Semantic Memory and Language Processing: A Primer

Sharon M. Antonucci, Ph.D.,[1] and Jamie Reilly, Ph.D.[2]

ABSTRACT

Semantic memory refers to our long-term knowledge of word and object meaning. There is increasing evidence that rather than being a passive warehouse of knowledge, semantic memory is a dynamic system whose effectiveness relies on the coordination of multiple components distributed across a large network of cortical regions. Damage to one or more of these components produces distinct profiles of impairment in aphasia and dementia. Furthermore, such differences are associated with different responses to behavioral treatment. That is, effective treatment for semantically based language disorders in aphasia may have very limited success in dementia. We argue that treatment specificity demands a comprehensive understanding of the structure of semantic memory and the nature of its compromise. Here, we review several neuroanatomically informed theories of semantic organization with respect to the effects of semantic impairment on language processing in aphasia and neurodegenerative disease.

KEYWORDS: Semantic memory, dementia, language, aphasia, memory

Learning Outcomes: As a result of this activity, the reader will be able to (1) describe the components of semantic memory, (2) distinguish among cognitive models of semantic memory, and (3) identify the common neural substrates of semantic processing.

Most of us have at one time heard descriptions of another person couched in terms of memory difficulties (e.g., Grandpa has trouble with his memory). Several impressions immediately come to mind when we hear that another person has memory impairment. One might expect to meet a disorganized individual who constantly forgets his keys

[1]Department of Speech-Language Pathology and Audiology, New York University, New York, New York; [2]Departments of Communicative Disorders and Neurology, University of Florida, Gainesville, Florida; Brain Rehabilitation Research Center, Malcom Randall Veterans Affairs Medical Center, Gainesville, Florida.

Address for correspondence and reprint requests: Sharon M. Antonucci, Ph.D., Department of Speech-Language Pathology and Audiology, New York University, 665 Broadway, 9th floor, New York, NY 10012 (e-mail: sma208@nyu.edu).

Semantic Memory and Language Processing in Aphasia and Dementia; Guest Editor, Jamie Reilly, Ph.D.

Semin Speech Lang 2008;29:5–17.

DOI 10.1055/s-2008-1061621. ISSN 0734-0478.

and is unreliable with appointments. Another impression is that of a confused and confabulatory patient unable to relay events surrounding his current hospital admission. A third impression, perhaps fueled more by television drama than by neuropsychological reality, is that of an individual with severe retrograde amnesia who is unable to recall extensive periods of his past. Very few of us have the impression of memory loss presenting as degradation of object meaning (e.g., Grandpa has forgotten what an apple is). Such fundamental knowledge is represented within *semantic memory*, a system that supports long-term knowledge of word and object meaning.[1,2] The deterioration of semantic memory is associated with several neurologic conditions addressed in this issue. It is our aim here to provide an introduction to gross structure and neuroanatomic substrates of semantic memory from a perspective clinically relevant to speech-language pathology.

SEMANTIC MEMORY IN THE TAXONOMY OF HUMAN MEMORY

The different impressions of impairment described above highlight variability on everyday tasks that rely on human memory. Rather than being a unitary system, there is strong evidence to suggest that human memory fractionates into several distinct subsystems.[3–7] A multitude of neuropsychological and functional imaging studies suggest that these individual memory systems have both overlapping and distinctive neuroanatomic substrates.[8–14] The nature of discrete representation versus interactivity within different memory systems remains an issue of central debate in cognitive neuroscience. Nonetheless, due to this "patchy" anatomic overlap, neurologic damage may result in impairment of one or more domains of human memory with relative preservation of other domains. For example, the ability to tie one's shoe relies heavily on procedural motor memory that is strongly linked to the cerebellum,[15] whereas conceptual knowledge of SHOES (hereafter we represent concepts in SMALL CAPITAL letters) relies on semantic memory. Thus, it is feasible that a patient with semantic impairment secondary to extensive temporal lobe damage could lace his shoe without substantive knowledge of what a shoe is.

Squire[6,16] proposed a taxonomy of human memory based on the distinction between declarative and nondeclarative systems. Declarative memory is information that one has conscious or explicit access to, whereas nondeclarative memory includes implicit processes such as motor schemata (e.g., lacing a shoe) or classic conditioning effects (e.g., salivating when hearing the dinner bell). Within this classification, *semantic memory* is a type of declarative knowledge that exists alongside other forms of declarative knowledge such as working memory and episodic memory. In a further fractionation of declarative memory, Tulving[2] demonstrated that semantic memory (general knowledge) and episodic memory (i.e., memory for the details of a specific event) are also dissociable. That is, one's knowledge of DOGS is dissociable from one's memory of a particular dog (e.g., *Bob*) or a particular event in which one encountered a memorable dog. More specifically, semantic memory encompasses our stored knowledge of meaning about the world, extending from encyclopedic facts (e.g., George Washington was the first U.S. president), to concrete object knowledge (e.g., this red sphere is an apple) through abstract lexical-semantic meaning (e.g., *melancholy* is a type of sadness).[17–20]

Although partially dissociable, there is an intimate relationship between episodic and semantic memory. Many researchers have argued that context-specific event memories eventually consolidate into a semantic memory that is context-free.[21,22] That is, memory of single episodes or exemplars evolves into abstract conceptual knowledge. As an illustrative example, consider one's episodic memory of a childhood dog, *Max. Max* is inextricably linked to a particular context and time (i.e., Max was a chocolate Labrador retriever who lounged around the house and snatched food from the counter when we were not looking). However, one's semantic memory of DOGS is more abstract, generalizing beyond *Max* to other category members. Ultimately, conceptual representation is shaped by one's

experience with many dogs and the integration of information from other modalities into a representation that is not constrained to a specific context. Thus, the formation of a stable concept often reflects an amalgamation of sensory-motor features (e.g., DOGS have tails, fur, can bark), affective experience (e.g., DOGS are friendly), and encyclopedic facts (e.g., A DOG is a mammal.) among other traits. This shift from memory of specific exemplars to more general knowledge is crucial because it allows us to rapidly generalize to new category members by establishing a semantic field that spans the family of DOGS.[23–26]

SEMANTIC MEMORY AND LANGUAGE

Much of the literature on conceptual development does not draw sharp distinctions between words and their associated concepts, whose relationship is generally considered to be arbitrarily symbolic. Saussure (1857–1913), one of the critical figures in modern linguistics, compared the relation between words and concepts to the opposite sides of the same page.[27] This associative link between language and meaning enables us to make strong inferences about the structure of semantic memory from language. That is, in the absence of impaired access to word meaning (e.g., aphasia), lexical knowledge is also semantic knowledge.

