The Cognitive Neurosciences

Michael S. Gazzaniga (Ed.)
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Michael Gazzaniga has put in a tremendous amount of effort into promoting and shaping the emerging field of cognitive neuroscience. He has made important contributions, both in terms of his own research (e.g., Gazzaniga, 1989) and as the editor in chief of the *Journal of Cognitive Neuroscience*. He has popularized the field in books (e.g., Gazzaniga, 1992), and helped introduce many young hopefuls to cognitive neuroscience via his role as organizer for the Cognitive Neuroscience Summer Institutes. Seen in this light, Gazzaniga's newest contribution in the form of the edited volume *The Cognitive Neurosciences* would seem to be "a major new reference that documents and defines the emerging field of cognitive neuroscience" (as claimed on the dust cover). However, the question arises as to what extent cognitive neuroscience is really *defined* in terms of the 92 original review articles found in this book. Two answers come to mind: Either cognitive neuroscience *is* defined by the Gazzaniga book (and others whose research is not included or mentioned are *not* really doing cognitive neuroscience), or, the volume covers a particular *brand* of cognitive neuroscience.

In the preface, Gazzaniga writes that the volume "is the beginning. It represents the taking stock of five years of attacking the problem of mind and brain. Each section grapples with the most fundamental problem of modern science—the problem of the explanatory gap. The gap here is the one between biologic process and the processes of the mind. This problem and the science built up to understand how the brain enables mind has come to be called cognitive neuroscience." (p. xiii). This review of cognitive neuroscience resulted in a volume with 11 broad sections, starting at the molecular level and ending up with the supposedly highest level of mind: consciousness.

The first section, *Molecular and Cellular Plasticity* (edited by Ira Black), touches on

topics such as plasticity in vision and body image perception, plasticity through synaptic changes or the expression of nerve growth factor genes, and the use of discharge synchrony as means of representing percepts. The next section, *Neural and Psychological Development* edited by Pasko Rakic, stands out as the only section which directly aims to span the gap between biological and behavioral research in cognitive neuroscience. It contains two neurobiological review chapters on corticogenesis, complemented by two chapters reporting on psychological experiments pertaining to physical reasoning in infancy and a chapter reviewing event-related potential (ERP) studies of language and visual development. In sharp contrast to these empirical chapters, the section also includes a highly speculative chapter on the origins of human social competence—a chapter which would have been better placed in the section on evolutionary cognitive neuroscience. Section 3, *Sensory Systems,* is edited by Colin Blakemore and J. Anthony Movshon and covers single neuron encoding of perceptual input, sensory processing in ensembles of neurons, the production of topographical sensory maps, and the combination of different kinds of sensory information into a comprehensive account of the world. The fourth section, *Strategies and Planning: Motor Systems* edited by Emilio Bizzi, discusses how the central nervous system plans and executes motor movements (especially of the limbs) and possible computational implementation of these processes. Section 5 edited by Michael Posner is on *Attention.* Using the tools provided by computational models, ERP, positron emission tomography (PET), cellular recordings, and analyses of brain lesions and brain development, this section addresses the issues pertaining to attentional orientation towards sensory stimuli—with the exception of two chapters discussing arousal and executive control systems. *Memory* is the focus of the sixth chapter, edited by Endel Tulving, covering topics such as, working memory, implicit memory, the use of PET and ERP techniques in memory research, the role of frontal lobes in memory performance, and whether memory can be localized to particular brain structures. Steven Pinker is the editor of the section on *Language*, which reviews a variety of processing and acquisition phenomena. A section on *Thought and Imagery* is edited by Stephen M. Kosslyn and discusses the neural bases of mental imagery and complex reasoning as evidenced by PET studies, animal models, behavioral experiments and theoretical research. Section

9 edited by Joseph E. LeDoux investigates the neural underpinnings of *Emotion,* presenting evidence from e.g., single unit recordings, depth recordings from epileptic patients, and PET studies. The tenth section on *Evolutionary Perspectives,* edited by Leda Cosmides and John Tooby, invites cognitive neuroscientists to look to evolutionary biology to gain insight into the functional circuitry of the brain. The final section is edited by Daniel L. Schacter and seeks to attack *Consciousness* from various perspectives, including philosophy, cognitive psychology, cognitive modeling, cognitive neuropsychology, and cognitive neurophysiology.

