Preface

Linguists have mapped the topography of language behavior in many languages in immaculate detail. However, to understand how the brain supports language function, it is necessary to bring the principles and regularities of neural function to the table. Mechanisms of neurolinguistic function cannot be inferred solely from observations of normal and impaired language. Our understanding of principles and regularities of neural function relevant to language stems predominantly from two sources: (1) knowledge of neuroanatomy and the neural systems that are based upon this anatomy and (2) knowledge of the patterns of behavior of neural networks composed of large numbers of highly interconnected units and supporting population-based (distributed) representations.

The core neuroanatomy underlying language was largely subsumed in the Wernicke–Lichtheim model (Lichtheim 1885), and our knowledge of it has scarcely advanced beyond the principles laid out in Norman Geschwind's famous paper "Disconnexion Syndromes in Animals and Man" (Geschwind 1965). Functional imaging studies from the outset suggested a remarkable degree of bilateral engagement of the brain in language function, particularly in the perisylvian regions, but functional imaging is generally ill equipped to distinguish regions that are essential from those that are incidental. As it turns out, studies of aphasia, looked at from the right perspective, and with particular attention to the effect of lesions on both white and gray matter, provide us with fairly powerful evidence of the extent to which various components of language function are bilaterally represented, and even the extent to which this might vary from language to language. This aspect of aphasia studies, largely overlooked to date, will constitute one of the recurring themes of this book.

The evolution of our understanding of neural systems over the past 20 years has revealed the importance of systems dedicated to "keeping order in the house"—that is, maintaining coherent patterns of activity in the brain's 100 billion neurons such that all is not cacophony and adaptive behavior more or less consistently emerges. Key are systems underlying selective engagement of particular neural networks in particular ways (Nadeau and Crosson 1997), which support what Patricia Goldman-Rakic (1990) termed working memory. Working memory and its hippocampal complement, episodic memory (Shrager et al. 2008), play very substantial roles in language function, roles that we are beginning to understand and that will constitute another recurring theme of this book. Much less well understood are the mechanisms by which linguistic behavior is driven by systems underlying goal representations.

Our understanding of the population dynamics of neural network systems owes almost entirely to the study of parallel distributed processing (PDP), which was thrust so dramatically onto the world's scientific stage by David Rumelhart and Jay McClelland and their collaborators in their seminal two-volume text, published 25 years ago (McClelland, Rumelhart, and PDP Research Group 1986). The science of PDP has continued to evolve at a stunning pace ever since, enhancing our understanding of constraints governing neural network systems, demonstrating how powerful these systems can be, and demonstrating new ways in which neural networks might support particular functions. Before PDP was established as a field of research, behavioral neuroscientists could only hope that one day, the complex behaviors they were systematically studying could ultimately be related in a precise way to neural structure and function. In a flash, PDP research showed how this could be done, and, repeatedly, PDP simulations have shown the power of neural networks to account in a highly detailed way for behavior in normal and damaged brains.

This book begins with the development of a comprehensive, neurally based, theoretical model of grammatic function, drawing on principles of neuroanatomy and neurophysiology and the PDP literature, together with cognitive psychological studies of normal language, functional imaging studies, and cognitive neuropsychological and psycholinguistic studies of subjects with language disorders due to stroke, Alzheimer's disease, Parkinson's disease, and frontotemporal lobar degeneration. The remarkably detailed understanding of semantic function that has emerged substantially from the 20-year effort of the Addenbrookes Hospital group (Hodges, Patterson, Lambon Ralph, Rogers, and their collaborators, most notably Jay McClelland) has proven to be particularly important. From this, we have a cogent theory of semantic instantiation and breakdown. Much of grammar (that not dependent on networks instantiating sequence knowledge) turns out to be semantics. Research on the neural foundation of semantics, coupled with the studies of many other investigators, has led to a conceptualization of verbs as the product of multicomponent frontal and postcentral distributed representations that engage and modify noun representations, even as they are engaged by noun representations. Equally important has been PDP work on the capacity for instantiation of sequence knowledge by certain neural networks, coupled with work by psycholinguists, most notably Thompson and her colleagues at Northwestern

University, on sentence-level sequence breakdown in aphasia and patterns of reacquisition of this knowledge during speech–language therapy. Concept representations interfaced with sequence knowledge provide the intrinsic basis for the temporal dynamic of language.

The second half of this book reviews the aphasia literature, most importantly including cross-linguistic studies, testing the model in its ability to account for the findings of empirical studies not considered in its development. The model fully accommodates the competition model of Bates and MacWhinney (1989), which provided an enormous advance in our understanding of the neural basis of grammatic function, and it extends the competition model. It accounts for perhaps the single most trenchant finding of cross-linguistic aphasia studies—that the most powerful determinant of patterns of language breakdown in aphasia is the premorbid language spoken by the subject ("You can't take the Turkish out of the Turk"). It does so by accounting for grammatic knowledge in terms of the statistical regularities of particular languages that are encoded in network connectivity. Only the most redundantly encoded regularities, or those that have significant bihemispheric representation, survive focal brain damage. The model provides a surprisingly good account for a large number of findings and unprecedented resolution of a number of controversial problems, including whether grammatic dysfunction reflects loss of knowledge or loss of access to knowledge; relative sparing of grammaticality judgment; the problem of verb past tense formation, including some of the wrinkles that have appeared in the course of cross-linguistic studies; cross-linguistic differences in patterns of syntactic breakdown; and the impact of inflectional richness on the resilience of phrase structure rules and grammatic morphology in the face of brain lesions. To the extent that the proposed model did not fully account for observed patterns of language breakdown, aphasia studies have provided the basis for elaborating the model in ways that are interesting and important, even as these elaborations are entirely consistent with the general principles of the original model and in no way involve ad hoc extensions.

Ultimately, however, the model represents but a new beginning. I have done my best, particularly in the concluding chapter, to delineate possible directions for further research.