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What Makes a Metaphor an Embodied Metaphor?

Abstract: What does it mean for metaphors to be "embodied"? Here we describe an influential theory of embodied cognition according to which thoughts are implemented in perceptuo-motor simulations, in the brain's modality-specific systems. This theory is invoked in nearly every paper on "embodied metaphor," across linguistics, philosophy, psychology, and cognitive neuroscience. There appears to be overwhelming support for the conclusion that representations of metaphorical "source domains" are embodied in perceptuo-motor simulations. Here we show, however, that when the data are evaluated appropriately there is very little evidence that metaphors are embodied in this sense. The kind of data that offer compelling support for the embodiment of concrete, literal ideas like "grasping the ball" are nearly absent for abstract, metaphorical ideas like "grasping the explanation." There is now abundant evidence that metaphors structure our thoughts, feelings, and choices in a variety of conceptual domains. But evidence for metaphorical mental representation is not necessarily evidence for embodiment. If any metaphorical source domains are embodied in modality-specific simulations, they may be the exception rather than the rule.

Keywords: Conceptual Metaphor Theory, embodied cognition, mental metaphor

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1 Mental metaphors

Metaphors aren't just ways of talking, they are ways of thinking. This claim, the central message of Conceptual Metaphor Theory (Lakoff and Johnson 1980, Lakoff and Johnson 1999), was once supported only by analyses of metaphorical language. Since the turn of the twenty-first century, however, experimental tests of metaphor theory have accumulated at an astonishing rate. There is now abundant evidence that people think metaphorically, across numerous conceptual domains, even when they are not using metaphorical language (for reviews, see Casasanto and Bottini 2014; Landau et al. 2010). For example: (1) when people experience physical warmth they feel "more warmly" toward their friends, expressing more emotional attachment to them (Ijzerman and Semin 2009; see also Citron and Goldberg 2014a; Williams and Bargh 2008). (2) When people see words presented closer together in space, they judge them to be "closer" in meaning (Casasanto 2008; see also Boot and Pecher 2010; Winter and Matlock 2013). (3) When people move objects upward they tend to retrieve more positive autobiographical memories (i.e., times when they were feeling "up" or "high on life"), and when they move objects downward they retrieve more negative memories (Casasanto and Dijkstra 2010; see also Brunyé et al. 2012; Crawford et al. 2006; Meier and Robinson 2004; Riskind 1983; Tracy and Matsumoto 2008).

These studies test three of what Lakoff and Johnson (1999) identified as "primary metaphors" (Affection is Warmth, Similarity is Proximity, and Happy is Up), and what we will refer to more generically as "mental metaphors," which are implicit associations between two analog continuums: the "source domain" continuum, which is typically more concrete and can be experienced directly through the senses (e.g., touch for warmth, vision for spatial proximity or height), and the "target domain" continuum which is typically more abstract and

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can only be experienced through introspection (e.g., affection, similarity, happiness).[1] These examples, like many other mental metaphors, are typically referred to as "embodied metaphors." The notion that mental metaphors are embodied is deeply entrenched in growing literatures spanning linguistics, philosophy, psychology, and cognitive neuroscience, and theories of metaphor and embodiment often appear mutually inextricable (Gallese and Lakoff 2005; Gibbs 2003; Lakoff 2014; Lakoff and Johnson 1999; Shapiro 2011).

The goal of this paper is to raise the question: Are mental metaphors necessarily "embodied"? What precisely does this claim mean, how can it be evaluated, and what's the evidence for it? Here we will describe the theory of embodiment most commonly invoked by papers on mental metaphor and explain the predictions this theory makes about the way source-domain representations are instantiated in the brain. We then discuss how this theory can and cannot be tested, and evaluate the evidence that mental metaphors are embodied, in this sense.