Given the breadth and the sheer number of articles in this book, one is struck by the fact that it does not include a *single* connectionist paper. A search through what otherwise appears to be a rather comprehensive subject index for "connectionism" and related words reveals very few reference points. Of course, as the subject index does indicate, there are a few papers which either talk about or directly involve neural networks. However, these papers predominately address issues pertaining to sensory or motor systems. Much of this kind of neural network modeling has a "neuronal" flavor to it, aiming to model specific aspects of "real" neurons and/or biological networks. On the other hand, the last decade has seen a vast amount of artificial neural network modeling at the cognitive level, focusing on the psychological aspects of behavior rather than on a close relationship with the underlying brain physiology. Are we to believe that this research has nothing to do or even to offer to the field of cognitive neuroscience? A quick glimpse at another recent major reference work, Michael Arbib's *The Handbook of Brain Theory and Neural Networks*, suggests that we should not. Indeed, one of its 8 major sections is allocated to "Connectionism: Psychology, Linguistics and Artificial Intelligence". In addition, most connectionists would probably think of themselves as trying to understand the mind (or particular aspects of it) using a style of processing abstracted from the workings of the brain; *viz.,* the parallel interaction of a multitude of simple processing units (somewhat like neurons). Thus, it would appear that much connectionist work does fall within the boundaries of cognitive neuroscience (at least at the level of abstraction found in sections such as, *Language*). However, *The Cognitive Neurosciences* leaves this immense area of research largely untouched; and one is left with a nagging thought: "What else may have been left out of this reference work?"

No reviewer can promise to do justice to a book of this size in a single review (within reasonable space limitations), nor is it likely that a single reviewer is able to critically assess the contributions within all of the eleven sections. In the remaining part of this review, I therefore concentrate on the *Language* section, briefly discussing relevant chapters and pointing to work—connectionist or otherwise—which has been left out.

Language

A number of the chapters in the book appears programmatic—and this is especially true of the *Language* section—often omitting discussions of alternative viewpoints in anything but a cursory manner. The perspective on language which emerges from this section is one in which the mechanisms subserving our linguistic abilities are highly modularized and in which processing and acquisition necessarily rely on an innate body of language specific knowledge. This is an influential view of language which Gazzaniga has espoused elsewhere (e.g., 1992), but a view which, contrary to what the reviews in the language section may suggest, is far from universally accepted. The decade following the publication of the PDP volumes (McClelland & Rumelhart, 1986; Rumelhart & McClelland, 1986b) has seen a veritable explosion in connectionist research, particularly within the study of language processing and acquisition (for overviews, see Chater & Christiansen, to appear, and Plunkett, 1995, respectively). The view of language which has emerged from this research suggests that language processing need not be strongly modularized and that acquisition may proceed without much innate language specific knowledge.

Innate structure is undoubtfully required for the acquisition of language. However, an important question is whether this structure necessarily must be language specific in order for acquisition to be possible. Stromswold argues in her review, "The Cognitive and Neural Bases of Language Acquisition", that "the structures and operations that are involved in language seem to be anatomically and functionally modular and apparently do not have nonlinguistic counterparts. (...) These innate mechanisms may allow children's brains to solve the otherwise intractable induction problems that permeate language acquisition" (p. 866). As a paradigmatic example of her view, she refers to the acquisition of English

auxiliary and lexical verbs. These verbs are so semantically, syntactically and lexically similar to each other "that a learner who has no knowledge about auxiliary and lexical verbs (i.e., a simple correlational learner) is almost certain to confuse the two types of verbs" (p. 857). But what kind of "simple correlational learner" does Stromswold have in mind? Recent years have seen a surge of statistical approaches to language acquisition, but this research is also left largely untouched in the *Language* section. This is unfortunate as much of this research directly addresses the question of what correlational learners may actually be able to learn. For example, using a simple statistical method encoding word co-occurrence relations between elements within a 5 word window Finch & Chater (1993) and Redington, Chater & Finch (1993) found that auxiliaries clustered together, forming a category separated from the categories containing lexical verb clusters. Thus, a "simple correlational learner" may utilize such distributional information to treat auxiliaries differently from lexical verbs both in production and processing. Of course, this does not explain all the details concerning children's acquisition of the two types of verbs and the errors they make when using them. It does, however, suggest that one should be careful in dismissing "simple correlational learners" without a discussion of potential distributional learning mechanisms which could potentially provide a plausible basis for a statistical explanation of the phenomena—an explanation which, moreover, is likely not to require strong *a priori* claims about innate, language specific knowledge. Stromswold presents other evidence supporting her position based on classic poverty of the stimulus arguments. I will not discuss these details further here, but refer to Seidenberg, Allen, Christiansen & MacDonald (in preparation) for a comprehensive, critical discussion of this line of argumentation.

