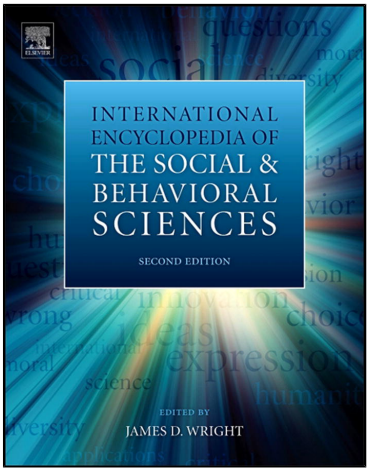

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Embodiment Theory

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Abstract

Embodied cognition (EC) views propose that cognition is shaped by the kind of body that organisms possess. We give an overview of recent literature on EC, highlighting the differences between stronger and weaker versions of the theory. We also illustrate the debates on the notions of simulation, of representation, and on the role of the motor system for cognition, and we address some of the most important research topics. Future challenges concern the understanding of how abstract concepts and words are represented, and the relationship between EC and other promising approaches, the distributional views of meaning and the extended mind views.

Definition of Embodied Cognition

Embodied cognition (EC) theory is intended as a response to the increasing dominance of the classic representational and computational theories of mind (RCTM) in cognitive science. Despite many versions of embodied theories, there are at least two commonalities between all EC approaches. The first is the view that cognitive processes are constrained by perception and motor processes, and therefore that the kind of body possessed by organisms shapes their cognition. The second is the refusal of the information processing model of the mind, and of the metaphor of the mind equated with software that manipulates symbols.

The view that perception and action contribute to cognition is in contrast with the classic view of cognition as separated from sensorimotor control, and that perception, cognition, and action are temporally and functionally independent processes. In contrast to this "sandwich model of the mind" (Hurley, 1998), proponents of EC underline the circularity of these processes, inspiring research programs aimed at showing that action influences both perception (Creem-Regehr and Kunz, 2010; Proffitt, 2006; Witt, 2011) and abstract thought (Goldin-Meadow and Beilock, 2010).

The second tenet, that is, the refusal of the view that cognitive processes involve computations on amodal representations (RCTM), leads to two different variants of EC. The critique advanced by proponents of the first variant is limited to the view that representations are amodal symbols, expressed in propositional format and arbitrarily linked to their referents (Fodor, 1975). In contrast, EC suggests that all concepts rely on the reactivation (or the simulation) of the sensorimotor experience with objects or events they refer to. The propositional approach has indeed to face the symbol-grounding problem (Harnad, 1990). In a nutshell, arbitrary symbols can be grounded only in other symbols, but in order to understand what objects are, we need to exit this vicious circle, 'grounding' the word meaning. The proponents of the first EC variant however, accept the computational side of the RCTM, bridging the gap between RCTM and EC. Accordingly, many EC theorists assume that cognition consists in computations on representation, but endorsing action-oriented representations expressed in bodily formats, including visuomotor, somatosensory, affective, and interoceptive formats (Goldman and de Vignemont, 2009). This EC variant is an improved version of the computational functionalisms on which RCTM is based. A more drastic critique to the second tenet comes from radical versions of EC (REC; Chemero, 2009; Hutto and Myin, 2013; van Elk et al., 2010; Wilson and Golonka, 2013) that refuse the assumption that cognition requires content of any kind. This antirepresentational version of EC abandons the idea that cognition requires content-involving representations and, given the RCTM mantra "no computation without representation", it also discards the computational thesis. Accordingly, REC considers cognition as a dynamical system characterized by continuously and interdependently changing variables that are better described by dynamic system theory (e.g., Spivey, 2007) than by representational explanations.

EC studies cover most areas of psychology and cognitive neuroscience (Borghi and Pecher, 2011; Davis and Markman, 2012; Chatterjee, 2010; Gentner, 2010), including development (Thelen and Smith, 1993), social cognition and emotions (Niedenthal, 2007; Semin and Smith, 2008; Becchio et al., 2010), attention, memory, and language (Barsalou, 2008; Pecher and Zwaan, 2005; Meteyard et al., 2012). Intriguing combinations between different research areas are emerging, including tighter relations between studies on attention, action, and social cognition (Galantucci and Sebanz, 2009; Knoblich et al., 2011). Aside from psychology and cognitive neuroscience, EC theories have developed in a variety of areas, including robotics and computer science (Ziemke, 2002; Arbib, 2006), linguistics (Lakoff, 2012), and philosophy (Chemero, 2009; Nöe, 2004; Hutto and Myin, 2013; Prinz, 2002; Shapiro, 2011).