2 What do we mean by embodiment?

What does it mean for thoughts to be "embodied"? Although embodiment can mean many things, we use this term as it is used in a landmark paper by Lawrence Barsalou (1999), and in the more than 4,000 papers that have cited it to date. According to Barsalou's theory of embodied cognition, thinking involves constructing "simulations" of bodily experiences. People interact with the world via multiple input and output "modalities": we see a car's shape, hear its engine, grip the wheel with our fingers, smell that new-car scent, and experience the thrill of the open road. Each of these perceptual, motoric, and affective components of the "car" experience is implemented initially in different modality-specific neural systems, which include brain structures that are highly specialized for one input or output modality: visual cortex, auditory cortex, somatosensory cortex, motor cortex, olfactory cortex, and structures in the limbic system that enable us to experience emotions. This information is then rapidly integrated in multimodal neural "convergence zones" that receive inputs from various modality-specific systems (Barsalou et al. 2003; Damasio 1989). Each episode of interacting with cars leaves a memory trace in these convergence zones, resulting in a schematic long-term memory representation that is built out of modality-specific information accumulated over an individual's experiences. Barsalou (1999) calls this representation in long-term memory a "simulator."

When you think about cars or use the word "car," this simulator is activated and it produces a "simulation," which according to Barsalou and colleagues (1999, 2003), is a partial re-enactment of your previous car experiences. Crucially, this simulation involves activity in the same modality-specific input and output areas of the brain that allow us to interact with cars in the first place. On this view, a simulation constitutes an instantiation of a concept or a word's meaning. The neural activity that occurs when simulators are creating simulations *is not limited to modality-specific brain areas*, but modality-specific neural activity is the *sine qua non* of embodied simulations.

Observing modality-specific neural activity is the *only way* to distinguish embodied simulations from disembodied (or non-embodied) alternatives according to which thinking happens entirely in modality-nonspecific areas of the brain (Fodor 1983).[2] A modality-nonspecific brain area could be "multimodal,"

1 We use the term "mental metaphor" as a generic alternative to Lakoff and Johnson's (1980, 1999) brand-name "conceptual metaphor," with the goal of freeing metaphor theory from some of Conceptual Metaphor Theory's commitments – such as the commitment to metaphors' developmental origins (see Casasanto 2008; Casasanto 2009; Casasanto 2010; Casasanto 2013 for discussion). Furthermore, the term "conceptual metaphor" is often used ambiguously, sometimes to refer to conventions in language and other times to hypothetical nonlinguistic associations in memory; we avoid this ambiguity by using the term "linguistic metaphor" for the former and "mental metaphor" for the latter. The term "mental metaphor" was used differently by Gentner and Gurdin (1985) to mean "a metaphor for the human mind" (e.g. Minds are Computers); our use of the term is much broader.

2 Here a "disembodied" theory is one that assumes thinking happens entirely in amodal symbols. A "non-embodied" theory (or result) is one that is agnostic to a role for modality-specific simulation in thinking.

meaning that it integrates information from multiple modalities, and that this information retains some trace of its modality-specific origins. Alternatively, it could be "amodal," meaning that modality-specific input is transformed into some common representational format and stripped of all modality specificity. At present, there is no way to distinguish these possibilities; thus, simulation theories can only be tested in modality-specific parts of the brain. For an experiment to support an embodied simulation claim, it must provide clear evidence that an observed behavior (e.g., understanding a word) corresponds to modality-specific neural activity: this is the minimum requirement for an experiment on embodiment to have "construct validity" (i.e., for it to test what it claims to be testing).

2.1 Why is it important to know whether metaphors are embodied in simulations?

Why is it important to find out whether mental metaphors are implemented by modality-specific simulations?

> [M]etaphor theory may be of critical importance for advancing embodied theories of mental representation[.] Theories of embodied cognition, such as Barsalou's Perceptual Symbol Systems, posit that concepts are constituted, at least in part, by mental simulations of our perceptions and actions. […] Abstract concepts, however, present a serious challenge for embodied theories: Thinking about concrete objects and actions may involve perceptuo-motor simulations, but how can we perceptually simulate things that we can never perceive? (Casasanto 2008: 1048)

Metaphorical target domains like "similarity" and "importance" are imperceptible. By contrast, the source domains of primary metaphors are, by hypothesis, schematic representations of perceptuo-motor experiences (Lakoff and Johnson 1999): the kind of experiences that could be represented in perceptuo-motor simulations. If metaphorical source domains are embodied in modality-specific simulations, they can help to address the problem of embodying imperceptible concepts in perceptuo-motor areas of the brain (Casasanto 2008, Casasanto 2009) – a problem which, some critics have suggested, threatens to make all of embodied cognition a nonstarter (Mahon and Caramazza 2008).

