

Organization and Structure of Conceptual Representations

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Abstract

This chapter addresses a question at the intersection of language production and semantic memory: what are representations of word meanings like? An important problem this raises is how the abstractions used in thought and language make contact with the world accessed through the senses. Proposals from embodied cognition deny the distinction between sensory representations and processes and conceptual ones. Evidence about the neural basis of conceptual knowledge is reviewed to critically assess the claims of the embodied view, and to support the opposing conclusion that conceptual representations are in part distinct from sensory-motor representations. Furthermore, any shared neural resources drawn on by perceptual and conceptual tasks are not interpretable until their representational properties are described. Instead, research that specifically characterizes supramodal representations in the brain may be the best route to understanding the neural basis of conceptual knowledge.

Key Words: cognitive neuroscience, conceptual knowledge, semantics, words, embodiment, perception, neuroimaging

Language production begins with the selection of meaning, before it can proceed to the selection and articulation of words. Thus, two important questions spanning both language production and semantic memory are: (1) What are representations of word meanings like? (2) How are these meanings attributed to words? Starting with the second question, which remains largely unanswered, this chapter proceeds to the first (what are meaning representations like), and considers in particular how neural evidence can inform the answer.

From Where do Words Obtain their Meaning?

One relatively simple solution to the question of how words map onto meanings is to assume that words obtain their meanings from associated lexical concepts (Levelt, Roelofs, & Meyer, 1999). This relationship is possible to the extent that there is a

one-to-one mapping between lexical concepts and lexical nodes; unfortunately, there are several reasons this is not the case. First, there is a slippery relationship between words and their various related senses (i.e., polysemy; Caramazza & Grober, 1976; Ravin & Leacock, 2000; Murphy, 2002). A second reason is that the presumed borderline between world knowledge and the set of clearly defined lexical concepts is not only arbitrary, but also not psychologically real. Some encyclopedic knowledge must form part of the lexicon to allow us to understand even simple sentences, such as the distinction between “to bake a cake” and “to bake a potato,” such that only in the former is there a sense of creation (Pustejovsky, 1995). If there are lexical concepts, one must explain how they are carved out of the rest of conceptual knowledge. Thus, the problem of word meanings is really a problem of semantic knowledge. It is with this topic that the rest of the chapter is concerned.

Models of Semantic Knowledge

There are two principal stances on the representation of meaning: either concepts¹ obtain their meaning from relations to other mental representations, or they obtain their meaning via a relationship to the world (Putnam, 1975; Margolis, 1998; Fodor, 1990). This distinction falls alongside the difference between views in which concepts are structured compositions of smaller units (componential view) and concepts that are holistic (atomic view). Under the atomic view, concepts have no structure or components; each concept's meaning is derived directly from its particular causal relationship with things in the world to which it refers² (Fodor, 1990; Laurence & Margolis, 1999). The holistic view has as its burden to explain how such a causal relationship is established and is maintained (see Margolis, 1998, for one possibility). Because an answer to this question must refer to mental representations and processes, the holistic view must face the same psychological problem as the componential view, of how something in the world is recognized and categorized.

The partial answer offered by componential theorists is that concepts break down into primitive components, by which we recognize instances of categories. This account must also explain the nature of this vocabulary of primitive elements, and how each of them links both to concepts and to the world.

Psychological investigation of concept knowledge typically assumes the componential stance (Muphy, 2002; Smith & Medin, 1981). Most of such research therefore begins with the question, what are the components? In which kinds of structures and processes do they participate? Two sorts of answers have classically been pitted against each other. In the *conceptual* componential view, the components are other concepts; in the empiricist version, the elements can be only sensory impressions. This distinction has been of recent concern in the literature on semantic memory, and therefore forms the focus of this chapter.

The Conceptual Componential Stance

In many models of semantic memory, the components comprising semantic knowledge are themselves categories (abstract properties, such as "wing" and "tail"; and taxonomic designations, such as "bird" and "animal"). For instance, semantic network models (e.g., Collins & Loftus, 1975) describe conceptual meanings as constituted by a set of links

to other concepts. Distributed semantic network models (Rogers & McClelland, 2004) offer a related characterization, albeit without being implemented with localist units that explicitly stand in for components.³ Yet other models propose that concepts are represented by the features of a prototypical member of a category rather than by a strict set of defining features (Rosch, 1978, 1999). The conceptual structure account (Tyler et al., 2000; Tyler & Moss, 2001) is another variant of the conceptual componential view, but further elaborates the importance of different conceptual components in composing concepts in different semantic domains (e.g., the importance of certain features is based on how well they can distinguish between members of a domain, such as living things). Despite the many differences among these briefly overviewed models, all of these characterizations depict semantic memory as made of conceptual units, and these units do not easily reduce to percepts or sensory impressions. For instance, the notion of a "wing" indicates a protrusion that helps with flying; it cannot be more specifically described without losing its function in these models, as a part shared by many birds.

Empiricist Models and Recent Incarnations

In the empiricist tradition, previously elaborated by Locke and Hume, the source of all knowledge is sensory experience. The elements out of which conceptual knowledge is built are therefore sensory primitives, and all concepts have their origin in, and are constituted reductively by, sensations.

Recent "embodied" theories are an instantiation of such views, but often go beyond these tenets. For instance, it has been suggested that concepts never need representations any more abstract than sensory impressions (Barsalou, 1999). Others suggest that conceptual mechanisms are really perceptual mechanisms, re-engaged in remembering just as they were engaged in perceiving (Allport, 1985; Martin, 2007; Barsalou, 2008). Embodiment is thus a claim against the presence of conceptual components in semantic memory and conceptual systems.

The Interface Problem

One of the main tensions in models of concepts is the dual role concepts must play in serving the demands of both generality and specificity. Smith and Medin (1981) pointed out that components, or "features," of concepts have to be formed out of the relevant units, units that are psychologically real (take part in categorization processes) and that can

capture relations between concepts. For instance, the component "tail" is useful for establishing the similarity between dogs and cats; if it was more specific or more general, it may not properly serve this role. Thus, many components that seem to be useful for including in concepts are already recognized, whole objects and parts like "wing," "tail," and "red" (Smith & Medin, 1981; Fodor, 1975).