Confrontation naming is perhaps the most common tool used to assess the integrity of language functioning (and by default the integrity of semantic memory). Although naming is seemingly straightforward, naming difficulties can reflect impairment to one or more processes. These processes are often depicted using the ubiquitous "box and arrow" format, wherein boxes represent distinct levels of processing and arrows represent connectivity among these levels. Figure 1 displays a classic example of a cognitive model of single-word processing from the visual modality. Consider, for example, how the concept of CAT would be processed in this model. When viewing a picture of a cat, sensory processes linked to visual perception of color, line orientation, and texture (e.g., yellow, round, and fluffy) are followed by matching of form to a stored visual-perceptual representation. Disruption to this pathway results in inability to name from a visual stimulus as demonstrated in patients with visual agnosia,

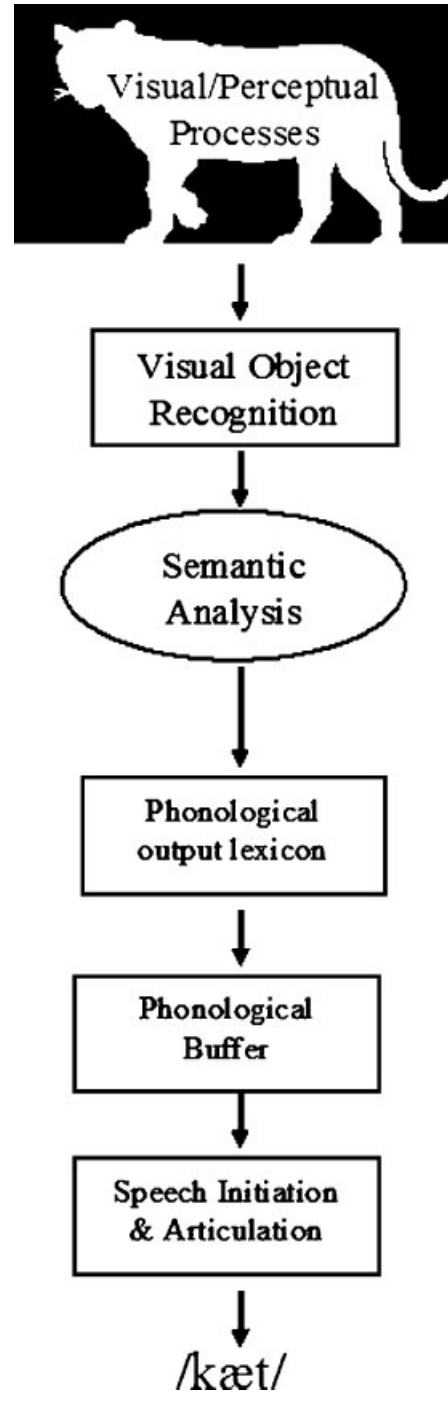

Figure 1 Cognitive model of intact single-word processing for the concept CAT, from visual perception to spoken naming.

who are able to name the same concept from auditory or tactile stimuli. Assuming the integrity of this pathway, stored visual object representations activate meaning associated with CATS. This encompasses hierarchical taxonomic representations (e.g., is an ANIMAL), features shared among other category members (e.g., has legs, walks), and distinctive features that discriminate *cats* from other category members (e.g., meows, elliptical pupils). In addition to these feature-based distinctions, meaning is represented also in encyclopedic memory (e.g., cats land on their feet), episodic memory (e.g., *my childhood cat, Tom*), and through abstract semantic associations (e.g., *cats are evil*). Successful word retrieval requires effective storage of discrete pieces of conceptual knowledge and the dynamic integration of these parts into a cohesive representation. One common assumption underlying traditional aphasia therapy is that patients have preserved conceptual knowledge and that impairment results from disrupted access to that knowledge.

Figure 2 represents possible stages of breakdown associated with several classic cortical aphasia syndromes. Some patients appear to demonstrate disconnection between intact semantic knowledge and preserved phonologic representations (e.g., pure anomia). In these individuals, naming attempts are characterized by predominance of semantic circumlocutions (Fig. 2A). In contrast, other patients who experience degraded phonologic representations (e.g., Broca's aphasia) frequently produce phonemic paraphasias (Fig. 2B). Common among aphasia syndromes is that although word retrieval is impaired, patients are typically able to demonstrate preserved conceptual knowledge through alternative modalities such as gesture, appropriate object use, or drawing, if not through verbal description.[28] There are clinical populations, however, in which the assumption of intact conceptual knowledge is not upheld. This issue of *Seminars* addresses language function within several patient populations who experience progressive loss of conceptual knowledge that is not reducible to selective impairments of input (i.e., agnosia) or output (i.e., lexical retrieval). Treatment for language impairment in these patients, as well as in those who experience degraded access to conceptual knowledge, is explored. The remainder of this review will focus on the development of theories of the organization of conceptual knowledge and the neural substrates thereof.

THEORETICAL MODELS OF SEMANTIC ORGANIZATION

Theories of semantic organization revolve primarily around two fundamental questions. First, is there one semantic system that processes conceptual information for all modalities regardless of the input/output route, or are there multiple semantic systems dedicated to processing modality-specific information? Second, how is semantic knowledge itself (i.e., concepts and the features that define concepts) organized?

Interaction of the Semantic System with Input/Output Modalities

The semantic system described in Fig. 1 corresponds with an amodal system in which separate modality-specific perceptual processes all access a unitary semantic store. As described above, this system contains information about objects' physical properties, functions or actions, and associations with other concepts, all of which is represented in an abstract, modality-independent format. Concepts created in this format may be mapped onto any type of output, accessed for example by phonologic lexical output for oral naming or orthographic lexical output for written naming. One influential example of such a model is the organized unitary content hypothesis (OUCH),[29] which proposes that certain types of input/output modalities have "privileged access" to certain types of semantic features (e.g., visual presentation rapidly accesses semantic knowledge).