Not everyone agrees that mental metaphors could be an important part of a theory of embodied cognition. Although Barsalou (1999) is regularly cited as having suggested that abstract concepts are embodied in metaphors, what this influential paper actually proposed is that "a direct, non-metaphorical representation of an abstract domain is essential," and that "perceptual symbol systems can represent all abstract concepts directly" (Barsalou 1999: 600; see also Barsalou and Wiemer-Hastings 2005; Prinz 2002). On this proposal, abstract concepts can be embodied without metaphor.

Conversely, mental representations can be metaphorical without being embodied. How? Representations of source domains like space are not necessarily implemented in modality-specific brain areas. Perceiving the distance between two points on a computer screen requires visual cortex, but representing this distance subsequently (in the absence of explicit visual imagery) may not; representations of spatial distance appear to rely most critically on parts of the parietal lobe that process information from multiple modalities. Our argument here is that metaphor theory *could help* to solve a hard problem for embodied cognition, but it is an empirical question whether it *does help* – that is, whether source domain representations involve modality-specific brain areas.

2.2 Behavioral (non-) evidence for embodiment of source domains

Are metaphorical source domain representations embodied in modality-specific simulations? According to a large behavioral literature, the answer is yes. Yet, according to our minimum requirement for testing embodied simulation theories, most of these studies do not support this answer. Almost without exception, studies that are framed as *addressing the question* whether mental metaphors are embodied actually *beg the* *question*, committing the reasoning fallacy known as *petitio principii* – asserting the critical conclusion without offering any evidence for it.

To illustrate this problem we will focus on the Good is Up mapping, which has been validated by many behavioral experiments and provides one of the richest sources of experimental evidence for mental metaphor. The earliest Good is Up experiments were conducted decades before theories of mental metaphor and embodied cognition were framed. For example, Wapner et al. (1957) found that participants who had just received a good grade on a test showed an upward bias when bisecting a square. Years later Stepper and Strack (1993) found that people expressed more pride in their performance when they were forced to sit up straight rather than slumping down. People are faster to judge the valence of positive words like "loyal" when they appear at the top of a screen, and negative words like "cruel" when they appear at the bottom (Meier and Robinson 2004). The valence of pictures biases people's memories for their locations. Participants tend to misremember positive pictures as having appeared higher on a computer screen than negative pictures presented in the same locations (Crawford et al. 2006). Likewise, when asked to recall the locations on a map where positive and negative incidents occurred (e.g., winning a prize vs. having an accident), the locations of positive events tend to be shifted upward in people's memories, and the locations of negative events shifted downward (Brunyé et al. 2012).

Across cultures, people spontaneously elevate the chest or raise the arms above the head to express pride, and hang the head or slump the shoulders to express shame. Accordingly, upward- and downward-directed bodily actions can influence the retrieval of emotional memories. People retrieve positive memories more efficiently when smiling and sitting erect, and negative memories more efficiently when frowning and slumping down (Riskind 1983). Even congenitally blind people express pride and shame with upward and downward postures and gestures, although they have never seen these behaviors modeled by other people (Tracy and Matsumoto 2008).

A study by Brookshire et al. (2010) established the automaticity with which space-valence associations can be activated. Participants saw positively or negatively valenced words (e.g., hero, villain) presented in the center of a screen in either purple or green font, and pressed a button that matched the font color. Pressing one button required an upward movement, and the other a downward movement. Participants responded faster when the direction of movement was congruent with the valence of the word (up for positive, down for negative) than when direction and valence were incongruent. This space-valence congruity task, in which neither the meanings of the words nor the directions of the responses were relevant, has been replicated and extended in subsequent studies (e.g., Santana and de Vega 2011; Dudschig et al. 2014). Together, this body of studies illustrates that people activate nonlinguistic mental representations in the source domain of vertical space with a high degree of automaticity when they process the target domain of emotional valence.