Such components may be useful for relating concepts to each other, but they do not describe objects in perceptual terms. As pointed out by critics and proponents (Laurence & Margolis, 1999; Jackendoff, 1987; Levelt et al., 1999), many models of semantic knowledge already assume a process that accomplishes the mapping from percepts to concepts, including the recognition of wings and tails. This mapping problem is not trivial; it is the core problem of object recognition.

The problem is difficult because conceptual units are not specified in perceptual terms. Tails are visibly highly different; and they may even differ more within a category than between categories. A golden retriever's tail is as different from a shih tzu's tail as it is from the tail of a cat. Thus, something makes tails similar across all these instances, but this "core" meaning of tail is not a good indicator of category membership from the point of view of object recognition.⁴ In other words, concepts allow us to treat some things as similar and others as different, especially when category boundaries do not clearly correspond to surface similarity (Tversky, 1977; Shepard, 1980; Freedman et al., 2001). There is thus a tension between the role concepts have to play in being simultaneously specific and general.

This issue is a facet of the fundamental problem in cognition of how the abstractions we use in thought make contact with the world we access through the senses. Although this is a timeless problem that yet awaits a solution, one can consider whether some models of semantic memory offer better promise of an answer. To this end, the evidence for empiricist and conceptual compositional models is reviewed.

Evidence for and Against Embodiment *Tenets of Embodied Theories*

Embodied theories have lately become increasingly influential. Various recent reviews of semantic knowledge have revealed empiricist commitments, and have suggested that the bulk of the evidence sides with embodied views (Thompson-Schill, 2003; Martin, 2007; Vigliocco & Vinson, 2007). This section reviews the tenets of embodied theory, and then considers the kinds of evidence used to

support it, and evaluate whether it might offer a viable solution to the interface problem.

As introduced above, the embodied proposal is that the representational format and mechanism of conceptual knowledge are identical to those involved in perception and action. Thus, in contrast to the conceptual componential view, here concepts are composed not of relations to other concepts, but entirely of various sensory-motor primitives, stored in modality-specific format, and implemented in perceptual systems. The solution offered to the interface problem is that, effectively, there is not such a problem: because conceptual representations are no different from percepts, there is no difficulty in mapping between percepts and concepts.

The embodied view of concepts can be summarized by two general claims:

1. *The Location Claim.* Semantic memory is housed in the same neural systems as those used to process sensory signals; remembering or knowing involves regenerating parts of the state of neural activity that occurred during the processing of those sensory signals (termed *simulation*).

2. *The Format Claim.* The representations within these systems are sensory-motor in nature; in other terminology, the format of representations in these perceptual systems is "modal." It is important to note that the claims are not about what is represented, but about format (e.g., Barsalou, 1999, 2008; Patterson et al., 2007; Stanfield & Zwaan, 2001; Paivio, 1991). The strongest version of the claims is that no amodal representations exist at all (Barsalou, 1999).

An influential formulation of the embodied view was postulated by Barsalou and colleagues (1999, 2008; Kan & Barsalou, 2003). The view that Barsalou *opposes* (the conceptual componential view) can be exemplified in the following quote: "The amodal symbols that represent the colors of objects in their absence reside in a different neural system from the representations of these colors during perception itself. In addition, these two systems use different representational schemes and operate according to different principles" (1999, p. 578). The rejection of this picture entails a commitment to both the Location claim and the Format claim. Although the idea of a "modal representational scheme" is still unspecified, the meaning and operationalization of this property are explored in the present chapter.

In a similar vein, Thompson-Schill (2003) offered the following overview of the evidence: "Semantic

memory is not amodal: each attribute-specific system is tied to a sensorimotor modality (e.g., vision) and even to a specific property within that modality (e.g., color). Information about each feature of a concept is stored within the processing streams that were active during the acquisition of that feature. These findings are problematic for many current theories of semantic memory which represent concepts with amodal symbols... (p. 283)." In the following section, the evidence is reviewed to see whether and how what we know about semantic memory is in fact problematic for conceptual componential theories and supportive of embodied theory.

Examples of Evidence from Behavioral Paradigms

A series of experiments by Zwaan and colleagues (Zwaan et al., 2002; Stanfield & Zwaan, 2001) found that knowledge of what objects look like influences sentence processing, even when that particular information is not strictly relevant to the task. In one experiment, participants read sentences that denoted objects in particular configurations, such as an eagle in the sky (where wings are presumed to be outstretched) or an eagle in a nest (where wings are folded). They then saw a picture that contained an eagle with either outstretched wings or folded wings. Participants were slower to name the object in the picture if it mismatched the wing position denoted by the preceding sentence, than if it matched. Nothing in the lexical entry for eagle (or sky, or nest), as described by semantic network theories of word meaning, would directly specify the wing position of the eagle; yet, anyone with world experience easily infers the wing position. This information about wing position must have also been retrieved during sentence processing, because it primed the subsequent processing of the picture. Such information is typically called either "perceptual knowledge" or "world knowledge," and its activation during a linguistic task suggests that more than just core word meaning is engaged in reading sentences.

These findings are reminiscent of evidence used to illustrate the issue of compositionality in lexical semantics (e.g., Pustjevsky, 1999; Rips, 1995). Compositionality is the process of word combination to imply meanings that are not contained within the lexical entries for the component words (i.e., why *baking a cake* involves creating a new object, whereas *baking a potato* does not; or why a *smokey chimney* emits smoke, whereas a *smokey apple*

tastes like it). In all of these cases, additional meaning beyond the strict word meaning is automatically activated, much as in the case of the eagle sentences in the Zwaan et al. studies. In other words, the demonstration of how extralexical knowledge influences meaning comprehension is not novel, and has not given rise to embodiment claims in the past. It further does not help address the issue of what this additional knowledge is like.