Reports of patients with *optic aphasia*,[30,31] an impairment characterized by difficulty naming visually presented objects in the context of preserved ability to pantomime the action associated with those objects and name from tactile and auditory stimuli, seemed to argue against the existence of an amodal semantic system. This observation led to theories

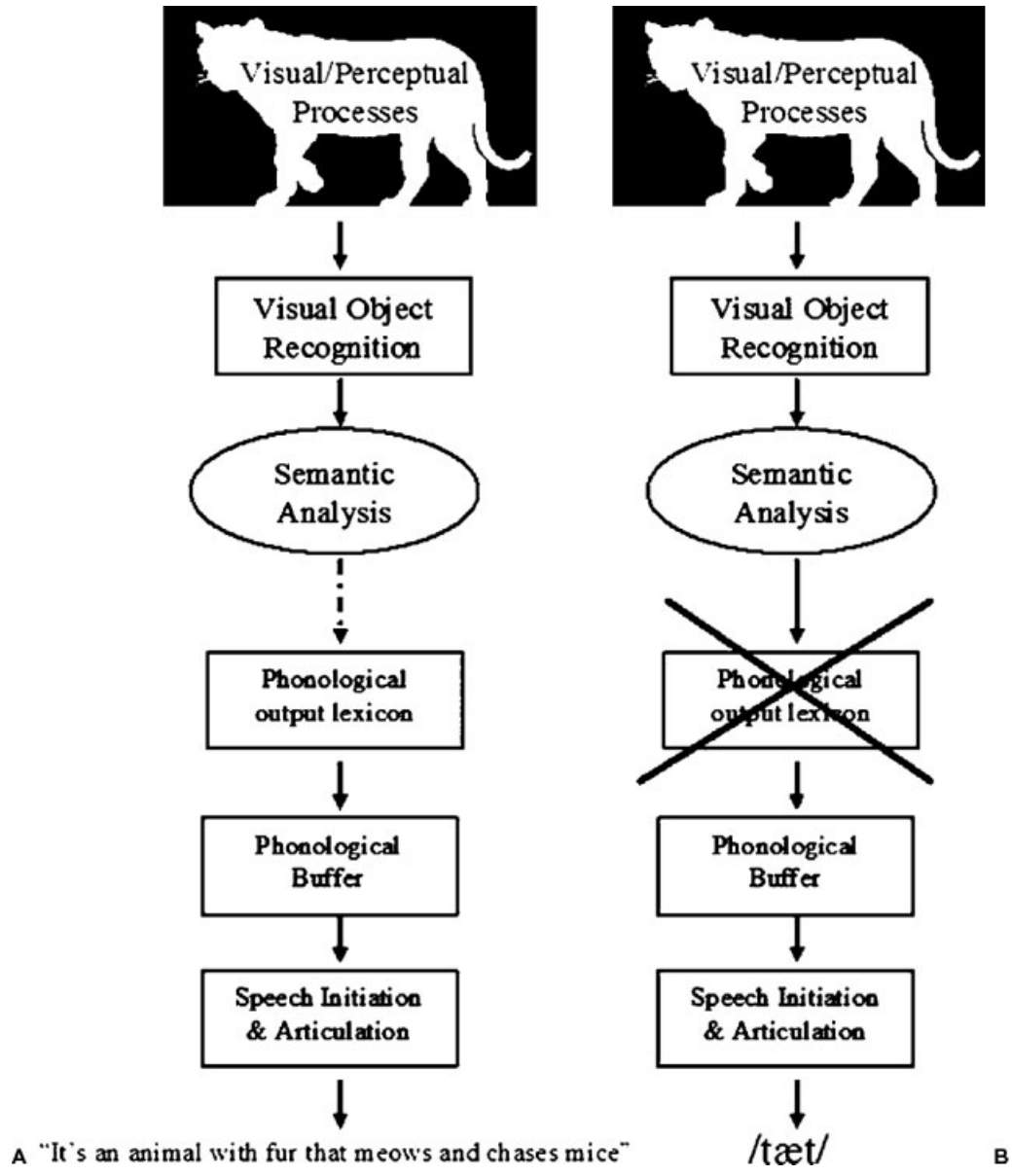

Figure 2 Cognitive models exemplifying breakdown of spoken single-word naming as the result of (A) disconnection between intact semantic knowledge and preserved phonologic representations and (B) degradation of phonologic representations.

espousing separate semantic systems dedicated to processing specific types of information (e.g., visual versus auditory/verbal versus tactile). A seminal paper by Warrington and Shallice,[32] comparing naming of the same concepts from visual and verbal stimuli across multiple sessions, supported this hypothesis. Patients' responses to the same items presented multiple times in the same modality were fairly consistent. However, there was less consistency in responses across modalities. Response consistence within modality was considered evidence of degradation of, rather than disrupted access to, semantic knowledge, and response inconsistency between modalities was considered evidence of separate visual and verbal semantic systems that could be independently damaged. Whereas some more contemporary work

continues to support the notion of multiple modality-specific semantic systems,[33–35] unitary accounts of the semantic system have become more commonly accepted likely in large part because they more parsimoniously explain semantic deficits observed across modalities (i.e., impairment to comprehension and production regardless of how the information is accessed).[28]

