Cognitive and Neural Foundations of Concepts

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Introduction

Concepts in long-term memory are important building blocks of human cognition and form the basis for language, thought and action. Traditionally, concepts are specified as abstract mental entities different from perceptual or motor systems. From this perspective, sensory or motor features of objects and events are transformed into a common amodal representational format, in which original modality-specific information is lost (Fodor, 2001). Researchers often assume that a single abstract representation underlies conceptual processing, such as feature lists, semantic networks or statistical vectors.

Challenging this classical view, recent modality-specific approaches propose that concepts are essentially grounded in perception and action (Barsalou, Santos, Simmons, & Wilson, 2008). Conceptual features (e.g., visual, acoustic, action-related) are represented by cortical cell assemblies in sensory and motor areas established during concept acquisition. Hence, access to concepts involves a partial reinstatement of brain activity during perception and action (Kiefer, Sim, Herrnberger, Grothe, & Hoenig, 2008).

The nature of conceptual representations is at the heart of a fierce debate in the cognitive sciences. In this symposium, we give an overview of the latest theoretical and empirical developments in research on the functional and neural architecture of conceptual memory. Speakers from a variety of disciplines including cognitive science, cognitive psychology, neuropsychology and cognitive neuroscience critically discuss the sensory and motor foundations of concepts in mind and brain on the basis of different theoretical and methodological approaches.

Is there an amodal conceptual structure?

The existence of an amodal conceptual structure is one of the key questions in the present debate. Based upon neuropsychological studies in brain-damaged patients, the contribution of Karalyn Patterson (MRC Cognition and Brain Sciences Unit, U.K.) provides arguments for an amodal component of the distributed conceptual brain network that goes beyond the modality-specific sensory and motor aspects of conceptual knowledge (Patterson, Nestor, & Rogers, 2007). One variant of the set of neurodegenerative conditions known collectively as Fronto-Temporal Dementia, called Semantic Dementia (SD), arises from relatively focal degeneration of the anterior temporal lobes bilaterally. The hallmark of SD is a degradation of conceptual knowledge that applies across all modalities of input and output and across all types of concepts and all types of conceptual features. The main principles governing the progressive deterioration of knowledge are the familiarity of an object or concept and its typicality within its domain: less familiar and less typical things are both more vulnerable.

The combination of (a) the amodal, across-the-board semantic disruption characteristic of SD, (b) the sensitivity of the impairment to the typicality structure of conceptual knowledge and (c) the consistently focal and predictable lesion site leads to the following hypothesis: all of the specific sensory, motor and linguistic aspects of concept knowledge, which are in far-flung regions across the brain, communicate with a conceptual hub in anterior temporal cortex that represents semantic structure and that is essential to semantically-guided human behavior.

Perceptual or conceptual processing?

Examination of category-specific impairments in brain-damaged patients as well as neuroimaging studies in healthy subjects demonstrating category-specific brain activation have been an important source of evidence in favor of a modality-specific representation of concepts. However, explanations of these findings remain controversial because the pattern of results has been rather inconsistent with regard to the precise anatomical locations associated with different types of knowledge.

The contribution of Christian Gerlach (University of Århus, Denmark) presents the results of a recent meta-analysis of functional imaging studies of picture processing (Gerlach, 2007), and highlights potential causes of the observed inconsistency. The meta-analysis suggests that many of the category-specific activations observed during visual object processing may reflect differences between categories in terms of structural similarity, with natural objects being more structurally similar than artifacts. Hence, at least in some cases, category-specific disorders may be caused by visual rather than conceptual impairments. Evidence in favor of this proposition also comes from neuroimaging studies of visual object processing in normal

subjects where category effects have been demonstrated to depend on several factors likely to affect pre-semantic perceptual processing. To account for such observations a Pre-semantic Account of Category Effects (PACE) in visual object recognition has been proposed. On this account, category effects can arise at two stages in visual object recognition: during shape configuration, where visual elements are bound into elaborate shape descriptions in which the relationships between the objects' constituent parts are specified, and during selection, where the configured shapes are matched with representations stored in visual long-term memory. It is proposed that category-specific effects in conceptual tasks may reflect perceptual stages and not necessarily processing of conceptual features.

Simulation or lexical processing?

The contribution of Lawrence Barsalou (Emory University, U.S.A.) examines the nature of processes typically involved in a conceptual task. It is argued that conceptual processing is often a mixture of word association and situated simulation based upon modality-specific representations (Barsalou et al. 2008). Methodologically, this issue is of importance because alleged conceptual tasks may actually be tapping more into word association in the lexical system than into knowledge in the conceptual system.

Processing in a conceptual task is typically a mixture of representations, where one is grounded in words, and the other is grounded in modality-specific representations. Depending on task constraints, a given paradigm may tap more into one process or the other. In behavioral studies of property generation and property verification, the presence of relatively fast word association processes is observed that precede the production of conceptual representations, which appear to have a perceptual character. When conditions allow, subjects rely almost totally on word association to perform the task. When the word association process is blocked, however, subjects use conceptual representations. Results from recent neuroimaging studies also converge on these conclusions. Only when task conditions prevent or discourage subjects from using word association in property verification do visual brain areas become active.

Together these findings suggest that two different systems are active during conceptual processing: word association and situated simulation. Task conditions modulate the particular mixture of these two processes that subjects use on a given occasion. Word association appears central to much conceptual processing as claimed in previous theories. Unlike these theories, though, there is more to conceptual processing than word association. When the word association process is blocked, other forms of conceptual representation, such as situated simulation, take over.

Do concepts reflect sensory experience?

Modality-specific theories of conceptual representations propose that concepts are essentially grounded in perception and action. Markus Kiefer (University of Ulm, Germany) presents cognitive studies in combination with neurophysiological recording techniques that demonstrate the foundations of concepts in the sensory and motor brain systems. It is shown that conceptual word processing engages brain areas typically involved in representing sensory and motor information (Kiefer et al., 2008). Activity was strongest and started as early as 100 ms after stimulus onset when the conceptual features relevant for a given category were also task-relevant.

In generalizing and substantiating the view of concepts embodied in perception, acoustic conceptual features could be unequivocally linked to the auditory perceptual system: Conceptual processing of words referring to objects for which sound information is highly relevant activated auditory brain areas, which were also activated by listening to real sounds. Importantly, activity within this area increased selectively as a function of acoustic, but not of visual and action-related feature relevance. This shows that access to concepts involves a partial reinstatement of brain activity during the perception of objects.

Furthermore, both training studies with novel objects, in which new concepts had to be acquired under different sensory-motor interactions, and studies with real objects in experts revealed experience-dependent brain activity: A conceptual task activated a given sensory and motor area only when participants had rich opportunities to interact with the object through the corresponding sensory and motor channel during concept acquisition.

The specificity of activity in sensory and motor areas during conceptual processing, its early onset and anatomical overlap with perceptual processing as well as its experience-dependent plasticity strongly suggest that conceptual features are represented in a modality-specific fashion. These findings support the view that concepts are grounded in perception and action as a function of the sensory-motor experience during concept acquisition.

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