Perception versus Action?

All EC approaches ascribe a crucial relevance to perception and action. However, the role played by perception or by action for

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cognition has been differently emphasized depending on the cultural tradition on which the various approaches relied. The theoretical background of EC can be found in American empiricism and pragmatism and in European phenomenological tradition. Even if some EC approaches underline the role of perception and other stress the importance of action, the two views are not incompatible; in addition, most EC theories emphasize the role of both, arguing that cognition is grounded in the sensorimotor system (see Borghi, 2005 for discussion).

The role of perception has been underlined in particular in research influenced by phenomenology. The "primacy of perception" was stressed by early phenomenologists, including Husserl and Merleau-Ponty, and inherited by contemporary phenomenologists (Gallagher and Zahavi, 2008). Furthermore, phenomenology impressed some of the early proponents of embodiment theories (Varela et al., 1991; Thompson, 2007). Finally, the interest in phenomenology offered new tools to study the body and its extensions (e.g., Berlucchi and Aglioti, 1997; Umiltà et al., 2008) and the relationship between the body and the self, stressing the dichotomy between body schema and body image, and that between sense of body ownership and sense of agency (Tessari et al., 2010; Tsakiris et al., 2007). The role of perceptual aspects has also been emphasized relying on the empiricist philosophical tradition, in particular on the work of Hume and Locke. Work by Barsalou and, on the philosophical side, by Prinz (2002), is in continuity with this tradition. According to the Perceptual Symbols Theory (Barsalou, 1999), no transduction process from sensorimotor experience to symbolic knowledge is necessary. Perceptual symbols, the building block of knowledge, have the combinatorial and productivity characteristics of arbitrary symbols, but they are modal rather than amodal, because they reflect the sensory qualities of the perceived entities. Stressing the role of perception has led some authors to remark the fact that bodily states do play a role but not an exclusive one. For this reason Barsalou and collaborators have proposed using the label 'grounded cognition' instead of 'embodied cognition' to underline the fact that cognition is grounded in a variety of situations, situated simulations, and not only in bodily states (Barsalou, 2008; Pezzulo et al., 2011).

The American pragmatist tradition and the ecological psychology of Gibson (1979) represent the theoretical background of the approaches that put a strong emphasis on action for cognition. Furthermore, an emphasis on the role of the motor system and of the overt behavior comes from the ordinary language philosophers, such as Gilbert Ryle and the late Wittgenstein. As nicely summarized by Wilson (2002) at the beginning of the EC wave, the principle underlying EC is that "knowledge is for action" – knowledge is both grounded and oriented to action. Accordingly, many authors described EC as a pragmatic turn in cognitive science, according to which cognition should not be understood as providing models of the world but as subservient to action, being grounded in sensorimotor coupling and in the ongoing interaction with the external world (Engel et al., 2013). In psychology, work on memory and on language grounding by Glenberg exemplifies this motor-oriented approach. In his BBS paper of 1997, significantly entitled "What Memory Is For," Glenberg argued that memory has an important adaptive role to support us in situated actions.

In neuroscience, the role played by the motor system in perception and cognition was emphasized by the research on the mirror and canonical neurons (Gallese et al., 1996; reviews: Rizzolatti and Craighero, 2004; Rizzolatti and Sinigaglia, 2010). Mirror and canonical neurons are located in the motor system and contribute to action execution. However, they support different cognitive processes. Mirror neurons are activated during the execution of a specific action and the observation of the same action performed by another agent, thus suggesting that the passive observation of actions recruits the corresponding motor representation in the observer motor system. After their discovery in different stations of the motor system, including the primary motor cortex, other similar mirror mechanisms have been found in emotional and sensory areas, suggesting that the perception and comprehension of others' intentional actions, emotional expressions, and somatosensory experiences depend on an implicit and automatic simulation within the sensorimotor system (see Buxbaum and Kalenine, 2010 for an embodied view according to which mirror neurons are not sufficient for comprehension of actions). The interpretation of the mirror neuron system offered by the Embodied Simulation theory (Gallese, 2001), according to which the observation of others' behavior triggers an automatic, subpersonal, and preconceptual simulation, provides an embodied account of intersubjectivity, in antithesis to the two cognitivist explanations of the theory of mind abilities (the theory–theory and the simulation theory). Furthermore, the mirror mechanisms opened new important perspectives in research on cognitive processes such as language comprehension and imitation, as well as a new key to interpret the social deficit in autism. Canonical neurons are premotor neurons that discharge both when interacting with objects and when passively observing them. Their discovery supports the view that perception involves the motor system and, in particular, the preparation of possible interactions with objects. This discovery contributed to launching studies and research on object affordances.