A third possibility has also been proposed, in which the semantic system is not thought of either as modality-specific or amodal but rather multimodal. Early forms of this model were proposed by Karl Wernicke, who described the semantic system as a network in which concepts emerge from the interaction of modality-specific sensory perceptions[36] (see also Rogers et al[37]). An analogous comparison might be that between a library and a librarian. Though the format and content may be represented differently, both modality-specific and amodal models of the semantic system suggest that it functions like a library, as a repository of facts. Alternatively, multimodal theories of the semantic system could liken it to the librarian, who does not contain the information, but knows where to go to get it and helps to cross-reference and synthesize it. A set of related theories have emerged, which are known as *simulationist* or *embodied* models of semantic processing. Within this framework, conceptual representations are grounded in the sensory-motor processes that were active when a concept was first acquired. The strongest interpretations propose that each time we encounter a concept such as CAT, whether by looking at a picture, hearing a description, or recalling how frequently *Fluffy* made us sneeze, the sensory-motor areas of the brain engaged during perception of an actual cat are reactivated in a simulation of that experience. Some authors propose that higher-order association areas in the brain act to integrate this information,[38,39] and even more radical proponents contend that sensory-motor areas themselves are *heteromodal* and interaction among them is sufficient not only to fully represent concrete concepts but also ultimately abstract, metaphorical concepts (e.g., love) as well.[40] A less extreme formulation is the sensory/motor model of semantic representations of objects.[12,41] In this model, object concepts are formed, in part, by core features or *semantic primitives* stored in the same neural mechanisms active when the concepts' features were first acquired. Specifically, semantic features related to perception of visual form and motion are stored within visual processing systems, and features related to manipulation and function are stored in motor systems[42–45] (also see Pulvermüller[46,47]). In this view, semantic representations are grounded in the implicit activation of these semantic primitives. However, such features do not encompass our entire conceptualization of concrete objects, which also includes explicit encyclopedic and associative knowledge, or our understanding of more abstract concepts.

Organization of Semantic Knowledge

We now shift our attention to the internal structure of the semantic system, focusing on how concepts and the features that define concepts are themselves organized. Attempts to discern these patterns dominate the literature, much of which has been borne from attempts to interpret *category-specific deficits* in patients with brain injury. The most frequently reported are those in which patients have difficulty processing information about concepts within the domain of living things with less frequent reports of the opposite dissociation in which nonliving concepts are impaired (for review, see Capitani et al[48]). The variable patterns of impairment in these individuals provide important clues about how semantic knowledge is organized. Any comprehensive model of the semantic system must account for or predict all permutations of impairment, a mandate that has yet to be realized.

Models of the internal organization of semantic knowledge fall into two broad camps, *feature-based* and *category/domain-based*. An organizing principle of feature-based models is that they consider category-specific impairments to emerge from damage to the underlying features that define concepts. A prime example of these was the *differential weighting hypothesis* offered by Warrington and colleagues,[49–51] in which they observed a close relationship between the types of categories

and specific impairment to characteristic semantic features (e.g., color discriminates many different types of fruits and vegetables). The premise is that domain-specific impairments result from damage to the underlying features that are most salient in defining the concepts belonging to those domains, and this damage was interpreted in the context of modality-specific semantic systems that process different feature types. The authors proposed that processing of living things was more reliant on sensory (i.e., visual-perceptual) features used to differentiate among them, whereas processing of nonliving things was more reliant on differentiation based on function. As such, deficient sensory feature processing would result in semantic impairment for living things while deficient processing of functional features would result in impairment for nonliving things. This theory proposed a broad dichotomy between domain (living vs. nonliving) and feature (sensory vs. functional) and came to be known as the *sensory/functional hypothesis*. Subsequent work revealed inconsistencies with the predictions of the sensory/functional hypothesis, such that some patients demonstrate impairment for living things without an accompanying disproportionate visual-perceptual feature deficit,[52,53] and others demonstrate visual-perceptual feature impairment that does not result in a domain-specific deficit for living things.[54,55]

Furthermore, it was observed that deficits could fractionate within the domain of living things, specific to either animal or plant categories.[53] To account for these dissociations, feature-based models emerged proposing that the structure of object representation was based on intercorrelations among semantic features.[29,56,57] In this view, categories emerge because similar concepts share more features and these features tend to co-occur in particular patterns. For example, dogs share more features with cats (e.g., have legs, walk, have fur) than they do with knives. In addition, in animals, visual features shared by all members of the category tend to co-occur (e.g., if you have eyes, you also probably have a nose and a mouth), and there tends to be a relationship between shared visual and functional features (e.g., having a nose is associated with breathing air). In contrast, nonliving things tend to share more functional features (e.g., things used to cut, things used to write), and form-function relationships tend to be specific to distinctive features of the objects (e.g., containing ink is associated with writing). Overlap among features leads to similar concepts being stored in close proximity to each other, so that damage to a particular area of *semantic space* will result in impairment to similar concepts (i.e., categories). Differences in the strength of intercorrelation among features are also considered important in these models. The predicted direction of category-specific deficits (e.g., living vs. nonliving categories) depends more on the severity of damage to the semantic system than on damage to a particular feature type, though different interpretations have made opposite predictions regarding the relationship between severity and direction of impairment.[58,59] In addition to these more cognitively based approaches, early formulations of the sensory/motor model of semantic processing attempted to discern the neuroanatomic structure of feature-based organization, proposing that activation of different brain regions during processing of objects from living versus nonliving categories reflected automatic processing of the features that defined those concepts.[12,41]

In response to the fact that feature-based models did not provide a unified account for all permutations of category-specific deficits, the *domain-specific knowledge hypothesis* was proposed.[53] In this view, the semantic system evolved categorically as the result of evolutionary imperatives, for quick perception and analysis of those categories that were most salient for survival: animals (predator or prey), plants (food or medicine), and nonliving objects (that could be manipulated to achieve some goal). The finer-grained impairment within the living domain between animals and plants was thus explained. The disproportionate occurrence of impairment for living things was accounted for by the proposal that processing of living things requires more highly specialized neural mechanisms, which are more likely to be localized and hence more susceptible to selective damage.[53] Whereas the original proposal was concerned with the tripartite distinction among animals, plants, and

nonliving things, subsequent iterations have addressed the additional category of *conspecifics* (i.e., other humans).[8] Caramazza and colleagues have also pointed out that even though categorical distinctions are considered the first-order constraint on semantic organization in this model, feature-based theories may be relevant in describing the organization of semantic knowledge within categories.[53] The original proposal also did not address which might be the particular neural substrates of categorical knowledge. Recent developments of the sensory/motor model of semantic organization suggest that within brain regions that process particular featural information, there may be categorical structure as well.[12,42–45]

At this stage, no one theory appears adequately developed or specified to comprehensively describe semantic organization. Continued progress toward this goal will likely result from convergence of behavioral study of brain-injured and neurologically healthy individuals, complemented by a better understanding of how semantic knowledge is represented in the brain. We turn now to a review of these neural substrates.