The discussion of whether language comprehension is highly modularized or not has been going on for many years. One view is that syntactic processing is autonomous (ala Fodor, 1983) and takes place in a parser independently of other language processes. An alternative view is that a variety of non-syntactic information constraints the way we comprehend sentences. In his review, "The Cognitive Neuroscience of Syntactic Processing", Caplan subscribes to the first modular view, claiming that "models that recognize the existence of complex syntactic structures and a parser are the only models that deal with many of the

psycholinguistic phenomena currently described in the literature, such as the garden path effects ..." (p. 873). And judging from the references listed, not much research has been done within the alternative perspective since 1990. This is, however, a misrepresentation of the state of the field as well as the debate between the two views of language comprehension. In fact, the constraint based view of language processing has gained much support in the first half of the nineties. Space does not permit me to review the relevant research here; instead a few important references will serve to illustrate this ommission: MacDonald (1993), MacDonald, Pearlmutter & Seidenberg (1994), Trueswell & Tanenhaus (1994). This research is furthermore often linked with connectionist modeling, e.g., Kawamoto (1993). In short, the reader is left with the impression that the modular position is the only tenable view of language processing—despite the fact that much recent evidence points in another direction.

This impression is further fueled by the chapter on "The Structure of Language Processing: Neuropsychological Evidence" in which Garrett reviews evidence from recent ERP studies of language processing. This evidence appears to point towards modularized language processing because significantly different ERP effects are found when people are exposed to sentences involving semantic and syntactic errors, respectively. Briefly, words that are syntactically incongruous produce a late positive shift in potential (called SPS for "syntactic positive shift"), whereas words that are semantically anomalous elicit a negative shift. However, the exact interpretation of these phenomena is not clear, and Garrett does acknowledge (as one of the only authors to do so in the book) that "a summary discussion of the sort in this chapter sets aside many differences of detail among experimental data reports that may ultimately prove of importance, and it would be unwise to celebrate the similarities of outcome without recognizing the potential complications presented by unevaluated differences" (p. 897). Indeed, new ERP evidence questions whether it can be concluded from the above mentioned results that syntactic processing is fully autonomous. Patel, Gibson, Ratner, Besson & Holcomb (1996) compared ERP responses to structural incongruities in language and music, and found that linguistic and musical incongruities resulted in SPS potentials which were statistically indistinguishable from each other. These results suggest that the

SPS response is not specific to language, but relates more generally to the processing of hierarchically organized temporal sequences. Hence, on closer inspection the ERP evidence does not necessarily support the modular view of an autonomous, language specific syntactic processor.

Returning to the issue of omissions, three additional chapters spring to mind. The *Language* section contains two chapters concentrating mainly on aphasia written by Rapp & Caramazza, "Disorders of Lexical Processing and the Lexicon", and by Blumstein, "The Neurobiology of the Sound Structure of Language". Treatment of least two lines of aphasia research are missing from these chapters. For example, the work by Kolk and colleagues (e.g., Kolk & van Grunsven, 1985) on aphasia as a timing deficit is not mentioned in either of the chapters. Also the recent work by Saffran, Schwartz and colleagues is neglected (e.g., Martin, Dell, Saffran & Schwartz, 1994)—work which incorporates connectionist modeling of impairments. Sproat is the author of the only computational modeling chapter in this section, and does not include a single reference to a connectionist paper. Although the first half of the chapter considers computational modeling of aphasic prosody, the second half discusses computational models of morphology (including inflection). The lack of mention of connectionist models constitutes a rather grave ommission as it is within the area of morphology that connectionism has created the most debate (see Chater & Christiansen, to appear, for an overview). Good scholarship would seem to require at least mentioning, if not briefly discussing, connectionist morphology models such as Rumelhart & McClelland (1986a), MacWhinney & Leinbach (1991) and Plunkett & Marchmann (1993).

Overall the *Language* section may serve as reference for the perspective on language in which processing is highly modularized and acquisition is heavily guided by innate language specific constraints. However, the chapters present a quite biased view of what language processing and acquisition may look like—a view which has come increasingly under attack and whose appeal diminishes once *all* relevant evidence is considered.

Conclusion

Despite the comments above, *The Cognitive Neurosciences* is an impressive book. It is, however, not an introductory book. Readers with no knowledge of neuroscience may find some of the chapters hard to take in (although a couple of the cognitive neuroscience techniques are introduced in chapters 49 (PET scans) and 50 (ERP studies)). Nevertheless, the volume is likely to serve as a valuable reference for the particular brand of cognitive neuroscience that Gazzaniga champions, but it does not cover all there is to this field. In this review I have pointed to what may be the most striking omission: the lack of reference to connectionist research. The discussion of the *Language* section revealed additional laxness, and yet other omissions may still be lurking. So, if one chooses this volume as a source of reference to cognitive neuroscience, then one would be well-advised to consult additional complementary works (e.g., Arbib, 1995) in order to get a fuller, and more balanced, picture of how the brain may enable the mind.

Morten H. Christiansen
Program in Neural, Informational and Behavioral Sciences
University of Southern California
University Park MC-2520
Los Angeles, CA 90089-2520

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