Ideomotor theories (Prinz, 1997) represent an important family of theories investigating the relationship between perception and action, and the goal-directed character of action. According to one of the most influent ones, the Theory of Event Coding (TEC) (Hommel et al., 2001), perceived events and actions rely on common representational structures, that is, they are represented by a network of feature codes. TEC predicts that perception is facilitated in case of overlap between the action an organism perceives and the action he or she is able to perform. Evidence in support of ideomotor theories ranges from imitation to attention to social cognition. For example, the compatibility between observed actions and responses influences the attribution of personal traits: finger-key responses lead to faster identification of individuals typing rather than performing sporty activities (Bach and Tipper, 2007). The mirror neuron system represents the neural underpinnings of ideomotor theories: our brain resonates more when observing actions we can reproduce than unknown action. Motor resonance has been documented in a variety of areas; a notable one concerns

empathy for others' pain (e.g., Avenanti et al., 2010; Iacoboni, 2009).

The Notion of Simulation

The concept of simulation was originally introduced in the field of social cognition, to account for our folk psychological abilities to predict others' behavior by ascribing mental states. This account was intended as a response to the theory–theory perspective, which conceives folk psychology as a theoretical and observational enterprise, suggesting that mindreading is rather based on using ones' own subpersonal models as the measure of everyone else's. In a seminal paper, Gallese and Goldman (1998) suggested a possible role of mirror neurons in mental simulation. More recently, theorists differentiated between an explicit (non-embodied) simulation, based on the view that simulation depends on a deliberative inference, versus an implicit, embodied simulation involving subpersonal activation of mirror mechanisms and shared representations (Gallese, 2005). Both versions were criticized by proponents of REC, suggesting that the resonance processes, including the mirror mechanisms, are part of the processes that underlie intersubjective 'direct perception' rather than simulation (Gallagher and Zahavi, 2008).

Besides of its use in social cognition, the concept of simulation was also used to account for the recruitment of the same perceptual, motor, and emotional system during the interaction with objects and entities in the world, as well as during imagery and language comprehension. Starting from this general idea, this notion now has a variety of connotations, also due to the different nuances that EC has assumed. Some authors intend simulation as a form of reenactment "of perceptual, motor, and introspective states acquired during experience with the world, body, and mind" (Barsalou, 2008), while others, underlining its predictive aspects, prefer to use the term 'motor simulation', intending it as a form of action preparation (Gallese, 2005; Grush, 2004). In addition, while some authors underline the implicit, automatic aspect of simulation (Jeannerod, 2006), others tend to equate it with a form of (motor) mental imagery, which may occur *a posteriori* (Decety and Grèzes, 2006). Finally, in their attempt to highlight dynamic and flexible aspects of cognition and to reject representations, REC avoids using the notion of simulation, particularly if intended as a form of reenactment.

The Agenda

EC theories have received ample support in a variety of domains. We will refer to some important areas, with no pretense of being exhaustive.

Affordances

The notion of affordance (Gibson, 1979) refers to the fact that objects invite organisms to act and suggest actions. For example, apples suggest grasping to humans, but not to worms. Affordances are therefore interactive properties, emerging from the relationship between organisms and environment, and pertain at the same time to perception and action. In the last years many studies have focused on affordances and 'micro-affordances', a term introduced by Ellis and Tucker (2000) to highlight both continuities and discontinuities with Gibson. Microaffordances are more specific that Gibson's affordances: they refer to action components (e.g., grasping) suitable for specific objects, thus implying object recognition. Furthermore, while Gibson's view is externalist and not focused on brain representations, microaffordances are neural representations corresponding to patterns in the brain of conjoint perception and action experiences. Numerous studies have demonstrated that observing objects activates affordances (e.g., grasping actions); recent work on affordances highlights their flexibility and contextual dependency (review: Thill et al., 2013).

Concepts and Words

According to all EC views, concepts and language are grounded in perception, action, and emotional systems (reviews: Coello and Bartolo, 2012; Fischer and Zwaan, 2008; Gallese, 2008; Jirak et al., 2010; Willems and Hagoort, 2007; special issues: Cappa and Pulvermüller, 2012; Cangelosi and Borghi, in press).