NEURAL SUBSTRATES OF LEXICAL-SEMANTIC KNOWLEDGE

Evidence that the neural substrates of semantic processing are distributed throughout the brain comes from neuropsychological lesion studies of patients with brain damage and functional brain imaging studies of neurologically healthy individuals. In this review, we focus primarily on studies of patients with brain damage that provide a window into the relationship between the brain and behavior.

Frontal Networks and Semantic Processing

As reviewed above, one way to think about semantic processing might be as the integration of stored factual knowledge with the control processes that allow us to access and make connections among pieces of knowledge in task-appropriate ways. Evidence suggests that left frontal cortex may contribute at each of these levels, supporting storage of particular types of semantic features and contributing to executive control of semantic information.

Disproportionate difficulty processing conceptual representations of actions has been observed after lesion to left frontal cortex, particularly within the frontal operculum and inferior frontal gyrus, in patients with chronic lesions[60,61] and degenerative cortical atrophy.[62,63] To examine conceptual knowledge of actions distinct from lexical retrieval, participants in these studies typically respond to instructions by choosing from an array of pictured or photographed actions. Patients with both chronic and degenerative lesions to frontal cortex have also demonstrated disproportionate difficulty retrieving action names (i.e., verbs). Several studies suggest that this difficulty results from damage to semantic representations, though debate continues regarding the cognitive mechanism of impairment in patients with word class effects (e.g., verbs worse than nouns), with some authors suggesting that this pattern reflects syntactic/grammatical rather than semantic impairment (see Gainotti[64] for review).[65–67] Lesions in patients with impaired semantic processing of actions are not always restricted to frontal cortex but may also extend to left parietal and posterior middle temporal cortices,[61] a distributed network that has also been observed in functional neuroimaging of healthy adults (see Martin and Chao[12] for review). Though not frequently observed in the neuropsychological literature, individuals who demonstrate disproportionate semantic impairments for nonliving things, particularly manipulable objects such as tools, often demonstrate lesion to the aforementioned dorsolateral network (see Gainotti[68] for review). The fact that this same cortical network is engaged when we observe, imagine, and perform actions provides some support for the notion that sensory-motor processes contribute to concept formation (see Gainotti[64] and Martin[42,69] for reviews of lesion and functional imaging work, respectively).

Left prefrontal and inferior frontal regions have also been implicated in supporting executive control of semantic knowledge, and damage to these regions may manifest in several ways. In a recent study comparing semantic

dementia and stroke-aphasia patients, Jefferies and Lambon Ralph[70] suggested that the group of chronic aphasia patients, the majority of whom had large left frontal lobe lesions, demonstrated deficient *semantic control* characterized by difficulty apprehending relevant semantic associations and rejecting semantic distracters. Converging evidence is derived from patients with progressive nonfluent aphasia (PNFA), a neurodegenerative disorder characterized by atrophy of left inferior frontal and premotor cortices.[71–73] In PNFA patients, categorization deficits were apparent when individuals were required to make "rule-based" judgments by attending to relationships among salient semantic features.[74] In addition, naming errors made by individuals with PNFA tend to be semantic coordinate errors (e.g., zebra: *horse*), suggesting that damage to left frontal regions may also disrupt the ability to differentiate among category members, a process requiring selective attention to distinguishing features, inhibition of competing responses, and working memory processes. Observation of these deficits in patients with damage to left premotor and inferior frontal cortices is consistent with evidence from functional neuroimaging studies suggesting that these regions subserve "controlled" semantic retrieval[75] and/or selection among competing alternatives.[76,77] Furthermore, a recent case report of an individual with right inferior prefrontal damage suggests that participation of right frontal homologues is critical when tasks require particularly demanding executive semantic processing, such as when semantic distracters are more strongly associated with a stimulus than is the correct response.[78]

Temporal Cortex and Semantic Processing

In contrast with the relative importance of frontal regions for conceptualization and naming of actions, the left inferior temporal lobe has been implicated in lexical-semantic processing of objects.[56,79] Damage restricted to posterior regions, typically observed in chronic stroke patients, has been reported to result in a disconnection between preserved semantic knowledge and phonologic word forms.[80,81] As described above, these patients with *pure anomia* are fluent with well-spared auditory comprehension, and their naming errors tend to be semantic circumlocutions (e.g., bed: *It's something to sleep on*). In contrast, central semantic impairment resulting from loss of semantic knowledge has been associated with damage to more anterior temporal regions resulting from disease processes including temporal lobe epilepsy, herpes simplex encephalitis, and semantic dementia.[82–87] In contrast with pure anomia, individuals with *semantic anomia* tend to produce semantic paraphasias (e.g., apple: *orange, fruit*) or ambiguous, empty circumlocutions, and concomitant comprehension deficits are also observed. Although severity of semantic impairment has been correlated with left anterior temporal atrophy,[88,89] recent evidence obtained from patients with unilateral left temporal lesions[90] supports the notion that severe semantic impairment requires bilateral temporal damage as observed in patients with herpes simplex encephalitis and semantic dementia.

The broad role of inferior temporal cortex in lexical-semantic processing of objects can also be further specified by examining particular patterns of impairment. Damage to inferior temporal cortex has been associated with category-specific deficits for living things (see Capitani et al for review[48]) and disproportionately impaired processing of visual-perceptual semantic features (e.g., Lambon Ralph et al[55,91]). As noted above, these deficits sometimes co-occur,[32,90,92] but both profiles have also been observed separately.[93] Impairment of visual/perceptual features is often attributed to the fact that the inferior temporal lobes are part of the ventral visual processing stream critical for object recognition (for comprehensive anatomic review, see Gloor[94]). As noted above relative to the dorsolateral processing network, such interpretations converge with sensory-motor models of semantic organization positing that semantic features' representations are linked to the sensory-motor brain regions active during initial acquisition of the features.[41] Category-specific deficits for living things that result from damage to temporal cortex are sometimes interpreted in the context of theories that posit disproportionate importance of visual/

perceptual features in conceptualization of living things, suggesting that the deficit seen for living things may be an emergent property of disrupted processing of visual-perceptual features subserved by these regions.

