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Semantic embodiment, disembodiment or misembodiment? In search of meaning in modules and neuron circuits ☆

Friedemann Pulvermüller *

Brain Language Laboratory, Freie Universität Berlin, 14195 Berlin, Germany
Medical Research Council, Cognition and Brain Sciences Unit, Cambridge CB2 7EF, UK

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ABSTRACT

"Embodied" proposals claim that the meaning of at least some words, concepts and constructions is grounded in knowledge about actions and objects. An alternative "disembodied" position locates semantics in a symbolic system functionally detached from sensorimotor modules. This latter view is not tenable theoretically and has been empirically falsified by neuroscience research. A minimally-embodied approach now claims that action–perception systems may "color", but not represent, meaning; however, such minimal embodiment (misembodiment?) still fails to explain why action and perception systems exert causal effects on the processing of symbols from specific semantic classes. Action perception theory (APT) offers neurobiological mechanisms for "embodied" referential, affective and action semantics along with "disembodied" mechanisms of semantic abstraction, generalization and symbol combination, which draw upon multimodal brain systems. In this sense, APT suggests integrative-neuromechanistic explanations of why both sensorimotor and multimodal areas of the human brain differentially contribute to specific facets of meaning and concepts.

1. Introduction

Semantic and conceptual information is, at least in part, based on information in action and perception systems of the brain and mind. This position has sometimes been called semantic "grounding". All well-developed "embodied" theories adopt such semantic grounding in action and perception information, but also discuss mechanisms not specific to individual modalities which make additional contributions to semantic and conceptual processing (for example, Arbib, 2008; Barsalou, 1999, 2008; Fischer & Zwaan, 2008; Gallese & Lakoff, 2005; Glenberg & Gallese, 2012; Kiefer & Pulvermüller, 2012; Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012; Pulvermüller, 1999; Pulvermüller & Fadiga, 2010). In Barsalou's proposal, perceptual information processed in sensory systems along with resultant activation in multimodal systems jointly contribute to bottom-up concept processing (Barsalou, Kyle Simmons, Barbey, & Wilson, 2003). In my own proposals, neuronal circuits (cell assemblies) distributed over sensory, motor and multimodal association areas are the neurobiological correlates of meaningful words and constructions (Pulvermüller, 1999). A key concept is that of semantic circuits: cell assemblies that bind modality specific semantic information into a more abstract multimodal, and therefore in a sense "amodal"[1] and "modality-unspecific", representation (Fuster, 1995; Pulvermüller, 2012). These semantic circuits are widely distributed and can reach into modality-specific and multimodal areas of cortex. Crucially, semantic circuit topographies (their distributions over the cortex) can reflect aspects of the category-specific meanings they carry. As I explain in Section 3 below, this theoretical perspective covers all aspects of cognition sometimes claimed to be missing from some versions of embodiment theory, including mechanisms for abstraction, generalization and symbol combination.

A so-called "disembodied" perspective has been proposed according to which semantic representations and processes are located exclusively in amodal mind and brain systems. In this modular perspective, sensory and motor processes are viewed as being entirely "ancillary" to meaning and concepts. However, on the basis of theoretical arguments and recent evidence – for example the semantically specific influence of motor action on abstract sentence semantics (Glenberg, Sato, & Cattaneo, 2008) or the causal effect of magnetic stimulation of arm/leg motor areas on the

* Address: Brain Language Laboratory, Department of Philosophy and Humanities, Cluster of Excellence, "Languages of Emotion", Freie Universität Berlin, 14195 Berlin, Germany. Fax: +49 (0) 30 838 52273.
E-mail address: friedemann.pulvermuller@fu-berlin.de

[1] I normally tend to avoid the term "amodal" in this context, for reasons similar to those for calling a multilingual person multilingual and not alingual (or aphasic).

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processing of semantic subclasses of action-related words used to speak about arm or leg actions (Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005) – it is now generally acknowledged that action and perception systems, possibly interacting with additional multimodal (or "amodal") systems, can make semantically-specific contributions – at least to the processing of some semantic aspects of at least some words and constructions.[2]

However, this new evidence does not force one to adopt standard embodiment accounts. Coming from a modularist tradition, one may prefer a strategy to design a theory that builds on an amodal semantic system and just gives way to alternative proposals as much as it must under the pressure of the data. A disembodied approach with just a grain of embodiment has been proposed by Caramazza and his colleagues (for example, Bedny & Caramazza, 2011; Mahon & Caramazza, 2008). This present paper will discuss disembodiment along with such minimal-compromise positions (part 2), highlight their difficulties, and review an alternative, a view on abstract semantic mechanisms grounded in concrete neuronal brain circuitry (part 3). Relevant evidence is discussed throughout and is the focus of the final section (part 4).