But what is the nature of these spatial source domain representations? Are they embodied simulations? In their study of vertical space-valence associations, Santana and de Vega (2011) concluded that "metaphors are embodied" (p. 1), and that the congruity effects they reported were the result of "motor simulations" (p. 10). Likewise, Dudschig et al. (2014) referred to their findings as "simulation effects" (p. 20), and suggested that they reflect "reactivation of experiential sensorimotor traces in the brain" (p. 14). These claims about the embodiment of space-valence mappings are prefigured or echoed by many similar claims, from numerous supposed tests of "embodied metaphors" such as Power is Height (Schubert 2005), Importance is Weight (Jostmann et al. 2009), Time is Motion (Miles et al. 2010), Evil is Darkness (Sherman and Clore 2009), and Suspicion is Fishy-Smelling (Lee and Schwarz 2012); etc. Yet, there is simply no evidence to support these papers' assertions that their metaphor congruity effects are due to the embodiment of source domain representations.

The idea that mental metaphors are embodied may arise, in part, from the belief that they are learned through habits of bodily experience. For example, vertical space-valence associations *could* develop as people learn correlations between bodily postures and the emotions that accompany them: people stand tall when they feel proud or happy, and slouch when they feel sad or ashamed (Lakoff and Johnson 1999). Although there has been much written about the presumed bodily origins of primary metaphors, there is almost no experimental evidence to support this presumption (Casasanto 2009; Casasanto 2013). More to the point, even if a mental metaphor *were* learned through correlations in direct bodily experiences with the source and target domains, this would not imply that its source domain gets instantiated later via modality-specific simulation. The studies reviewed above provide a wealth of evidence for a Good is Up mapping in people's minds, but they provide no evidence that the spatial source-domain representations activated during these experiments are implemented in modality-specific neural systems. And there are good reasons to believe they may not be.

2.2.1 Non-embodied explanations for behavioral results

Non-embodied alternative explanations are readily available for the source-target congruity effects reviewed above – explanations that rely on basic principles of perception, language, and memory that are much older and better-established than embodied simulation is. Consider the highly cited space-valence congruity effect reported by Meier and Robinson (2004) in which participants were faster to judge the valence of positive words when they were presented at the top of the screen and negative words presented at the bottom. This is a stimulus-stimulus congruity (SSC) effect. The study by Brookshire et al. (2010) in which upward movements were faster for positive words and downward movements for negative words is a stimulus-response congruity (SRC) effect. In both SSC and SRC effects, the semantics of a stimulus word are either congruent or incongruent with a spatial aspect of the stimulus or the response. Such spatial-semantic congruity effects were extensively studied prior to the rise of interest in embodied cognition, and were described for decades in perfectly disembodied terms (e.g., Banks et al. 1975; see Kornblum et al. (1990) and Lu and Proctor (1995) for reviews). There is, therefore, neither any need nor any justification for interpreting space-valence congruity effects as evidence for embodied simulation of percepts or actions.

To make this point clear: the theory of embodied simulation could be *100% false*, and the space-valence congruity effects reviewed above (and related effects) would still be easy to predict and explain, on the basis of well-established principles of perception, language, and memory that predate embodied cognition.

How could spatial-semantic congruity effects be disembodied? People experience space through the senses, so aren't spatial representations inherently embodied? No. Space is experienced through multiple modalities (e.g., vision, touch, audition), and spatial information from different input modalities must be integrated – this integration allows us, for example, to determine how large an object will appear to be visually based only on the sound that it makes (e.g., imagine judging the visual size of a soda can vs. an oil drum based upon hearing someone hit them with a spoon). The fact that we can integrate spatial information across multiple modalities suggests that at least some spatial representations may be modality-nonspecific. And indeed, most research in the cognitive neuroscience of human spatial cognition has focused on brain areas that are modality-nonspecific. Spatial source-domain representations (and other source-domain representations) could, in principle, be implemented exclusively in modality-nonspecific brain areas (see Section 2.3); none of the behavioral experiments reviewed above allow us to distinguish modality-specific (embodied) from modality-nonspecific (non-embodied) source domain representations.[3]

3 Due to space constraints, we omit discussion of an influential set of studies by Arthur Glenberg and colleagues (2002, Glenberg, Sato, and Cattaneo 2008a, Glenberg, Sato, and Cattaneo 2008b) which has been interpreted as evidence that people's understanding of the metaphorical "transfer" of information from one person to another is represented via motor simulations. We do not believe the studies support this conclusion, in part for reasons articulated here. However, these innovative studies merit full consideration, and are discussed at length in Casasanto and Gijssels (2014). For the time being, we note that (a) these studies include one of the most ingenious attempts to date to test the simulation hypothesis using behavioral methods (Glenberg et al. 2008a), and that (b) still, we do not believe the attempt was successful. These studies do not constitute an exception to the generalizations we make here about obstacles to testing simulation claims with behavioral methods.

