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Neural Systems and Language Processing: Toward a Synthetic Approach

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With the birth of a new century comes an opportunity to take stock and to consider the future as it is informed by the past. Research on the neural and biological bases of language has a rich but rather short history. Nonetheless, the findings have laid the groundwork for what will appear to others outside the field to be a natural evolutionary course. Within the field, however, the struggles may be a bit more difficult, as it will be necessary, even essential, to integrate new ways of thinking and new methodologies about the brain and language. And it this realization and integration of new directions that may be the biggest issue that we face in the new millennium.

What are these new ways of thinking? Perhaps the greatest challenge for us will be to consider language beyond its structural/componential base. The past 30 or so years of research on the brain and language has focused on delineating aphasic deficits in terms of the structural components of language. This modular approach, considering language to be comprised of separable but interacting components including sound structure, lexical structure, syntactic structure, has allowed us to chart the patterns of language

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ability and disability, and to explore the extent to which such deficits are selective with respect to types of aphasia.

This important task has been largely accomplished. What we have learned are two complementary findings: (1). that structural analyses reveal similar patterns of breakdown (qualitatively, not quantitatively) across patients. In particular, those properties of language that are more ''complex'' are more vulnerable and a hierarchy of impairment can be established within each linguistic domain, and (2). that patients rarely have a selective impairment affecting only a single linguistic component. Most patients evidence a constellation of impairments implicating deficits that affect phonology, the lexicon, as well as syntax.

To account for these deficits researchers have attempted to identify processing impairments within each particular linguistic component. However, it would seem that consideration of the patterns of deficits in the aphasias provides us an important clue, one which challenges us to consider an alternative hypothesis. Namely, the co-occurrence of language impairments that appear to be related to different components of the linguistic grammar, and hence regarded as isolable and distinct impairments, may have at their basis a common etiology. And this etiology may not be linguistic in the strict sense of the word, but may reflect at its base an impairment that alters the dynamics of neural activation. It is these changes in the dynamics of activation which results in the patterns of deficits seen in aphasic patients. For example, in recent years, our lab has hypothesized that many aphasic language symptoms can be attributed to alterations in the dynamics of lexical activation and the resulting spread of activation from one lexical representation to another (Blumstein and Milberg, 1999; Milberg et al., 1995). Because lexical access processes are crucially involved in all aspects of language processing including identifying word candidates form sound structure, deriving the meanings of individual word as well as the syntactic roles they play, this impairment has a cascading effect on language processing, cascading in the sense that it has repercussions at all ''levels'' of the linguistic grammar. It is also proposed that the dynamics of activation across the neural systems underlying language vary as a function of the particular neural system, hence resulting in such clinical syndromes as Broca's and Wernicke's aphasia and in the different patterns of performance in on-line language processing tasks shown by these patients (cf. also McNellis & Blumstein, 1999).

That there may be different neural systems underlying language also suggests that future work must integrate behavioral results with investigations of the neural substrates of language. Such investigations of the neural substrates of language will no doubt include structural imaging of brain-lesioned patients, but also functional neuroimaging of both normal and brain-injured subjects. There are already clear indications from the neuroimaging literature that language functions are distributed over a broad network that is lateralized, although not completely, and includes greater involvement of multiple peri-sylvian areas. Moreover, this network appears to be comprised of a number of neural systems which may have different ''functional'' roles in the service of a particular language ''goal'' or task. As an example, speech/phonological processing has traditionally been associated with damage to the auditory association areas, and in particular, to the superior temporal gyrus. In fact, the dense auditory comprehension deficit of Wernicke's aphasics had been attributed to a loss of ''phonemic hearing'' (Luria, 1966).

And yet, speech perception studies with aphasic patients have shown impairments in all patients, including Broca's aphasics, and performance on such tasks has shown little relation to the severity of the auditory comprehension impairment of these patients (Blumstein, 1998). Recent neuroimaging studies using PET and fMRI have shown activation in the superior temporal gyrus as well as in the inferior frontal gyrus in tasks of phonological processing (Zatorre et al., 1992, 1996; Binder, 1997; cf. Poeppel, 1996). Importantly, recent results have suggested that the different neural structures implicated in phonological processing have different functional roles (Burton et al., 1998, 1999; Zatorre et al., 1992, 1996). Namely, perceptual analysis of the speech input itself appears to be largely a function of auditory association areas, and in particular, of the superior temporal gyrus. In contrast, the involvement of frontal areas appears to reflect task demands for output rather than the perceptual analysis of the speech input itself. The relevant task demands are those that require the subject to extract a phonetic segment and retain it and/or compare it to a phonetic label for response (Burton et al., 1998).

In sum, a critical issue for the study of the brain and language for the twenty-first century will be to build a cognitive architecture of language that is informed by consideration of the dynamics of the neural system underlying it. To this end, it will be necessary to build quantitative neural net models of language and test them via an integrated approach that intersects behavioral studies in normal and brain-injured patients with both structural and functional neuroimaging.

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