2. Embodiment vs. disembodiment: multiple confusions

Theories are sometimes called *embodied*, because they ground cognitive processes in bodily action and perception (Barsalou, 2008; de Vega, Graesser, & Glenberg, 2008; Fischer & Zwaan, 2008; Kiefer & Pulvermüller, 2012; Meteyard et al., 2012). Note again that this position implies that action and perception mechanisms play a role in the semantics of at least some words, symbols and constructions, but it does not preclude other (nonmotor and nonsensory) mechanisms to contribute to semantics. Models including a semantic module encapsulated from action and perception systems are key examples of *disembodiment*. In modular models, conceptual/semantic, action and perception systems are each thought to be informationally encapsulated from each other, therefore excluding a direct contribution of action and perception information to meaning representation (Fodor, 1983). Consequently, action and perception mechanisms are not considered semantic (Mahon & Caramazza, 2008).

The above explanations of the terms "embodiment" and "disembodiment" may be shared by some, perhaps most, in the field, but they are not agreed upon generally. As a consequence, it is sometimes not clear what the dispute about embodiment is actually all about. Upon recent reviews highlighting the embodiment debate, the present section will specifically discuss misrepresentations of embodiment ideas ("misembodiment") and recent proposals of "minimal embodiment".

2.1. Confusions about embodiment: misembodiment

Caramazza and his group did not frame the contrast between embodiment and disembodiment as explained above. In their view, *embodiment* means "that conceptual content is reductively construed by information that is represented within the sensory and motor systems" (p. 59, Mahon & Caramazza, 2008) and "that concepts are no more than a recapitulation of sensorimotor experiences" (Caramazza, NLC2011 abstract). This vision of "embodiment" is not appropriate if it is meant as a description of current approaches. Not a single one of the major approaches to conceptual and semantic mechanisms shares these assumptions. As embodiment positions are fundamentally misrepresented by Caramazza and his colleagues, I will speak about *misembodiment* in this context.[3]

Caramazza et al.'s misrepresentation of embodiment theories leads these authors to state that, according to one of the key papers in the field of embodied cognition (Barsalou, 1999), concepts are "no longer embodied" (p. 68, Mahon & Caramazza, 2008). This is because, in Barsalou's model, convergence zones in "higher" association cortex receive a role in multimodal integration of information and concept processing, a key feature of this and most other models currently treated under the "embodiment" label. In my own work, I drew attention to the fact that the functional properties of neuron circuits enable them to approximate logical operations, including AND and OR,[4] a well-known fact which has been emphasized early for abstract neuron models (see Kleene, 1956; McCulloch & Pitts, 1943) and more recently for interlinked neuronal assemblies (e.g., Buzsáki, 2010; Hayon, Abeles, & Lehmann, 2005; Palm, 1982; Pulvermüller, 2002b; Wennekers, Garagnani, & Pulvermüller, 2006; Wennekers & Palm, 2009). Therefore, neuronal machines can easily accommodate abstract symbolic processes. If there are neuronal assemblies with strong links into cortical areas important for action and perception, which can therefore be called "embodied", these same circuits can certainly, at the same time, serve their normal function as "symbolic" processors. Such circuits would obviously do more than "recapitulating sensory experiences" although they would still be, in a sense, "embodied". In my view, many distributed neuronal sets carrying semantic function are both "embodied" and symbolic.

2.2. Confusions about the role of action perception circuits

Similar to disembodiment, Mahon and Caramazza propose "an 'abstract' and 'symbolic' level of conceptual content (...) not constituted by sensory and motor information". In Caramazza et al.'s hands, sensorimotor systems are allowed to functionally contribute to conceptual or semantic processing, although this contribution is described, rather metaphorically, as "coloring" or "dressing" the concept (p. 68f, Mahon & Caramazza, 2008). However, there is some lack of clarity as to what the terms "coloring" and "dressing" mean in this context. In line with the observation that colors and dresses can be put on an object but are not part of the object, Bedny and Caramazza further stress the idea of abstract concepts in "modality-independent" areas, now arguing *against* a role of sensorimotor systems in conceptual processing (Bedny & Caramazza, 2011). It therefore appears that, in this perspective, action and perception systems are seen as capable of changing the *appearance* (color, dress) of concepts, but not of changing their *essence*, which is contained in the "amodal" symbolic system.

As sensory and motor information is not viewed as "constitutive" or fundamental, removal of these systems should be possible without affecting conceptual or semantic content. However, the authors' statements in this context are vague. They write that "'removing' the sensory and motor systems (as in brain damage) would result in impoverished or 'isolated' concepts" and in this sense the "activation of sensory and motor processes during conceptual processing is not necessarily 'ancillary to' or 'inconsequential for' conceptual processing" (p. 68, Mahon & Caramazza, 2008). Note that these statements suggest a deficit, but are compatible

[2] Please note that there are signs that do not directly relate to objects and actions – most notably grammatical function words along with grammatical affixes (Pulvermüller, 1999) – and that even for very clearly object- or action-related expressions there are semantic aspects not captured by object or action links (Frege, 1980; Pulvermüller, 2012).

[3] To preclude any confusion: By "misembodiment", I mean misconceptions about embodiment and grounded cognition.

[4] As neurons are probabilistic devices, it is best to think of their symbolic capacities in terms of probabilistic logic.