2.2.2 Summary of behavioral (non-) evidence for embodied source domains

There is a large and rapidly growing body of behavioral studies claiming support for "embodied metaphors," and specifically claiming evidence for perceptuo-motor simulations underlying metaphorical source domains. Findings in this literature have, on the whole, been misinterpreted. Many behavioral results showing activation of source-domain representations during target-domain processing *do* provide evidence for metaphor theory, and may be important in this regard. But they *do not* provide evidence for embodiment. On the basis of the results reviewed above, it is impossible to determine whether source-domain representations are instantiated in modality-specific or only in modality-nonspecific neural systems; that is, it is impossible to determine whether they are embodied or disembodied, in the senses of these terms described by Barsalou (1999) and invoked by nearly every paper in this literature.[4]

2.3 Neural (non-) evidence for embodiment of source domains

In contrast with the numerous behavioral studies in our testbed of vertical space-valence associations, we are aware of only one neuroimaging study that addressed the critical question: are spatial source-domain representations embodied or disembodied? Quadflieg and colleagues (2011) asked participants to distinguish "high" vs. "low" stimuli of four kinds while they underwent functional magnetic resonance imaging (fMRI): shapes presented at the top or bottom of a screen, words referring to objects associated with high or low locations in space (e.g., attic, basement), words associated with power or powerlessness (e.g., boss, intern), and words associated with positive or negative valence (e.g., beauty, tragedy). The authors used a statistical technique called multivoxel pattern analysis (MVPA) to determine the neural correlates of visual height judgments, and then tested whether information from this analysis could be used to discriminate the "height" of items in the verbal conditions: literal spatial height, power, or valence.

Of primary interest, the MVPA classifier that was trained on high and low shapes was also capable of discriminating brain activity corresponding to words referring to objects associated with high and low spatial locations, and to words with positive and negative valence. However, the activity associated with valenced words was not found in modality-specific brain areas. Visuo-spatial information is processed in some modality-specific and some modality-nonspecific brain areas. Since the classifier algorithm was trained on visually presented shapes, in principle it should have been capable of revealing activity associated with literal or metaphorical height within visual cortex; it did not. Rather, "high" and "low" valence were discriminated in the intraparietal sulcus and the supramarginal gyrus – two regions known to be involved in processing spatial information (and other information) across multiple modalities. This experiment was capable of providing evidence that spatial source-domain representations activated during valenced word processing are embodied simulations – but it did not. Nor did it simply produce a null result. It produced evidence that spatial source-domain representations for valence are implemented in modality-nonspecific brain areas, failing to support an embodied neural implementation of Good is Up.

What about the other mental metaphor tested in Quadflieg et al.'s (2011) experiment, Powerful is Up? The MVPA classifier trained on visuo-spatial height did not succeed in discriminating brain activity associated with high- and low-power words. The "power" condition of the experiment produced a null result. This outcome should not be interpreted as evidence against the psychological reality of the mental metaphor Powerful is Up, which has been supported by numerous behavioral experiments (e.g., Schubert

4 How could so many studies be so confused about what constitutes evidence for embodied simulation? It is easy to posit an explanation for confusion concerning supposed tests of whether metaphors are embodied; inferential problems may be inherited from similar behavioral studies that sought to demonstrate that simulations underlie the meanings of words for objects with canonical spatial locations (e.g., Estes et al. 2008; Zwaan and Yaxley 2003). Explaining how this crisis of evidence arose lies beyond the scope of this article (see Casasanto and Gijssels 2014); the crisis is not limited to studies on mental metaphor. Rather, it extends to nearly all behavioral studies that have attempted to test simulation claims.