In addition to world knowledge, other non-typically linguistic representations have also been shown to play a role in language tasks. Glenberg and Kaschak (2002) investigated an interaction between motor action and language processing, by having participants make actions that were either congruent or incongruent with a sentence meaning. Sentences implied either an "away" motion or a "toward" motion (i.e., by describing the opening or the closing of a drawer). Participants then judged the sensicality of the sentence by pressing a button either far or close in front of them, thus varying whether arm motion was toward or away from the body. When the response involved a "toward" motion but the sentence implied an "away" motion, responses were significantly slower than when the motion and sentence meaning were congruent. This suggested that sentence meaning interfaced with motion in a content-specific way, and that motion processes must be able to interact with semantic processes, rather than such systems being entirely encapsulated. There have been many other demonstrations of the influence of motor knowledge in semantic tasks, such as reading sentences that describe manual rotation actions (e.g., opening a water bottle) interfere with responses made by turning a knob, such that making a response in a congruent direction with the sentence facilitates the response (Zwaan & Taylor, 2006). Glover et al. (2004) showed that the affordances implied by the name of an object influence grasp aperture to a target block (i.e., reading "grape" leads participants to bias their grasp apertures to slightly smaller than the real block requires, if that block is larger than a grape). This result, much as the others above, suggests that information not typically considered linguistic has an influence on how participants reason about objects and their properties.

In yet another domain, Richardson, Spivey, Barsalou, and McRae (2003) demonstrated that language processing interfaces with spatial attention. In this study, participants read sentences containing verbs that had either a horizontal or a vertical denotation (e.g., *lift* and *respect*); then, participants had to

identify a visual target (as either a circle or square). The target appeared away from fixation on either along a vertical axis (above or below) or horizontal axis (left or right). Participants were faster to identify the target if its position was *incongruent* with the axis of the verb, such that visual targets in vertical positions were identified faster when preceded by a horizontal verb than a vertical verb. Although the direction of the effect was opposite to that found in Glenberg and Kaschak (2002), the interaction was nonetheless content-specific. Such results reiterate that there must be an interface between word meaning and perceptual mechanisms. These results point to the importance of substantiating a mechanism for the interaction of linguistic and other semantic knowledge or perceptual mechanisms, and argue against a fully encapsulated language module.

At the same time, any number of findings supporting the above conclusions would not warrant the more extreme claims to which they have given rise. For instance, Glenberg and Kaschak (2002) argued that their results (as described previously) could only be explained if language was processed via the same mechanisms that execute motor actions. Their reasoning was not that semantic networks simply lacked an interface to other systems, but that their format of representation was fundamentally of the wrong type. There is nothing, however, to suggest this latter option over the former. More importantly, it is also not clear from this evidence that the interactions between semantic reasoning and actions occurred at the level of actions, rather than at the level of semantics. Presumably, making an action involves semantic reasoning. Thus, the Glenberg and Kaschak results could have occurred at the semantic level if actions were recoded into abstract terms, such as "away" and "toward" (Mahon & Caramazza, 2008). In other words, such effects could be caused by either the activation of motor sequences during the processing of the word "away," or the retrieval of the concept "away" while engaging in pushing. The question of how such interactions occur is largely open to investigation.

The findings of Richardson et al. (2003) regarding interface with spatial attention are less likely to be interpreted as an interface at a semantic level, because their spatial task was unlikely to engage a semantic coding of location. However, as the authors themselves concluded, the results likely show that spatial procedures (looking up or down) or representations of space might form part of the representation of a verb; and this may certainly be the case without supposing that meaning representations

literally *are* representations of space. After all, the vertical axis implied by "lift" cannot constitute the entire meaning of this verb, or else it could not be distinguished from the meaning of other verbs with similar motions, such as "rise." Overall, such findings might suggest that space-relevant representations can become tightly associated with the meanings of words, again illustrating the importance of an interface mechanism between conceptual knowledge and action.

The previously discussed results show the necessity of an interface between word meanings and world knowledge, perception, and action, but they do not elucidate what might be that interface mechanism (Mahon & Caramazza, 2008). The fundamental and empirical problem facing current research (and both embodied and nonembodied models) is how information is recoded and communicated between these systems; simply positing that no recoding takes place is a hypothesis, rather than a solution to this problem. Thus, other evidence needs to be considered to better understand the interface problem, and to lend support to either embodied or conceptual views.

Evidence from Semantic Deficits

Debates surrounding the nature of semantic knowledge, and its relation to perception, have long played out in the arena of neuropsychology. Evidence from this line of work has therefore been invoked in the context of current debates.

In neuropsychology, the strong version of sensory/motor theory of semantic memory might be a cousin of the empiricist/embodied view. One tenet of this view is multiple semantics, which is the notion that semantic memory is subdivided into modality-specific systems (vision, olfaction, motion), which together represent our knowledge of concepts (Allport, 1985; Shallice, 1988; Beauvois, 1982). According to this view, therefore, the semantic system closely parallels, if not entirely collapses onto, sensory/motor systems; and there is an important relationship between the semantic systems and their sensory/motor counterparts. In these ways, sensory/motor theory resembles embodiment theory. Support for sensory/motor theory may thus lend credence to the embodiment claim. However, such support hinges on the way the data allow one to interpret the notion of modality-specificity in the semantic system.

In one interpretation, a modality-specific semantic system is one that has a specific and privileged relationship to a sensory input channel for the

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acquisition and storage of semantic knowledge (Farah et al., 1989; Farah & McClelland, 1991; Humphreys & Forde, 2001; Warrington & Shallice, 1984; Warrington & McCarthy, 1987). Under this interpretation, evidence for modality-specificity in the semantic system is provided by reports of optic aphasia.

Patients with optic aphasia have a semantic deficit limited to a certain modality of access. For instance, patient JF (Beauvois, 1982) was unable to name objects presented as pictures, whereas he performed normally when touching the objects or hearing their sounds. The deficit could not be explained as a general difficulty with naming (aphasia) or as a problem with visual recognition: JF was able to use objects that he could not name, and to draw these objects from memory. Thus, the deficit was at a level in between visual categorization and naming; arguably, at the level of semantic memory. However, because this semantic deficit was limited to a certain input/output channel of access, it was suggested that semantic memory must be dissociated along the lines of modality.

However, as argued in Caramazza et al. (1990), the existence of modality-specific agnosias does not require that there are modality-specific modules in semantic memory with a special sensory format. Instead, it may be that semantic memory contains bona fide conceptual representations that, by virtue of their *content*, have privileged relationships to certain input channels. Thus, although there is a relationship between input/output channels and certain representations in semantic memory, these representations need not be composed of sensory features, and the relation to input channels is instead mediated by semantic relationships. This is therefore a very limited sense of modality-specificity, in the sense of having some (any) relationship to an input channel.⁵ In conclusion, when interpreting modality-specific systems in terms of their relation to sensory input channels, not much can be concluded, and therefore, evidence from optic aphasia cannot adjudicate between the embodied view and the conceptual componential view.