A burgeoning literature suggests that the temporal pole and anteromedial regions of temporal cortex support binding of semantic feature information that is stored in sensory-motor cortices.[94,95] The anterior temporal lobes serve as the end point of the ventral visual stream described above, and medial perirhinal cortex serves as a multimodal association area receiving converging inputs from all sensory modalities.[94,95] These interconnections render anterior temporal cortex well-suited for making fine-grained distinctions among visually and conceptually similar exemplars.[96] Damage to these regions, most frequently observed in individuals with semantic dementia and herpes simplex encephalitis, can manifest in difficulty processing distinguishing semantic features of objects, as well as in category-specific deficits for living things, which may be more difficult to distinguish because they share more semantic features than do nonliving things.[55,97] In accordance with proposals that temporal cortex is organized hierarchically along a posterior-anterior gradient, with progressively anterior regions subserving progressively more fine-grained discriminations, the temporal pole has been implicated in discriminating unique entities, and damage to the left temporal pole has been associated with deficient naming of familiar faces[79] and unique geographic landmarks.[98]

CONCLUSION

There is an intimate relation between conceptual representation and language processing. Furthermore, semantic impairment and its associated language deficits can emerge from a variety of causes, including stroke and neurodegenerative disease. We emphasize that semantic memory is a dynamic system that involves both the storage and the active manipulation of this knowledge. A comprehensive understanding of the breakdown of these processes is necessary to target effective, etiology-specific treatments for semantically based language disorders. The articles that follow in this issue of *Seminars in Speech and Language* address qualitative differences and similarities in the effects of semantic impairment on language processing in dementia and stroke aphasia.

REFERENCES

1. McClelland JL, Rogers TT. The parallel distributed processing approach to semantic cognition. Nat Rev Neurosci 2003;4:310–322
2. Tulving E. Episodic and semantic memory. In: Tulving E, Donaldson W, eds. Organization of Memory. New York, NY: Academic Press; 1972: 381–403
3. Baddeley AD. Working Memory. Oxford, UK: Oxford University Press; 1986
4. Schacter DL. Memory: memory systems. In: Kazdin AE, ed. Encyclopedia of Psychology. Washington, DC: American Psychological Association; 2000:169–172
5. Squire LR. Mechanisms of memory. Science 1986;232:1612–1619
6. Squire LR. The organization of declarative and nondeclarative memory. In: Ono T, Squire LR, Raichle ME, Perrett DI, Fukuda M, eds. Brain Mechanisms of Perception and Memory: From Neuron to Behavior. New York, NY: Oxford University Press; 1993:219–227
7. Tulving E. How many memory systems are there? Am Psychol 1985;40:385–398
8. Caramazza A, Mahon BZ. The organisation of conceptual knowledge in the brain: The future's past and some future directions. Cogn Neuropsychol 2006;23:13–38
9. Carpenter PA, Just MA, Reichle ED. Working memory and executive function: evidence from neuroimaging. Curr Opin Neurobiol 2000;10: 195–199
10. Dronkers NF, Wilkins D, van Valin RD, Redfern B, Jaeger JJ. Lesion analysis of the brain areas involved in language comprehension. Cognition 2004;92:145–177
11. Graham KS, Patterson K, Hodges JR. Episodic memory: new insights from the study of semantic dementia. Curr Opin Neurobiol 1999;9:245–250
12. Martin A, Chao LL. Semantic memory and the brain: structure and processes. Curr Opin Neurobiol 2001;11:194–201
13. Moscovitch M, Nadel L, Winocur G, Gilboa A, Rosenbaum RS. The cognitive neuroscience of remote episodic, semantic and spatial memory. Curr Opin Neurobiol 2006;16:179–190
14. Warrington EK. The selective impairment of semantic memory. Q J Exp Psychol 1975;27: 635–657

