Experience Dependence and Graded Organization of Semantic Representations: A Model of Association and Dissociation of Deficits in Semantic Dementia

Katia Dilkina (knd@andrew.cmu.edu)
Psychology Department and Center for the Neural Basis of Cognition, Carnegie Mellon University
5000 Forbes Ave, Pittsburgh, PA 15213 USA

James L. McClelland (jlm@cnbc.cmu.edu)
Psychology Department and Center for the Neural Basis of Cognition, Carnegie Mellon University
5000 Forbes Ave, Pittsburgh, PA 15213 USA

Pick's disease is a degenerative brain illness characterized by progressive atrophy of frontal and temporal cortex. The temporal atrophy starts from the pole and progresses backward toward modality-specific areas, producing a collection of behavioral symptoms called semantic dementia (SD), including impaired object/picture naming, word-picture matching, drawing and delayed copying. SD patients are also impaired on a number of linguistic tasks such as word reading, word spelling, verb past-tense inflection, and two-alternative forced choice lexical decision. Similarly to the semantic deficits, the linguistic deficits are most prominent for atypical low-frequency items.

In the majority of patients there is an association between the semantic deficit and the linguistic deficit (Patterson, Lambon Ralph, Jefferies, Woollams, Jones, Hodges, & Rogers, in press), but there have been a few case studies which report a dissociation – in particular, between SD and surface dyslexia. Patients EM (Blazely, Coltheart, & Casey, in press) and DRN (Cipolotti & Warrington, 1995) show no impairment on reading despite their profound semantic deficits. These case reports have been used as evidence that the semantic and the linguistic deficits – though often co-occurring – are in fact unrelated, that is they are caused by neurological damage to two functionally distinct (even if anatomically neighboring) systems (e.g. Coltheart, 2004).

The aim of the current study was to explore alternative hypotheses based on the authors' theory of semantic and lexical processing. The theory holds that robustness of semantic and lexical knowledge depend on amount of experience and rely on a graded topographic organization, so that observed differences in performance in SD patients might arise either from differences in experience or differences in the spatial distribution of their brain atrophy.

Method & Results

The hypothesis was tested with a neural network simulation that included four input/output layers – visual (V), motor (M), orthographic (O), and phonological (P) (figure 1). One version of the network has explored effects of experience, using full bidirectional connectivity between all input layers and semantics, and full recurrence within the semantic layer. There was also a direct pathway between the O and P layers of the network. The network was trained given a V pattern or an O pattern as input to produce all four corresponding outputs, and was tested on naming (producing the correct P pattern to a given V input) and reading (producing the correct P pattern to a given O input). **Effects of Experience**: When trained with twice as many O than V trials, reading was relatively spared, compared to the case where O and V training trials were equally frequent, indicating that pre-morbid differences in experience may contribute to relatively spared reading in some SD patients. **Effects of Spatial Distribution of Lesion**: The network was modified to include more semantic units, with 50% connectivity biased toward short connections (Plaut, 2002). This network was then damaged in one of three different ways. Each of the lesions included the center of the semantic layer, viewed as corresponding to the temporal pole. Two of the lesions were oriented towards the visual and the orthographic input units, respectively. The third (control) lesion had an equal spread in all directions. With current parameters, the orthographically biased lesion interferes more with reading than with naming, as expected. Effects of the other lesions, other aspects of performance, and of variations in network architecture are being investigated.
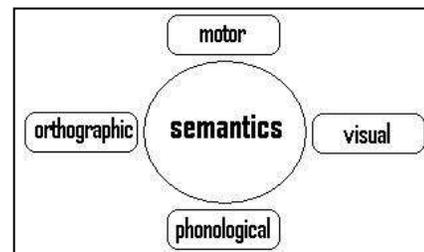

Figure 1: Network architecture.

References

Blazely, A., Coltheart, M., & Casey, B. J. (in press). Semantic impairment with and without surface dyslexia: Implications for models of reading.

Cipolotti, L., & Warrington, E. K. (1995). Semantic memory and reading abilities: A case report, *Journal of the International Neuropsychological Society*, *1*, 104-110.

Coltheart, M. (2004). Are there lexicons? *Quarterly Journal of Experimental Psychology*, *57*, 1153-1171.

Patterson, K., et al. (in press). 'Pre-semantic' cognition in semantic dementia: Six deficits in search of an explanation.

Plaut, D. C. (2002). Graded modality-specific specialization in semantics: A computational account of optic aphasia, *Cognitive Neuropsychology, 19*, 603-639.