The sensory/motor theory has also, alternatively, interpreted modality-specificity as a claim about representational format, rather than a strict relationship with a certain input channel for acquisition or access (Allport, 1985; Thompson-Schill, 2003; Farah & McClelland, 1991; Warrington & Shallice, 1984; Warrington & McCarthy, 1987). This interpretation of modality-specificity was developed as a way to account for patients with category-specific

semantic deficits, who show impairment in recognizing and reasoning about a particular class of objects, such as living things compared with nonliving things (Warrington, 1975). These deficits do not coincide with damage to the use of particular input/output channels, as in optic aphasia, but are rather present across multiple modes of presentation and multiple tasks. Initially, this type of deficit posed a problem for multiple semantics, because it suggested that the semantic system was not organized along the lines of modality, but along a semantic domain.

However, the theory was then adjusted to explain these patients (Farah & McClelland, 1991; Warrington & Shallice, 1984) by positing that each subsystem of semantic memory was characterized as a type of knowledge, rather than necessarily a strict reliance on a type of input channel (i.e., visual knowledge and functional knowledge; see Figure 7.1 for illustration). Furthermore, these different knowledge types (e.g., “sensory” features and “functional” features) were more or less important in processing each semantic category (“living,” “nonliving”). Thus, because each semantic category has a privileged relationship with one of these feature types, a category-specific deficit could appear to be affecting a semantic domain (“living things”) while really affecting a feature type (“visual”). With this proposal, one might still maintain that semantic memory is organized not along domains, such as “living” and “nonliving,” but rather along feature type.

To evaluate this proposal, tests were made of patients’ capabilities with these different feature types. For instance, Farah et al. (1989) used such questions as, “are the hind legs of a kangaroo larger than the front legs?” to test “visual” feature knowledge, and such questions as, “is peacock served in French

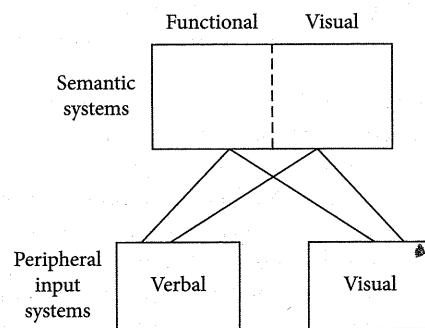


Figure 7.1 Schematic diagram of the parallel distributed processing model of semantic memory. Adapted from Farah and McClelland, 1991.

restaurants?" to test "functional" feature knowledge. Other assessments of a loss of visual or structural knowledge have included drawing named objects and making decisions about pictures of objects that are colored incorrectly or have untypical shapes or parts (Sartori & Job, 1988; Forde et al., 1997; Vandenburg et al., 2006). The aim of these studies was to demonstrate that patients with semantic impairments for living things also have greater difficulty with "visual" features than with functional features. Some studies indeed reported patients exhibiting such a pattern (Sartori & Job, 1988; Silveri & Gainotti, 1998; Farah et al., 1989; Hart & Gordon, 1992).

However, there are several obstacles to supporting the notion that living-domain deficits truly arise because of a deficit in a visual semantic store. First, it is not the case that all living-domain impairments are also impairments in "visual" feature knowledge. For instance, some patients with visual feature impairments have a deficit both for living things and for other categories of objects (Forde et al., 1997; Vandenburg et al., 2006; Laiacina et al., 1997; Caramazza & Shelton, 1998; Bright et al., 2007) or no deficit specific to living things (Lambon-Ralph et al., 1998). Yet others present with visual-knowledge impairments but no deficit for living things (Blundo et al., 2006). This patterning makes it difficult to conclude that living-things deficits arise because of visual-feature deficits, because these two dimensions (category and feature type) seem to operate independently, rather than consistently co-occurring. Thus, as concluded by Farah (1989), these two principles of organization are likely at work independently. This makes the notion that one type of deficit reduces to the other unlikely.

A second difficulty for the sensory/functional model, as reviewed in Caramazza and Shelton (1998), is its inability to explain the more specific category dissociations that have been reported, such as between animals and vegetables or between animals and musical instruments (e.g., Warrington & McCarthy, 1987; Hillis & Caramazza, 1991; Hart & Gordon, 1992). It is difficult to explain such dissociations on the basis of a differential reliance on visual versus functional properties among the dissociated categories. The distinctions are more fine-grained than sensory/functional theory originally postulated; although of course the theory can accommodate these findings post hoc by positing further distinctions between different sensory stores (Warrington & McCarthy, 1987).

Nonetheless, even if one accepts a sensory and functional feature typology, multiple semantics still

lacks support. This is because of the questionable relationship between categories of features and sensory modalities. To maintain the multiple semantics tenet, one must also show that visual and functional feature types are also somehow *modality types* (i.e., that features of each kind were encoded in such a way that they could be said to have a modality-specific format). Thus, support for multiple semantics ultimately depends on the nature of these feature types.

However, in the patient cases reviewed previously, impairments in visual/physical knowledge do not relate specifically to certain input channels. Patients can be impaired in reasoning about visual properties without an impairment specific to the visual modality of presentation. In fact, their performance is very consistent between visual, verbal, tactile, or auditory presentations of objects (Forde et al., 1997; Silveri & Gainotti, 1988). Even more strikingly, Hart and Gordon (1992) reported a patient who was impaired in retrieving physical attributes of living things, while maintaining an ability to match pictures of animal bodies to their appropriate heads, and to decide if an animal picture was correctly colored. This illustrates the dissociation of two systems, both of which specifically enable the processing of physical attributes, but where one is more abstract and another more specific to a sensory processing channel. This further supports the conclusion that knowledge of the physical attributes of objects can be quite removed from modality-specific systems, including sensory processing, and thus retains few dependencies on any sensory modality. Thus, one's understanding of what are "visual" features has to depend on the nature of the information as it is stored, rather than its access through vision.