15. Krakauer JW, Shadmehr R. Consolidation of motor memory. Trends Neurosci 2006;29: 58–64
16. Squire LR. The neuropsychology of human memory. Annu Rev Neurosci 1982;5:241–273
17. Cree GS, McRae K. Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). J Exp Psychol Gen 2003;132:163–201
18. Crutch SJ, Ridha BH, Warrington EK. The different frameworks underlying abstract and concrete knowledge: evidence from a bilingual patient with a semantic refractory access dysphasia. Neurocase 2006;12:151–163
19. Crutch SJ, Warrington EK. Abstract and concrete concepts have structurally different representational frameworks. Brain 2005;128: 615–627
20. Humphreys GW, Riddoch MJ. Features, objects, action: the cognitive neuropsychology of visual object processing, 1984–2004. Cogn Neuropsychol 2006;23:156–183
21. Burgess N, Maguire EA, O'Keefe J. The human hippocampus and spatial and episodic memory. Neuron 2002;35:625–641
22. Garrard P, Lambon Ralph MA, Hodges JR, Patterson K. Prototypicality, distinctiveness, and intercorrelation: analyses of the semantic attributes of living and nonliving concepts. Cogn Neuropsychol 2001;18:125–174
23. Gaskell MG, Marslen-Wilson WD. Integrating form and meaning: a distributed model of speech perception. Lang Cogn Process 1997;12:613–656
24. Keil FC. Concepts, Kinds, and Cognitive Development. 1st ed. Cambridge, MA: MIT Press; 1989
25. Koenig P, Smith EE, Moore P, Glosser G, Grossman M. Categorization of novel animals by patients with Alzheimer's disease and corticobasal degeneration. Neuropsychology 2007;21: 193–206
26. Steyvers M, Tenenbaum JB. The large-scale structure of semantic networks: statistical analyses and a model of semantic growth. Cogn Sci 2005; 29:41–78
27. Saussure Fd. Cours de linguistique generale (1907). New York, NY: Philosophical Library; 1916
28. Raymer AM, Gonzalez-Rothi LJ. Cognitive approaches to impairments of word comprehension and production. In: Chapey R, ed. Language Intervention Strategies in Aphasia and Related Neurogenic Communication Disorders. Philadelphia, PA: Lippincott Williams & Wilkins; 2001: 524–550
29. Caramazza A, Hillis AE, Rapp BC, Romani C. The multiple semantics hypothesis: Multiple confusions? Cogn Neuropsychol 1990;7:161–189
30. Beauvois MF. Optic aphasia: a process of interaction between vision and language. Proc R Soc (London) 1982;B298:35–47
31. Lhermitte F, Beauvois MF. A visual-speech disconnexion syndrome. Report of a case with optic aphasia, agnosic alexia and colour agnosia. Brain 1973;96:695–714
32. Warrington EK, Shallice T. Category specific semantic impairments. Brain 1984;107:829–854
33. McCarthy RA, Warrington EK. Evidence for modality-specific meaning systems in the brain. Nature 1988;334:428–430
34. Shallice T. Specialisation within the semantic system. Cogn Neuropsychol 1988;5:133–142
35. Shallice T. Multiple semantics: whose confusions? Cogn Neuropsychol 1993;10:251–261
36. Eggert GH. Wernicke's Works on Aphasia: A Sourcebook and Review. The Hague, The Netherlands: Mouton; 1977
37. Rogers TT, Lambon Ralph MA, Garrard P, et al. Structure and deterioration of semantic memory: a neuropsychological and computational investigation. Psychol Rev 2004;111:205–235
38. Damasio AR. Time-locked multiregional retroactivation: a systems-level proposal for the neural substrates of recall and recognition. Cognition 1989;33:25–62
39. Simmons WK, Barsalou LW. The similarity-in-topography principle: reconciling theories of conceptual deficits. Cogn Neuropsychol 2003;20:451–486
40. Gallese V, Lakoff G. The brain's concepts: the role of the sensory-motor system in conceptual knowledge. Cogn Neuropsychol 2005;22:455–479
41. Martin A, Ungerleider LG, Haxby JV. Category specificity and the brain: the sensory/motor model of semantic representations of objects. In: Gazanniga MS, ed. The New Cognitive Neurosciences. 2nd ed. Cambridge, MA: MIT Press; 2000:1023–1036
42. Martin A. The representation of object concepts in the brain. Annu Rev Psychol 2007;58:25–45
43. Martin A, Haxby JV, Lalonde FM, et al. Discrete cortical regions associated with knowledge of color and knowledge of action. Science 1995;270:102–105
44. Martin A, Weisberg J. Neural foundations for understanding social and mechanical concepts. Cogn Neuropsychol 2003;20:575–587
45. Martin A, Wiggs CL, Ungerleider LG, Haxby JV. Neural correlates of category-specific knowledge. Nature 1996;379:649–652
46. Pulvermüller F. Words in the brain's language. Behav Brain Sci 1999;22:253–279
47. Pulvermüller F. Brain reflections of words and their meaning. Trends Cogn Sci 2001;5:517–524

48. Capitani E, Laiacona M, Mahon B, Caramazza A. What are the facts of semantic category-specific deficits? A critical review of the clinical evidence. Cogn Neuropsychol 2003;20:213–261
49. Crutch SJ, Warrington EK. The selective impairment of fruit and vegetable knowledge: a multiple processing channels account of fine-grain category specificity. Cogn Neuropsychol 2003;20:355–372
50. Warrington EK, McCarthy RA. Category specific access dysphasia. Brain 1983;106:859–878
51. Warrington EK, McCarthy RA. Categories of knowledge. Further fractionations and an attempted integration. Brain 1987;110(Pt 5):1273–1296
52. Barbarotto R, Capitani E, Spinnler H, Trivelli C. Slowly progressive semantic impairment with category specificity. Neurocase 1995;1:107–119
53. Caramazza A, Shelton JR. Domain-specific knowledge systems in the brain: the animate-inanimate distinction. J Cogn Neurosci 1998; 10:1–34
54. Lambon Ralph MA, Graham KS, Patterson K, Hodges JR. Is a picture worth a thousand words? Evidence from concept definitions by patients with semantic dementia. Brain Lang 1999;70: 309–335
55. Lambon Ralph MA, Patterson K, Garrard P, Hodges JR. Semantic dementia with category specificity: a comparative case-series study. Cogn Neuropsychol 2003;20:307–326
56. Tyler LK, Moss HE. Towards a distributed account of conceptual knowledge. Trends Cogn Sci 2001;5:244–252
57. Tyler LK, Moss HE, Durrant-Peatfield MR, Levy JP. Conceptual structure and the structure of concepts: a distributed account of category-specific deficits. Brain Lang 2000;75:195–231
58. Devlin JT, Gonnerman LM, Andersen ES, Seidenberg MS. Category-specific semantic deficits in focal and widespread brain damage: a computational account. J Cogn Neurosci 1998; 10:77–94
59. Gonnerman LM, Andersen ES, Devlin JT, Kempler D, Seidenberg MS. Double dissociation of semantic categories in Alzheimer's disease. Brain Lang 1997;57:254–279
60. Saygin AP, Wilson SM, Dronkers NF, Bates E. Action comprehension in aphasia: Linguistic and non-linguistic deficits and their lesion correlates. Neuropsychologia 2004;42:1788–1804
61. Tranel D, Kemmerer D, Adolphs R, Damasio H, Damasio AR. Neural correlates of conceptual knowledge for actions. Cogn Neuropsychol 2003; 20:409–432
62. Bak TH, Hodges JR. The effects of motor neurone disease on language: further evidence. Brain Lang 2004;89:354–361
63. Hillis AE, Sangjin O, Ken L. Deterioration of naming nouns versus verbs in primary progressive aphasia. Ann Neurol 2004;55:268–275
64. Gainotti G. Anatomical functional and cognitive determinants of semantic memory disorders. Neurosci Biobehav Rev 2006;30:577–594
65. Bird H, Howard D, Franklin S. Why is a verb like an inanimate object? Grammatical category and semantic category deficits. Brain Lang 2000;72: 246–309
66. Damasio AR, Tranel D. Nouns and verbs are retrieved with differently distributed neural systems. Proc Natl Acad Sci U S A 1993;90:4957–4960
67. Daniele A, Giustolisi L, Silveri MC, Colosimo C. Evidence for a possible neuroanatomical basis for lexical processing of nouns and verbs. Neuropsychologia 1994;32:1325–1341
68. Gainotti G. What the locus of brain lesion tells us about the nature of the cognitive defect underlying category-specific disorders: a review. Cortex 2000; 36:539–559
69. Martin A. Neural foundations for conceptual representations: evidence from functional brain imaging. In: Hart JJ, Kraut MA, eds. Neural Basis of Semantic Memory. Cambridge, UK: Cambridge University Press; 2007:302–330
70. Jefferies E, Lambon Ralph MA. Semantic impairment in stroke aphasia versus semantic dementia: a case-series comparison. Brain 2006;129:2132–2147
71. Gorno-Tempini ML, Dronkers NF, Rankin KP, et al. Cognition and anatomy in three variants of primary progressive aphasia. Ann Neurol 2004; 55:335–346
72. Gorno-Tempini ML, Murray RC, Rankin KP, Weiner MW, Miller BL. Clinical, cognitive and anatomical evolution from nonfluent progressive aphasia to corticobasal syndrome: a case report. Neurocase 2004;10:426–436
73. Grossman M, Mickanin J, Onishi K, Hughes E. Progressive nonfluent aphasia: language, cognitive, and PET measures contrasted with probable Alzheimer's disease. J Cogn Neurosci 1996;8: 135–154
74. Koenig P, Smith EE, Grossman M. Semantic categorisation of novel objects in frontotemporal dementia. Cogn Neuropsychol 2006;23:541–562
75. Wagner AD, Pare-Blagoev EJ, Clark J, Poldrack RA. Recovering meaning: left prefrontal cortex guides controlled semantic retrieval. Neuron 2001; 31:329–338
76. Thompson-Schill SL, D'Esposito M, Aguirre GK, Farah MJ. Role of left inferior frontal cortex in retrieval of semantic knowledge: a re-evaluation. Proc Natl Acad Sci U S A 1997;94:14792–14797