The influential Perceptual Symbols Theory (Barsalou, 1999) states that understanding concepts depends on the ability to form and use simulations. Thus, to decide whether a telephone rings we need to form a multisensory simulation. The phone ring is not stored in propositional terms, as a mental word; rather, it is the acoustic record of previous experiences with phones. This view received great impulse thanks to studies on representation of categories in the modal areas of the brain (Martin, 2007). EC views contrast with domain specific approaches, according to which in the brain there are innate categorical subsystems. Rather, concepts are intended as modality-specific distributed and flexible representations (Kiefer and Pulvermüller, 2012).

In continuity with this view, Zwaan (2004) proposes that comprehending language implies activating a simulation involving the motor system (see also Kemmerer, 2006). Many experiments have demonstrated that the activation in perception and motor areas during language comprehension is sensitive to the effectors (foot, hand, mouth), to kinds of affordances, to the bodily space (Ferri et al., 2011), to the direction implied by sentences (toward vs away from the body) (Glenberg and Kaschak, 2002), and to the emotional connotations of words (we tend to attract positive words and reject negative ones, Chen and Bargh, 1999); furthermore, it is highly flexible and sensitive to the context (van Dam et al., 2012).

In the strong EC perspective proposed by Glenberg (1997), concepts support us in selectively focusing on affordances allowing us to interact appropriately with objects. Hence, concepts are constrained by the kind of body we possess; for example, we conceive cups in terms of their distance from us, weight, and so forth – more generally, in terms of what we can do with them. Gallese and Lakoff (2005) argued that concepts and language exploit at a more sophisticated and higher level the multimodal character and the basic structures of the sensorimotor system (Anderson, 2010). In continuity with these views, Glenberg and Gallese (2012) have proposed that mechanisms of motor control have been exploited for language learning, comprehension, and

production (on the involvement of the same systems during language comprehension and production, see also Pulvermüller and Fadiga, 2010; Pickering and Garrod, 2013; on the idea that language evolves from manual gestures, Gentilucci and Corballis, 2006).

Body and Emotion

Given its disembodied view, cognitivism rarely paid due attention to the study of the body. In contrast, EC recovered some conceptual distinctions from phenomenology and neuropsychology, thus allowing neuroscientific investigations on the bodily experience and providing new insights on topics such as tool use, agency, and emotion.

The recovery of the distinction between body image and body schema, the former being a mental construct or a set of beliefs about the body, and the latter being a nonconscious model that monitors posture and movement (Gallagher and Zahavi, 2008), brings to a deeper understanding of different psychological disorders. At the same time, it shows that a number of objects, including prostheses and tools, can be incorporated into the body schema and perceived as part of one's own body. Notably, neurophysiological and neuropsychological evidence showed that the use of tools operating in the far space entails the updating of the map of the body schema and, as a consequence, it extends in the new operational space the peripersonal space anchored to the body (Maravita and Iriki, 2004). The above-mentioned distinction between sense of ownership and sense of agency (Tsakiris et al., 2007) is a further phenomenological distinction adopted by EC researchers, which has been largely used in the study of the bodily self, becoming a useful tool in the study of mental disorders such as schizophrenia (Ferri et al., 2012).

Finally, the attention to the bodily representations breathed new life into the debate on emotion. EC retrieved and renewed the somatic theory proposed by William James, according to which the emotional experience consists in the central representation of the bodily response to an emotional stimulus. New evidence revealed the existence of an afferent neural system that represents the physiological condition of the physical body (interoception), thus constituting a central representation of the 'material self' founding subjective feelings and emotions (Craig, 2002). Remarkably, this new link between interoception and emotion suggested that different psychological disorders, including neuroticism, social phobia, anxiety, and eating disorders, could be dependent on anomalous interpretations of the bodily interoceptive feedback. At the same time, the link between body and emotion contributed to the formulation of the 'facial feedback hypotheses' (Niedenthal, 2007), according to which the facial feedback affects the emotional experience; it follows that the motor production of emotional expression is part of the emotional experience, as predicted by early American pragmatists (Caruana and Gallese, 2012).

Critiques and Debates

EC has been the object of a lot of criticism. One of the most debated issues concerns the role played by the motor system in concepts and word processing. In an influential paper, Mahon and Caramazza (2008) argued that, even though the evidence showing that the motor system is involved in conceptual and language processing is indisputable, it can be explained through activation spreading from 'disembodied concepts' to the sensorimotor system interfacing with them. Hence, the role played by the sensorimotor system would be only epiphenomenal and not necessary for language comprehension. If it was necessary, then disruptions of the sensorimotor areas should impair language processing.