As discussed in Caramazza et al. (1990), there is a variety of possibilities for why certain features could end up in the "visual" feature store rather than some other store. One possibility is that certain kinds of information have certain kinds of format inherently; that is, information about *what things look like* has a particular kind of format when it is stored in the brain, and on this basis is located in the visual store. This seems to be what is implied by the multiple semantics hypothesis. Another option is that this information is placed in the visual store because it was originally acquired through the visual modality, but now can be accessed through any other input channel (Beauvois, 1982; Silveri & Gainotti, 1988). Here, the principle of organization is the history of acquisition. This becomes difficult to test; there are many cases in which one learns about "visual" attributes nonvisually (through a

textbook or other means). One last option is that features end up in the visual store because they refer to a kind of content (i.e., are *about* what things look like). In this case, the distinction between semantic stores is *semantic* and no longer falls along the lines of sensory processing channels. If indeed the organizational principle is a type of content, then there is no reason to expect that each store is associated with a type of modality. Thus, the ambiguity of the basis of visual or functional stores is a persistent problem for the multiple semantics hypothesis, and it is still unclear what kind of evidence could explain why knowledge ends up in a "visual" store or otherwise.

In conclusion, evidence for multiple semantics from an input-channel interpretation of modality-specificity has not been borne out by the data. Under a feature-type interpretation of modality-specificity, it becomes unclear what provides semantic memory contents with a "modal" nature, and thus the distinction between modal and amodal views of semantic memory, remains without an empirical foothold.

Evidence from Neuroimaging

Neuroimaging has appeared to be a promising tool for settling the debate on the nature of semantic memory and its relationship to perception. In principle, all that is required to satisfy the embodied proposal (the Location claim and the Format claim) is to identify and delimit a perceptual/modal system in the brain, and then locate semantic representations within it. This endeavor relies on having a way to identify perceptual systems in the brain, and semantic representations, and comparing them directly. Neuroimaging has been invoked to do this task (i.e., by showing that a brain region has a privileged relation to some particular perceptual task or input channel and to a particular semantic task). Such evidence has been used to argue that perceptual systems and semantic systems are reducible to each other, and that semantic representations are modal, by virtue of residing in the same systems as perception.

It becomes clear, however, that relying on brain localization to identify either perceptual systems or semantic representations quickly becomes problematic. For one thing, a perceptual task (looking at a picture of an object) does not isolate perceptual processes from conceptual ones, as one unavoidably accesses semantic knowledge of that object. Likewise, any semantic task (e.g., retrieving properties of named objects) is unlikely to involve only semantic operations, but may conceivably also

recruit representations with modality-specific properties (i.e., ones that allow the concept to interface with perception) making it difficult to isolate which process is which. Even under a conceptual componential view of concepts, sensory correlates of objects must be represented at some level or stage, and may become activated during a semantic task (Mahon & Caramazza, 2008). Thus, regardless of one's theoretical stance on semantic knowledge, concepts and percepts are expected to coincide, and are thus not easily extricable from one another using neuroimaging.

A further complication in the endeavor to characterize the semantic system with neuroimaging is that neuroimaging data offer only a description at the level of implementation, and do not immediately offer descriptions of representational format (Marr, 1972). Current state of knowledge does not permit making inferences from brain localization to the level of representational format (e.g., whether it is modal or amodal). Thus, evidence from brain systems can at best address the question of whether given processes share a brain system; however, to infer that this brain system also has a certain (modal or amodal) type of representation requires independent support. In other words, it is argued that support for the Format claim does not fall out of satisfying the Location claim.

Despite these hurdles, it is nonetheless possible to consider to what extent the Location claim is itself satisfied (namely, that perceptual and conceptual tasks rely on the same brain systems) and what implications might follow from such a state of affairs. To this end, several exemplary findings, organized by their implication, are described.

Is there Evidence for Overlap between Perceptual and Conceptual Systems?

SEMANTIC KNOWLEDGE MAY BE ORGANIZED BY ATTRIBUTES

Several studies have shown that retrieving different types of properties in response to object names differentially engages different brain regions (Martin et al., 1995; Mummery et al., 1998; Chao & Martin, 1999; Kellenbach, Brett, & Patterson, 2001; Noppeney & Price, 2002; Phillips, Noppeney, Humphreys, & Price, 2002).

For instance, using positron emission tomography imaging, Martin et al. (1995) found that asking participants to name a color or action associated with black and white pictures of objects recruited different brain areas: specifically, retrieving color properties activated the fusiform gyrus bilaterally,

and action properties activated left middle and superior temporal gyri. The results were much the same when objects were presented as written names. Furthermore, the regions that were involved were nearby to regions previously reported during the perception of color and motion, respectively. However, the extent of proximity between these and the reported regions was not evaluated in most of these early studies (Martin et al., 1995; Mummery et al., 1998; Kellenbach et al., 2001).

Property type has been shown in several studies to affect the organization of semantic processing in the brain, although the specific regions engaged for a certain property are not always consistent among studies (Kellenbach et al., 2001; Kable, Kan, Wilson, Thompson-Schill, & Chatterjee, 2005; Phillips et al., 2002). For example, Mummery et al. (1998) reported an anteromedial left temporal region for color knowledge, relatively far from the region reported in Martin et al. (1995).

The observation that retrieving semantic knowledge activates different neural regions based on property rules out that a single neural locus is uniquely involved in retrieving object knowledge. This fact on its own has little relation to the present debate. Properties differ along a semantic dimension and in referring to different sensory attributes; thus, organization by property does not help determine whether semantic systems are organized by modality or sensory systems (Caramazza et al., 1990). Yet, this set of findings has, in fact, been taken to suggest exactly this (Thompson-Schill, 1999; Chao, Haxby, & Martin, 1999). These conclusions are not warranted because neural organization of semantic knowledge by attribute is not identical to organization by modality. For example, "action" is not itself a modality, particularly given that action properties have included such things as function (what an object is used for). Further studies have identified specific regions preferentially involved in abstract understanding of function as distinct from manipulation knowledge or knowledge of shape (Canessa et al., 2008; Creem-Regher, Dilda, Vicchirilli, Federer, & Lee, 2007). Furthermore, a study specifically looking for brain regions selective to words high in motion content (vs. low motion content) failed to find any region that cared about such a distinction (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008). Instead, a region in the left middle temporal gyrus (which has been implicated in action processing, as discussed previously), preferred verbs to nouns, independently of how much these words referred to motion. Thus,

the neural differences between property types cannot be reduced to differences in sensory modalities: it is difficult to imagine which sensory modality corresponds to either verb knowledge or function knowledge.

