions. Simulating has a predictive function, as it prepares us to interact with the objects and entities which are present in the current context/situation. We simulate when we perceive objects: for example, seeing an apple activates a grasping action, and it also pre-activates our gustatory and olfaction system. We simulate when we perceive others performing an action, and this action is part of our motor repertoire: for example, if we observe and hear a dog barking, we cannot simulate, since we cannot bark (Buccino et al., 2004). Since grasping objects is part of our motor abilities, we simulate when we observe monkeys grasping an object. Finally, we simulate when we comprehend language: for example, when hearing the sentence "he kicked the ball" we internally reproduce the situation described by the sentence, activating our legs. It is an open issue whether we simulate also when we understand abstract words, such as "truth". The neural basis of this simulation has likely to be found in the activation of the canonical and mirror neuron systems, i.e. of the systems activated while observing objects and people interacting with them (for reviews, see Rizzolatti & Craighero, 2004; Gallese, 2008). How does this simulation work during language comprehension? As an example, the Action Based Language model (Glenberg & Gallese, 2012), emphasizes the predictive aspects of the simulation we form during language comprehension. For example, upon hearing the verb “kick”, the mirror neuron system would be activated and possible outcomes of the action to perform would be generated. In the following part of the paper we will describe experiments performed in our lab which help exemplify how simulation occurs.

Simulating during object observation: affordances

Affordances are an important notion for EG theories, as they provide a bridge between perception and action. With affordance Gibson (1979) originally referred to the fact that the environment offers to us invitations to act: for example, a pen invites us to hold it. The notion of affordance has had a lot of success within psychology and cognitive neuroscience, at least as an inspiration source. In particular, Ellis and Tucker (2000) have proposed to use the notion of microaffordance, to indicate the similarities but also the differences between their own and Gibson's view. Microaffordances are rather specific and pertain components of actions, for example grasping and reaching affordances. Furthermore, activating the microaffordances of a given object, e.g. a cup, implies having recognized it. Finally, the authors proposing the notion of microaffordance are interested also in how they are represented in the brain, as the product of visuomotor associations developed through experience. This interest for the neural correlates of affordances (for a recent review see Maranesi et al., in press) was not present in Gibson's view.

Until some years ago the majority of studies focused on how affordances were activated, independently from the task. For example, in some elegant experiments Tucker and Ellis (1998; 2001) asked participants to categorize objects into natural objects and artifacts mimicking either a precision or a power grip, and found a compatibility effect between the object size and the grip to execute to respond: larger objects' category was determined faster and more accurately executing a power grip, while the opposite was true for smaller objects' category. The result of this study indicate that, even if the task - a categorization one - did not require access to objects size, microaffordances related to grasping were automatically activated. Very recent studies on affordances tend to highlight, rather than their automaticity, their flexibility and contextual dependency (e.g., van Elk et al., 2014; for an overview of recent work in our lab see Borghi, 2014). For example, Borghi et al. (2012) presented participants with objects and with a hand. The objects could be either linked by a spatial relation (objects typically located in the same context, e.g., knife-butter) or by a functional relation (objects typically used together, e.g. knife-coffee-mug), or by no relation. The hand could be displayed while grasping the object in order to move/manipulate it, in order to use it, or it could simply be near the object. In one condition no hand was present. Participants were required to press two different keys on the keyboard to determine whether the two objects were related or not. When the objects were functionally related manipulation posture were the slowest, while when the objects were spatially related functional postures were inhibited. This interaction was not present when participants were required to perform foot responses, by pressing a pedal. This suggests that observing hands in potential interaction with objects activates affordances, that differ depending on the context. Furthermore, the results indicate that observing a hand in potential interaction with an object elicits a motor simulation, which is specific for a given effector (here the hand, not the foot).

A further study (Scorolli et al., in press) investigates the role of the social context in affordance activation. We had again pairs of objects linked by a spatial relation (e.g., can-knife), by different kinds of functional relations or by no relation. The functional relations could either imply an individual action (functional–individual: e.g., can-straw) or an action to perform with somebody else (functional–cooperative: e.g., can-glass). Participants were asked to refrain from responding when the two objects were not related; when they were related they had either to move toward the experimenter, as if to give something to him (giving condition) or to move away from him, as when taking something for themselves (getting condition). We also manipulated the presence or not of eye gaze communication. Results revealed that participants were sensitive to the information given by the hand posture and by the eye gaze: responses were faster when the other was engaged in individual rather than in cooperative actions, and when the other used a manipulative hand posture, more open to cooperation, than a functional hand posture, used for individual actions. This study clearly shows how affordances are deeply modulated by the social and the physical context, and indicates that we possess a precise and sophisticated ability to predict others' actions, as well as their social vs. individual character.