2005). It should, however, be interpreted as a failure to provide evidence that the source domain of this mental metaphor is embodied. Papers reporting behavioral space-power congruity effects have expressly claimed that "the concept of power is embodied in vertical spatial positions" (Schubert 2005: 16), and that thinking about power "involves a perceptual simulation of vertical differences in space" (Schubert 2005: 3). Yet, these behavioral experiments are not capable of testing these claims, and the one relevant neuroimaging experiment provided no support for the claim that power is embodied in modality-specific simulations.

Do neuroimaging or neurostimulation studies show that the source domains of other mental metaphors are embodied? Not really. Language about the motor system has provided the most fruitful testbed for the embodiment of concrete, non-metaphorical concepts. Parts of the motor system in the human cerebral cortex are organized "somatotopically," meaning that there is a point-for-point correspondence between areas of the brain and parts of the body: hand areas in the primary motor and premotor cortices are responsible for planning and executing hand movements, whereas foot areas are responsible for foot movements, etc. Across numerous studies, language about hand and foot actions has been found to cue somatotopic activity: hand verbs like "throw" and "write" activate hand areas more than foot areas, and vice versa for foot verbs like "kick" and "step" (for reviews see Willems and Casasanto 2011; Pulvermüller 2005).

Several studies have contrasted literal vs. metaphorical or idiomatic uses of action verbs. In an fMRI experiment by Aziz-Zadeh et al. (2006), participants read matched literal and metaphorical action phrases (e.g., grasp the pen; grasp the idea), and also watched videos of literal actions (e.g., grasping a pen). Motor areas that were active during action observation were also active when participants read literal phrases about these actions – but not while they read metaphorical phrases with the same action verbs. This study by Aziz-Zadeh et al. adds to the body of evidence that language about literal action concepts is understood, in part, via modality-specific motor simulations. But it provides no evidence that simulations underlie the use of these action concepts as metaphorical source domains. Like the study by Aziz-Zadeh et al., other fMRI studies have also found motor simulation during literal uses of action language, but not during nonliteral uses (e.g., Desai et al. 2013; Raposo et al. 2009; Rueschemeyer et al. 2007).

Three neuroimaging studies (Boulenger et al. 2012; Desai et al. 2011; Lauro et al. 2013) and a neurostimulation study (Cacciari et al. 2011) have reported somatotopic motor activity during action metaphors or idioms. Although somewhat encouraging, these studies did not follow the most conservative statistical procedures to avoid false-positive results (e.g., testing for required higher-order interactions or correcting adequately for multiple comparisons). In light of the repeated null results from previous tests of somatotopy for action metaphors, results that are not supported by the most rigorous statistical tests should be treated with caution. It appears that "grasping the pen" is understood, in part, via embodied simulation, but "grasping the idea" may not be.

fMRI studies have tested for source-domain related activity in other modalities, including touch (Lacey et al. 2012) and taste (Citron and Goldberg 2014b). Lacey and colleagues asked participants to read sentences with tactile metaphors (e.g., she had a rough day) or non-tactile control sentences (e.g., she had a bad day). Sentences with tactile metaphors elicited more activity in parietal areas known to be active during tactile perception. Similarly, Citron and Goldberg asked participants to read taste metaphors (e.g., she looked at him sweetly) or non-gustatory paraphrases (e.g., she looked at him kindly), and found greater activity during the metaphorical sentences in brain areas known to be active during gustatory perception, including the anterior insula, orbitofrontal cortex, and inferior frontal gyrus.

These findings are hard to interpret with respect to embodied simulation because the source-domain related activity was found in modality-nonspecific brain areas. The parietal lobe processes many kinds of input: not just touch. If tactile metaphors had activated hand areas of the somatosensory cortex, this result could have supported an embodied simulation claim in the study by Lacey et al. (2012). Likewise, in the study by Citron and Goldberg (2014b), source-domain related activity was found in massively multifunctional brain areas, which are activated during gustatory perception but also during many other cognitive and perceptual processes. These results, therefore, underscore the message of the fMRI study by Quadflieg and colleagues (2011) on space-valence mappings: source-domain related activity can be detected in the cerebral cortex, but for the most part it is found in modality-nonspecific brain areas.