Thus, the fact that brain regions involved in property retrieval show organization by property does not support the idea that this organization reduces to, or overlaps with, a perceptual system organized by sensory modality, and rather suggests organization by semantic property.

CONCEPTUAL TASKS ACTIVATE BRAIN REGIONS PREVIOUSLY THOUGHT TO BE MODAL

Other neuroimaging evidence used in support of embodied claims has looked at neural regions that are traditionally sensory, and observed their involvement during conceptual tasks. Such evidence has been used to suggest that semantic properties really reside within modal brain areas. For example, Goldberg, Perfetti, and Schneider (2006) asked participants to perform a property verification task with attributes related to several sensory attributes (color, sound, touch, and taste). Functional magnetic resonance imaging (fMRI) evidence showed that the "predicted" sensory regions were activated according to attribute type (e.g., the somatosensory cortex was active during the processing of touch properties). Other research showed that sentences referring to mouth actions activate Broca area, which is loosely claimed to be important for articulation, and that hand-related sentences activate parts of the precentral gyrus thought to be involved in hand movement (Tettamanti et al., 2005).

These findings might be dismissed as being caused by mental imagery or motor preparation for action, processes that occur after actual language comprehension. However, research using event-related potential (ERP) and MEG has found that motor regions are activated automatically during language comprehension (Hauk & Pulvermuller, 2004; Pulvermuller, Hauk, Nikulin, & Ilmoniemi, 2005). In Hauk and Pulvermuller (2004), ERP signals were recorded during passive reading of arm-, leg-, or face-related words. The waveforms for each word type were differentiated in their topographic localization at 220 ms, suggesting that the localization differences occur early, and without explicit imagery. They appear to occur without much delay with respect to lexical access.

Although such results may be novel and intriguing, they do not directly support the Location claim. Neither the fMRI nor the ERP studies cited

previously *directing* language p... motor action. ... activations were... to be involved... hension and r... compared to se... lapping regions... language comp... identical mecha...

CONCEPTUAL ACTIVE DURING

Further stud... tual/motor and... extent of their... cranial magne... the causal role... tasks typically... lus, whereas co... on a cue. As w... processes or rep... ing such tasks; f... pending this cl...

Direct overl... tual tasks has r... and Martin (19... ing color perce... color retrieval (... and white objec... white abstract p... nearby, in the l... for color retriev... concluded that... are distinct from...

On the other... find one locus o... and color nami... portion of the l... color-perception... in fact, the ling... color perceptio... perception and... was limited to... tion. No effects... a whole-brain c... powered in det... unique to color... engaged while p... sible to quantify... ception and ret... from the result... between the two...

previously *directly* compared regions activated during language processing and those activated during motor action. Thus, although the language-related activations were roughly nearby to regions known to be involved in motor tasks, language comprehension and motor processing were not directly compared to see if they really involve entirely overlapping regions. It thus cannot be concluded that language comprehension and motor processing use identical mechanisms.

CONCEPTUAL TASKS ACTIVATE BRAIN REGIONS ACTIVE DURING PERCEPTION

Further studies have directly compared perceptual/motor and conceptual tasks to evaluate the extent of their overlap, and others have used transcranial magnetic stimulation (TMS) to evaluate the causal role of the implicated regions. Perceptual tasks typically involve the presentation of a stimulus, whereas conceptual tasks involve retrieval based on a cue. As will be discussed, it is unclear which processes or representations are isolated by contrasting such tasks; for now, the evidence is reviewed suspending this clarification.

Direct overlap between perceptual and conceptual tasks has not been very well supported. Chao and Martin (1999) compared regions activated during color perception with regions activated during color retrieval (naming the associated color of black and white objects, compared with viewing black and white abstract patterns). The regions activated were nearby, in the lingual gyrus, but were more lateral for color retrieval than for perception. The authors concluded that regions involved in color retrieval are distinct from those involved in perception.

On the other hand, Simmons et al. (2007) did find one locus of overlap between color perception and color naming tasks, but in a different region, a portion of the left fusiform gyrus. However, not all color-perception areas were active in color retrieval; in fact, the lingual gyrus was selectively active in color perception, indicating dissociation between perception and retrieval. Furthermore, the analysis was limited to regions active during color perception. No effects of color retrieval were visible with a whole-brain contrast. Thus, the study was underpowered in determining whether there are regions unique to color retrieval from memory that are *not* engaged while perceiving color. It was thus impossible to quantify the extent of overlap between perception and retrieval tasks. Nonetheless, it is clear from the results that were presented that overlap between the two tasks was quite limited.

Finally, as noted by Simmons et al. (2007), there is positive evidence illustrating the neural separability of color knowledge and color perception (Miceli et al., 2001; Luzzatti & Davidoff, 1994). Patient IOC (Miceli et al., 2001), for instance, selectively lost the ability to retrieve color properties of objects, but had normal color perception, and normal knowledge of other properties of objects. This illustrates even more clearly that the ability to perceive and recognize color has unique neural loci that are not essential for knowledge of typical object colors.

Another domain in which perceptual and semantic retrieval tasks have been compared is action concepts and the motor cortex. For example, Hauk, Johnsrude, and Pulvermüller (2004) used both a movement localizer and a language task to see whether words denoting actions also activate regions involved in moving one's own limbs. The findings revealed somatotopically organized activation of the motor-activated regions in response to arm, leg, and face words. Along similar lines, Buccino et al. (2005) found a content-specific decrease of motor evoked potentials in hand muscles and foot muscles when participants listened to hand- or foot-related sentences during concurrent TMS to hand or foot regions of their motor cortex, suggesting that effector-related signals had occurred in response to semantic processing of words. Finally, Pulvermüller et al. (2005) applied TMS to leg- and arm-related motor cortex, and showed that latency for reading leg- and arm-related words was modulated by these TMS pulses, respectively. Such results confirm that motor cortex activation is not simply epiphenomenal, but rather causally involved in language processing. Such evidence is reasonably convincing that there is involvement of motor regions in language comprehension.

The precision and specificity of motor region-action word overlaps has been questioned (Chatterjee, 2010; Postle et al., 2008), for instance on the basis of a failure to find somatotopically organized action word-related activation in cytoarchitecturally motor areas (Postle et al., 2008). Another concern is that, as in the case of color nouns, motor and nonmotor verb comprehension activates many regions besides the motor cortex, such as angular gyrus, precuneus, anterior temporal, and parahippocampal regions (Tomasino, Werner, Weiss, & Fink, 2007). It thus stands to reason that the overlap is not complete. Claims that action word comprehension literally consists of motor action simulation, and nothing else, are difficult to support.