We briefly reported these studies to show how initial work on affordances was focused on single objects, while now it becomes more important to show the effects of the physical context (see also Kalenine et al., in press), or of the social context (see also Ellis et al., 2013) on their activation.

Simulating during action observations - motor resonance

In the last years a number of studies have revealed the existence of motor resonance processes (e.g. Aglioti et al, 2008). Our mirror neuron system would respond more when we observe others performing actions that are part of our motor repertoire, compared to actions we are not able to perform. In the last years the literature has gone even further, revealing the existence of motor resonant processes when we observe others similar to us - for example sharing our culture, or our ideology.
In our lab we have performed some studies showing motor resonance processes when we observe actions of people whose bodily characteristics are similar to our own. Liuzza et al. (2010) have demonstrated this with a priming paradigm. Children were shown pictures of adults hands and children hands in a grasping posture or in a control posture (fist) followed by images of light vs. heavy objects (e.g., a block notes vs. a dictionary). They had to decide whether the target-objects they saw were light or heavy pressing a different key on a keyboard. We found that response times were faster when children observed children hands in a grasping posture compared to when they observed adults hands and children hands in a control posture. These results suggest that children simulate the action of lifting the object, thus their response times differ depending on the object's weight. More crucially, they resonate more when they observe hands similar to their own, as adults possess a completely different body schema. Ranzini et al. (2011) provided evidence of motor resonance processes with a line bisection paradigm, in which participants were required to bisect a line with two flankers. In one experiment the flankers consisted in the images of a hand displaying a precision vs. a power grip; they flanked a line which could be thin or thick. We found that people tended to bisect a line more toward the precision grip flanker when the line was thin, more toward the power grip flanker when the line was thick. This suggests that we are sensitive to the affordances provided by the line in combination with the action evoked by the hand posture. In further experiments we found an effect of motor resonance: participants tended to bisect the line more toward the precision grip, as if preparing themselves for a skilled action, such as the kind of action which is typically associated to a precision posture. Finally, the effect was modulated by motor resonance: it was stronger with human hands than with fake hands or with robotics hands. Further motor resonance processes were observed during observation of a hand grasping dangerous objects. In a recent study (Anelli et al., 2013) adults and children observed human and robotics hands of their own/a different gender followed by graspable neutral and dangerous objects (e.g., tomato vs. cactus). neutral graspable objects produced a facilitation of the motor response, while dangerous objects inhibited the response, probably due to an aversive effect. Both children and adults responded faster to human than to robotics hands, revealing a motor resonant mechanism. Specific

resonant mechanisms related to the gender of the hand emerged instead only in adults.
Overall, these studies show stronger motor resonance processes when we observe actions performed by someone possessing a body similar to ours, in terms of body schema (children vs. adults), of gender, of body parts (hands).

Simulating during language comprehension

What happens when concepts are expressed through words? We simulate the processes described by means of linguistic expressions (Barsalou, 2008; Borghi & Cangelosi, in press; Gallese, 2008; Glenberg and Gallese, 2013). Many studies in various labs, and in our lab as well, have demonstrated that this simulation is fine-grained: it is sensitive to object characteristics such as object shape, orientation, weight (Scorolli et al., 2009), as well as to characteristics of actions, as the effectors (hands, mouth or feet) used to perform them: for example, the arm/hand is activated while reading or hearing throw a ball, the foot while reading or hearing kick a ball (for an overview of the studies of our lab see Borghi, 2012). We recently demonstrated that the simulation differs when we read sentences referring to a different social context, such as "give the object to a friend vs. to an enemy" (Lugli et al., 2012). In a recent kinematics work (Gianelli et al., 2013), we investigated how the simulation of a social situation formed during language comprehension was modulated by a real social situation. Participants were required to evaluate whether sentences made sense or not by moving the mouse away or toward their own body. The sentences referred to objects characterized by positive or negative valence to bring or to give to someone else (e.g., “The object is ugly/smooth. Bring it to you/Give it to another person”). In one condition participants performed the task individually, in another an experimenter observed the performance, and in a further condition the experimenter interacted with participants relocating the mouse where they had left it. The simulation formed during the comprehension of the social context illustrated in the sentences was enhanced by matching it with the real social context given by the presence of the experimenter. Specifically, we found an increase in accuracy and a slowing down of RTs when the sentence stimuli referred to the "another person" target and the experimenter acted as a confederate. This is consistent with kinematics data showing that, in social situations, responses become slower to allow for an increase in accuracy (e.g., Ferri et al., 2010). Our results thus suggest that the simulation formed is sensitive both to the fictitious (linguistically expressed) and to the real social context.