Together, these results offer no clear support for the embodiment of mental metaphors. On the contrary, they suggest that source-domain representations are implemented in multi-modal or amodal brain areas – not in modality-specific simulations.

3 Summary and conclusions

There is strong evidence that people think in mental metaphors, and strong evidence that some of our thinking is embodied. But there is very little evidence that mental metaphors are embodied in modality-specific simulations. On the contrary, there is evidence that some mental metaphors are *not* embodied in this sense. There is, therefore, a Grand Canyon-sized gap between the strength of many researchers' belief in "embodied metaphors" and the strength of the evidence on which their beliefs should be based.

For a mental representation to be "embodied" in the sense most commonly invoked by metaphor researchers, it must be instantiated at least in part by a simulation of prior or potential bodily experiences, within modality-specific components of the brain's input and output systems (e.g., visual cortex, motor cortex; Barsalou 1999). There is only one way to demonstrate that a mental metaphor is embodied in this sense: show that source-domain representations are implemented in particular modality-specific systems. We do not claim that the neural substrates of mental metaphors should be *limited* to modality-specific areas, but at present there is no way to determine whether modality-nonspecific areas are supporting multimodal or amodal representations. Therefore, at present, it is only by testing for activity in modality-specific brain areas that embodied and amodal theories can be clearly distinguished; only modality-specific brain areas are useful for testing the embodied simulation hypothesis.

It is clear, then, what kind of data would be needed to support the embodiment of mental metaphors: if Understanding is Grasping is embodied, then activating the target domain of "understanding" should elicit source-domain activity in primary or premotor hand areas; if Knowing is Seeing is embodied, then activating the target domain of "knowing" should elicit source-domain activity in visual cortex; etc. To date, these predictions have almost no empirical support.

Dozens of behavioral studies have been interpreted as evidence for embodied metaphors. Most of these studies cite Barsalou's (1999) simulation hypothesis and claim to provide evidence that source-domain representations are implemented in perceptuo-motor simulations. In general, however, this claim is unsupported. Most behavioral experiments are incapable of fulfilling the minimum requirement for construct validity in a test of embodiment: evidence of modality-specific brain activity corresponding to the linguistic or cognitive process of interest (cf., Glenberg et al. 2008a). Therefore, most behavioral studies are not valid tests of embodiment, and their conclusions about perceptuo-motor simulation are misleading.

Even so, many behavioral studies of mental metaphor are valuable for at least three reasons. First, although these studies *do not* provide evidence for embodiment, many *do* support metaphor theory in creative and compelling ways. We now know that people activate source-domain representations with a surprising degree of automaticity when they process a variety of target domains. The profusion of experiments on mental metaphor over the past decade has transformed the landscape of evidence; it is no longer the case that metaphor theory is supported by analyses of linguistic metaphors, alone (Murphy 1996). Second, the behavioral study of mental metaphor has brought together communities of researchers who might not have interacted otherwise, from linguists and philosophers to psychologists (cognitive, social, developmental, clinical) and cognitive neuroscientists. Third, these behavioral studies provide evidence for a prerequisite to a theory of embodied metaphor: in order for people to activate *embodied* source domain representations, they must activate source-domain representations *of some sort*.

What sort of source-domain representations do people activate? Studies that allow observation or manipulation of neural states can address this question, and there is now a body of neuroimaging and neurostimulation experiments on mental metaphor. On the whole, they do not support the embodiment of source domain representations. Some show weak or null results. Others show clearly non-embodied results: source-domain representations are detected only in modality-nonspecific areas of the brain.

Perhaps these findings should not come as a surprise. “Image schemas” (Lakoff and Johnson 1999) such as verticality, containment, and support, which are hypothesized to be at the heart of source-domain representations, are highly abstract compared to percepts and actions. Even if image schemas are acquired through perceptuo-motor experiences, they are abstracted away from the particulars of those experiences. Mental metaphors could comprise source-domain representations derived from perceptuo-motor experience and stored in multimodal convergence zones, even if they do not typically involve modality-specific simulations. Testing this proposal awaits the development of methods that can distinguish *amodal* representations from *multimodal* representations in modality-nonspecific brain areas.

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