Lastly, it is difficult to ignore evidence that often, areas involved in conceptual and perceptual processes do measurably diverge, as in the study by Martin et al. (1995), where language-activated regions were near to those activated during perceptual tasks. Another important case is action verb comprehension, which activates the left middle temporal gyrus and measurably diverges from regions involved in processing visually conveyed motion (Bedny et al., 2008). In fact, recent reviews note that nonoverlap appears to be more the rule than the exception (Chatterjee, 2010; Bedny & Caramazza, 2011). Thus, the fact that relatively blunt neuroimaging tools can reliably detect these distinctions is good evidence the overlap is not complete.

There is other positive evidence, from neuropsychology, that systems for action execution and conceptual processing of actions are in fact distinct. This includes reports of stroke patients exhibiting impaired ability to use objects but intact ability to reason about actions (e.g., Negri et al., 2007). Other evidence includes dissociations within apraxia. In "ideational" apraxia, the ability to execute an action dissociates from knowing the appropriate actions to undertake, whereas "ideomotor" apraxia can affect action execution without concomitant deficit in understanding what the appropriate action should be (De Renzi & Lucchelli, 1988; Heilman et al., 1997). For instance, patients with ideational apraxia can mimic meaningless actions, but are unable to use objects in the *appropriate* ways (e.g., given a key, such patients might perform a hammering motion rather than a turning motion; De Renzi & Lucchelli, 1988).

In sum, there is evidence that although action understanding and motor execution share some neural geography, they are still dissociable subsystems, and do rely on distinct neural substrates.

Summary of Evidence from Brain Imaging

A wealth of brain imaging and neuropsychological evidence has been brought to bear on the first claim from the embodiment view: that sensory and semantic processes share neural substrates (the Location claim). Researchers have attempted to isolate these processes with tasks that involve the presentation of a stimulus and ones that require only retrieval from memory. The findings are mixed. Although certain portions of overlap have been identified between perceptual and semantic retrieval tasks, it appears that these tasks rely on regions that

remain to some extent distinct. Still, the partial overlaps that have been reported are important findings and deserve explanation.

What is the nature of the representations in these areas of overlap? There is much in common between perceiving an object's color and retrieving that color from memory, or from enacting an action and reading words denoting that action. The most obvious commonality is that they refer to similar content. Performing a perceptual task over meaningful objects inevitably engages conceptual knowledge; it is thus no surprise that overlaps should occur between perception and retrieval. Yet, the less intuitive explanation offered by embodiment theorists is by way of the Format claim: that the shared neural locus contains modality-specific representations encoded in a "perceptual" format. Which of these accounts is correct? Do we think with percepts, or do we perceive with concepts?

Evidence that Overlaps are Content-Based

A priori, it may appear unlikely that overlap between action understanding and action execution in primary motor cortex is a locus of abstract, conceptual knowledge rather than of motor commands specific to execution. However, there is evidence that makes the conceptual interpretation more likely than the other. This evidence comes from two principal sources: studies of mirror neurons in monkeys, and studies of cross-modal plasticity.

Mirror "neurons" are generally defined as a mapping system between observed actions (visible properties of actions performed by others) and execution of actions (the motor programs that are used to execute one's own actions; Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Tettamanti et al., 2005; Rizzolatti & Sinigaglia, 2010). Such a system appears to exist in the premotor cortex of monkeys: certain neurons in nonhuman primates (located in area F5 of macaque cortex) respond to both execution and observation of corresponding actions; furthermore, they are engaged during meaningful or goal-related actions, such as grasping or tearing, by the hand and mouth (Rizzolatti et al., 1996). The responsiveness of these neurons to meaningful actions already suggests that they encode information more complex than motor programs. Further evidence of their abstract content is that such neurons respond to a variety of hand configurations during grasping, but only to actions that accomplish a grasp, and not motions that simply

mimic grasping movements. Furthermore, Umiltà et al. (2008) reported neurons that responded to the use of two different pliers that are radically different in hand position and motion but which accomplish a similar goal. These findings and others (see review in Rizzolatti & Sinigaglia, 2010) suggest that these “motor” cortex neurons encode abstract relationship between hand, tool, and object (not specific motor patterns or motions) and are thus highly complex conceptual units. Thus, evidence from mirror neuron studies supports the view that regions thought to be modality-specific are in fact engaged in modality-general and abstract encoding, making it more likely that the role of premotor cortex in action word understanding reflects conceptual operations shared with action execution (rather than the activation of strictly motor representations as previously argued [e.g., Rizzolatti et al., 2001]).

Another line of work that has likewise expanded preconceived notions of “sensory” brain areas is the study of the neural organization of individuals who are blind from birth. Observations about multimodal plasticity (how brain functions change as a result of sensory deprivation) has led to the hypothesis of metamodality (Pascual-Leone & Hamilton, 2001), which proposes that the main principle of organization in the brain is not modality, but rather computation or function. This proposal emerges from observations that, whereas the sort of sensory channel that a brain region receives during development is not strictly fixed, its functional role persists despite early sensory loss. For instance, the occipital lobes of blind subjects are active during tactile discrimination (Sadato et al., 1998) and auditory localization tasks (Renier et al., 2010), rather than visual discrimination. It is well known that sensory deprivation leads to plasticity in modality-related areas; however, these findings additionally suggest that the novel role of the affected regions resembles its normal one computationally. In the previously mentioned cases, it could be said that the occipital lobe continues to be important for fine-grained spatial processing even in absence of vision.

One other strand of this research has explored the role of area MT, a superior portion of the middle temporal gyrus that is important in processing visually perceived motion (Zeki et al., 1991). Although considered a modality-specific visual region in sighted subjects, MT is activated in congenitally blind subjects in response to auditory motion (Bedny et al., 2010), indicating that this region adapts to sensory loss by continuing to process similar types of information from other input channels.