Abstract concepts

We have discussed so far of concepts of objects and of actions, as well as of concepts mediated by words. The notion of simulation can be applied in a rather straightforward way to concrete concepts, but it is much more complicated to defend the view that abstract concepts, such as "phantasy" and "truth", activate simulations. We have recently proposed the Words As social Tools (WAT) view on abstract concepts, and have collected some evidence supporting it (Borghi & Cimatti, 2009; Borghi & Binkofski, 2014; see also Borghi, 2013). According to traditional views, abstract concepts are represented solely on the basis of linguistic information: while concrete concepts and words such as "book" would activate visual information, this would not be the case for abstract words (e.g., Paivio, 1986). According to standard embodied views, abstract concepts as well would activate sensorimotor experience, hence simulations: for example, the concept of justice would reactivate the experience of a tribunal (for a review, see Pecher et al., 2011). Our view is an EG view, hence it proposes that abstract concepts are activate the perception, action and emotional systems. At the same time, however, we maintain that this is not the whole story, and that to fully account for abstract concepts representation EG views need to be extended. We propose indeed that not only sensorimotor, but also linguistic experience plays a major role in the acquisition and representation of abstract concepts. In our view, the modality of acquisition of concrete and abstract concepts profoundly differs, and this influences their neural representation. To form concrete categories such as those of dogs or chairs, the influence of language is certainly of importance, but not crucial, since the category members share many perceptual similarities. To form abstract categories, instead, hearing a common label that keeps together sparse and different experience, or hearing someone explaining to us the meaning of a given words, might be crucial. We therefore predict that for both concrete and abstract concepts sensorimotor and linguistic experience count, but that their distribution differs, since for abstract concepts linguistic information would be more relevant. Importantly, we speak of linguistic “experience”. We do not intend to deny the role of distributional statistical information for word meaning (see distributional views, according to which meaning of a word is given by its cooccurrence with other words, for an influent example see Landauer & Dumais, 2007). However, we do not with limit the contribution of language to this; rather, with linguistic “experience” we intend the whole social and emotional experience of being taught a word by somebody in a context, and of starting to use it to refer to a particular object, event, situation, event.

We have collected some evidence in support of this view. In two acquisition studies with adults (Borghi et al., 2011; Granito et al., in preparation) we have demonstrated that learning a novel label and receiving a meaning explanation facilitates more the acquisition of novel abstract than of concrete words, and that it leads to an activation of the mouth. Novel abstract words lead to faster responses with the mouth (using a microphone), while novel concrete words evoke faster manual responses. The result is further supported by ratings we obtained on a subset of abstract words (from the database of Barca et al., 2002). Participants were asked to rate to what extent an effector (hand or mouth) is involved in a possible action with the item. We found that, while the hand was preferentially activated for concrete words, both the hand and the mouth were activated with abstract words. This suggests that activation of the mouth underscores abstract concepts representation, be it due to the enhancement of past linguistic comprehension or linguistic production experiences (see Borghi & Binkofski, 2014, for a detailed discussion). Further work on the neural basis of abstract concept representation supports this view: in a TMS study (Scorolli et al., 2012) we found that, compared to phrases with a concrete verb (e.g., to grasp a flower/a concept), phrases with an abstract verb (e.g., to describe a flower/a concept) implied a late activation of the motor manual system, probably due to the fact that they activated first the mouth, and that this lead to a cascade activation of the hand. Furthermore, in an fMRI study (Sakreida et al, 2012) we found that sensorimotor networks in the brain are activated by both concrete and abstract phrases, while linguistic networks are activated mainly by abstract ones. Finally, in a recent study on Italian sign language (LIS) we found and illustrated examples of signs used to express abstract concepts (e.g. linguistics, truth) that exploit linguistic information, taken either from the same sign language or from a different language, be it spoken or signed (Borghi, Capirci, Gianfreda and Volterra, under review). Overall, the evidence described supports the WAT proposal on abstract concepts.

Conclusion

Concepts reactivate past experiences, to help us deal with current experiences. The chapter presents an EG view of concepts and overviews recent evidence supporting it.

The view that concepts of objects and of actions are grounded in sensorimotor system and evoke a simulation is supported by much evidence. Accounting for abstract concepts, instead, represents a major challenge for the future of EG cognition, not easy to deal with. We have recently proposed that, to explain abstract concepts representation, not only sensorimotor experiences should be taken into account, but also linguistic experiences, considered in their social and emotional complexity. Further research is needed to address this fascinating challenge.

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