77. Thompson-Schill SL, D'Esposito M, Kan IP. Effects of repetition and competition on activity in left prefrontal cortex during word generation. Neuron 1999;23:513–522
78. Samson D, Connolly C, Humphreys GW. When "happy" means "sad": neuropsychological evidence for the right prefrontal cortex contribution to executive semantic processing. Neuropsychologia 2007;45:896–904
79. Damasio H, Grabowski TJ, Tranel D, Hichwa RD, Damasio AR. A neural basis for lexical retrieval. Nature 1996;380:499–505
80. Foundas AL, Daniels SK, Vasterling JJ. Anomia: case studies with lesion localization. Neurocase 1998;4:35–43
81. Raymer AM, Foundas AL, Maher LM, Greenwald ML. Cognitive neuropsychological analysis and neuroanatomic correlates in a case of acute anomia. Brain Lang 1997;58:137–156
82. Bell BD, Hermann BP, Woodard AR, et al. Object naming and semantic knowledge in temporal lobe epilepsy. Neuropsychology 2001;15:434–443
83. Davies RR, Graham KS, Xuereb JH, Williams GB, Hodges JR. The human perirhinal cortex and semantic memory. Eur J Neurosci 2004;20:2441–2446
84. Glosser G, Donofrio N. Differences between nouns and verbs after anterior temporal lobectomy. Neuropsychology 2001;15:39–47
85. Hodges JR, Patterson K, Oxbury S, Funnell E. Semantic dementia: progressive fluent aphasia with temporal lobe atrophy. Brain 1992;115: 1783–1806
86. Pietrini V, Nertempi P, Vaglia A, Revello MG, Pinna V, Ferro-Milone F. Recovery from herpes simplex encephalitis: selective impairment of specific semantic categories with neuroradiological correlation. J Neurol Neurosurg Psychiatry 1988; 51:1284–1293
87. Snowden JS, Goulding PJ, Neary D. Semantic dementia: a form of circumscribed cerebral atrophy. Behav Neurol 1989;2:167–182
88. Mummery CJ, Patterson K, Price CJ, Ashburner J, Frackowiak RSJ, Hodges JR. A voxel-based morphometry study of Semantic Dementia: Relationship between temporal lobe atrophy and semantic memory. Ann Neurol 2000;47:36–45
89. Williams GB, Nestor PJ, Hodges JR. Neural correlates of semantic and behavioural deficits in frontotemporal dementia. Neuroimage 2005;24: 1042–1051
90. Antonucci SM, Beeson PM, Labiner DM, Rapcsak SZ. Lexical retrieval and semantic knowledge in patients with left inferior temporal lobe lesions. Aphasiology 2008;22:281–304
91. Lambon Ralph MA, McClelland JL, Patterson K, Galton CJ, Hodges JR. No right to speak? The relationship between object naming and semantic impairment: neuropsychological evidence and a computational model. J Cogn Neurosci 2001; 13:341–356
92. De Renzi E, Lucchelli F. Are semantic systems separately represented in the brain? The case of living category impairment. Cortex 1994;30:3–25
93. Moss HE, Tyler LK, Durrant-Peatfield M, Bunn EM. 'Two eyes of a see-through': impaired and intact semantic knowledge in a case of selective deficit for living things. Neurocase 1998;4:291–310
94. Gloor P. The Temporal Lobe and Limbic System. New York, NY: Oxford University Press; 1997
95. Bussey TJ, Saksida LM. The organization of visual object representations: a connectionist model of effects of lesions in perirhinal cortex. Eur J Neurosci 2002;15:355–364
96. Tyler LK, Stamatakis EA, Bright P, et al. Processing objects at different levels of specificity. J Cogn Neurosci 2004;16:351–362
97. Noppeney U, Patterson K, Tyler LK, et al. Temporal lobe lesions and semantic impairment: a comparison of herpes simplex virus encephalitis and semantic dementia. Brain 2007;130:1138–1147
98. Tranel D. Impaired naming of unique landmarks is associated with left temporal polar damage. Neuropsychology 2006;20:1–10