Another case is that of the lateral occipitotemporal cortex, which has been considered principally a visual area (Martin, 2007). Yet, this region appears to accomplish similar functions in subjects who have never had visual experience. Regions important in processing the shape of objects from visual input appear to be involved in processing shape properties of objects presented through the tactile modality in blind subjects (Pietrini et al., 2004). Furthermore, Mahon et al. (2009) demonstrated that in both sighted and congenitally blind participants, lateral temporo-occipital activation is spatially organized by object domain, such that responses to names of animals are located more laterally than responses to artifacts both in sighted and blind subjects. Thus, certain organizational principles and functions of the ventral stream are maintained even in the absence of visual input. This supports the idea that many regions maintain their functional role without input from a given sensory channel, and thus sensory channel is incidental to that functional role.

Despite the striking cross-modal plasticity of many parts of the brain, an embodied theorist might still object that in both sighted and blind, the brain regions involved in shape processing or motion processing are still modality-specific, but specific to a different modality in each case. To counter this objection, there is increasing evidence that even in sighted subjects multimodal functions can arise in putatively sensory areas with a relatively short amount of altered experience. For instance, Merabet et al. (2008) demonstrated that after just 5 days of blindfolding, sighted subjects displayed increased occipital responsivity to tactile stimulation, and enhanced tactile discrimination ability that is disrupted by rTMS to the occipital lobes. Equally dramatic are findings from Amedi et al. (2007) showing that subjects trained in interpreting auditory soundscapes (sound patterns that depict spatial topographies) show occipitotemporal activation when exposed to soundscapes depicting objects, whereas untrained control subjects do not. Because occipitotemporal cortex is involved in identifying object shape through vision, its expansion to the auditory domain is within the scope of its regular function. Thus, it appears likely that even in sighted subjects, occipitotemporal regions are not restricted to processing visual inputs, but rather can engage in functionally analogous tasks when the relevant information comes from a different sensory channel.

Overall, the evidence from monkey studies of premotor cortex and from cross-modal plasticity helps support the notion that classically unimodal

brain areas are characterized not by a privileged relationship to a sensory channel, but by a type of computation or content (action goals, object shape, motion) that operates across inputs from a variety of sensory modalities.

Conclusion

Taking the weight of the research reviewed in this chapter, one might now consider whether the embodiment claims have been supported. Evidence from behavioral paradigms and from neuropsychology have contributed to our general understanding of conceptual knowledge, but have been unable to lend support to the embodiment view. Brain imaging evidence, with respect to the claim that semantic and perceptual tasks share neural mechanisms, has shown that there is a shared reliance on some brain areas, and unique reliance on others. This state of affairs makes it impossible to conclude that semantic and perceptual neural systems are entirely reducible, but does allow the observation that some overlaps exist.

The looming question is the significance of these overlaps, and whether their existence offers support for the second claim, that semantic knowledge is represented in a modality-specific format. The tasks that are contrasted (moving one's hand and listening to hand-related action words) do not pull apart what embodied theory needs; that is, representations with semantic content on the one hand, and those with purely modality-specific format on the other hand. Because of the difficulty of isolating such representational attributes, the nature of representations in many parts of the brain is still inadequately known. Furthermore, our understanding of "sensory" brain regions is rapidly shifting given findings from cross-modal plasticity and much other research. How then can one argue that the involvement of a certain brain area indicates the involvement of a certain representational format?⁶

Clearly, the engagement of certain brain regions is not appropriate evidence to specify the format (modality-specific or otherwise) of the representations involved. Aydede (1999) was the first to point out that much of such reasoning in fMRI research is circular: without an independent way to probe the format of information stored in a brain region, the difference between modality-specific and amodal format rests on the theory's own distinction, which cannot itself be based on brain area. It appears that the current state of brain-based evidence has not surpassed this circularity.

Returning to the question of whether one type of model (the conceptual componential model or

the strong empiricist model) is more promising, one might conclude that the reducibility of conceptual to sensory knowledge has not been supported by recent evidence. Rather, there seem to be conceptual operations that do more than recapitulate distinctions made by the senses. This makes a very strong empiricist view (the embodied view) seem unlikely. That said, little evidence has so far been able to address the interface problem, or how to answer questions about the format of representations, nor to really settle the debate between conceptual and empiricist views more generally.

Recent research has, however, made clear progress in characterizing the neural basis of word meaning. Neuroimaging has revealed systems for many types of semantic knowledge: goals, functions, verbs, shapes, and colors. These systems do not appear to reduce to neural systems that encode information from particular sensory channels. Novel approaches in imaging research have furthermore revealed the flexibility with which regions of the brain can take input from atypical sensory channels and robustly continue their functions. Overall, if one believes the picture emerging from these data, one would conclude that the brain's semantic system is organized by many fascinating dimensions, of which sensory modality is minimally prominent.

Notes

1. Concepts are defined very loosely as units of semantic knowledge; thus, "conceptual knowledge" and "semantic knowledge" are used interchangeably.
2. This is different from the idea that components may exist but are simply not retrieved during lexical access (e.g., Roelofs, 1992). Even in the nondecompositional model proposed by Roelofs (1992), DOG has its meaning by being connected to concept nodes, such as BARKS, and has a TAIL, but these are not obligatorily retrieved.
3. It is not clear, however, whether connectionist models would deny or support that concepts break down into conceptual elements at a level above their implementation in a distributed network.
4. An abstract set of features also fails to specify necessary and sufficient characteristics to define reference (Laurence & Margolis, 1999; Smith & Medin, 1981).
5. The nature of this privileged relationship was not explicated in the sensory/functional theory literature, nor are there data to be brought to bear on the question.
6. One difficulty might be that "format" is an improperly specified construct. In the more common view, format is distinct from content in that it describes the way that information is encoded and conveyed, rather than what is represented (Kosslyn, 1994). No embodied theorist has attempted a model of how manner of encoding distinguishes modalities. If one looks in primary motor cortex, is information encoded in some particular way that is different from V1, apart from the information they contain? Yet others have interpreted format as a way to make certain information explicit (Marr, 1978),

something in between format and content. Under this view, representations of different formats diverge in terms of which information is most available (Jackendoff, 1987; Kosslyn, 1994; Pylyshyn, 1979). One example is that "pictorial" representations are ones that have the most information about spatial extent and geometric form (Pylyshyn, 1979). There is some correlation between the most prominent information conveyed and sensory modality, but it is not equivalent because there are many more types of information than there are modalities. An emphasis on content as an organizing principle seems to be in line with evidence regarding the organization of the brain. It may also offer a better empirical foothold.

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