In contrast with this view, EC proponents argue that the motor system involvement is constitutive of the process. This is supported by evidence showing that the motor system activation occurs early, in an automatic, bottom-up fashion, and that it is somatotopic, that is, different areas of the brain are activated during processing of words related to action with different effectors, such as arms, legs, and mouth (pick, kick, lick) (Pulvermüller, 2005). The discussion is still open, however, because there are some controversial results. For example, not all studies have found early activation of the motor and premotor cortices during language processing; in addition, even if the motor system is modulated during language comprehension, there is evidence of both interference and facilitation (Willems and Franken, 2012); finally, evidence on patients is clear (review: Pulvermüller and Fadiga, 2010), but some clinical studies suggest that motor system lesions do not always lead to comprehension impairments. An interesting solution to this debate is advanced by enactivists (van Elk et al., 2010). As it has been proposed, the issue of necessity implies the idea that words are characterized by a core meaning, but enactivists underline that words are action oriented and contextual dependent, and that the human brain is plastic. This makes it possible to predict that comprehension is also possible when sensorimotor activation during language comprehension does not imply forms of reenactment.

Future Challenges

Some of the most important challenges for EC concern the explanation of abstract concepts and the relationship with other approaches, as the distributional approach and the extended mind view. One of the main challenges of EC is to account for concepts and words without concrete referents, such as 'phantasy'. Several EC theories of abstract concepts and words (ACWs) have been proposed (review: Pecher et al., 2011; special issues: Borghi and Pecher, 2011; Tomasino and Rumiati, 2013). Some views underline that the systems involved in concrete word representation are responsible also for representation of ACW, since not only concrete but also abstract words activate the motor system. Other EC theories underline the differences between concrete words and ACWs. The most influential theory claims that abstract concepts are represented in terms of concrete ones, through the mediation of metaphors (Lakoff and Johnson, 1999); for example, the abstract notion of time is explained in terms of the concept of space (Casasanto and Boroditsky, 2008). According to another view, ACWs differ from concrete ones due to their content: ACWs rely more on

situations and introspective features (Barsalou, 1999), and activate more emotions (Vigliocco et al., 2013). Recently multiple representation theories have been proposed (Dove, 2011; Barsalou et al., 2008). For example, according to the Words As Social Tools (WAT) view (Borghi et al., 2011; Borghi and Binkofsky, in press), both concrete words and ACWs are grounded in sensorimotor systems; however, for ACWs linguistic information plays a major role, due to their acquisition modality: they are primarily acquired through words rather than through interaction with their referents, and verbal labels help assemble sparse sensorimotor experiences.

Promising future directions concern the relationship between EC and two views emerging in different areas (computer science and philosophy), that is, distributional approaches (DA) to meaning and extended mind (EM) views.

DA and EC have been typically considered as antithetical. For example, according to the embodied Indexical Hypothesis (Glenberg and Robertson, 2000), words' referents evoke affordances, and these affordances constrain the relationships between words. In DA, meaning derives from the statistical co-occurrence of words in text corpora: from the relationship between associate words (real words, not mental words), not between words and their referents. Therefore words are not embodied, and the symbol-grounding problem is present. This distributive information is, however, able to account for many empirical findings, such as semantic priming effects. Recently some hybrid approaches have been proposed (review: Andrews et al., 2013). In hybrid views, conceptual processing is both linguistic and embodied, depending on the task (Louwerse, 2011). In EC multiple representation accounts, instead, access to meaning occurs only through simulation, but linguistic shallow tasks such as lexical decision can be performed without necessarily using full embodied simulations: linguistic distributional information can be used as a shortcut, allowing fast responses (Barsalou et al., 2008; Connell and Lynnot, 2013).

According to the extended mind (EM) view, the mind is not limited within the boundaries of our head/brain but is rather distributed in our brain, body, and external devices, which possess the power to augment our computational abilities (Clark and Chalmers, 1998). Even if many proponents of the EM view favor an embodied view, EC and EM views are typically considered independent perspectives, both because EM is more widespread in philosophy than in neuroscience and because of its functionalist flavor (Kiverstein and Clark, 2009). However, interesting convergences between these two areas are emerging (see Borghi et al., 2013; Borghi and Cimatti, 2010; Clark, 2008), particularly in research on the sense of the body and on bodily extensions.

See also: Cognition, Evolution of; Embodied Social Cognition; Health and Illness: Mental Representations in Different Cultures; Human Cognition, Evolution of; Mental Imagery: Visual Cognition; Mind, Theories of; Mirror Neurons, Theory of.

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