

Preface

There is no greater fascination on the part of humanity than with the brain mechanisms that might explain our minds. What, we all ask, could possibly account for our personal awareness of the world of which we are a part? There are so many examples of this fascination in both popular culture and the scientific literature that it would be impossible to catalog them. Whether our personal answers to the great question of what we are mentally are to be found in religion, spirituality, philosophy, physiology, or psychology, the question is undoubtedly asked by virtually all of us at one time or another.

One of the most important developments in scientific history is that increasing numbers of people are attempting to answer this age-old question in terms of the biology of the nervous system and, in particular, of the nature of that magnificent organ—the human brain. The brain is probably the most complex system that has ever been discovered. Its complexity possibly rivals that of the universe and probably exceeds it in terms of the potential range and diversity of interconnections and interactions.

Cognitive neuroscience is the current manifestation of the theologies, philosophies, and sciences that have long been concerned with the relation between our minds and our brain. It asks (or should ask) questions such as:

1. How does the brain make the mind and control behavior?
2. What is the level of analysis of the brain that is the most likely basis of our cognitive processes?
3. How do traumatic brain injuries inform us about the relation of the mind and the brain?
4. How do surgically induced lesions inform us about the relation of the mind and the brain?
5. How do EEGs and brain imaging techniques inform us about the relation of the mind and the brain?
6. What is the significance of different patterns of activity on the brain when a person is stimulated or tasked?
7. Can brain imaging provide an alternative approach (to behavioral techniques) with which to measure, control, and predict behavior? Does it add value to the behavioral measures?

8. Given that the dominant current theory is that the mind can be parsed into relatively independent “modules” whose mechanisms can be localized in circumscribed regions of the brain, what is the current state of this theory?
9. What implications do new findings on the distribution of neural responses, brain “holism,” and cognitive inaccessibility have on the dominant theories of cognitive psychology and their efforts to discover the underlying neural mechanisms of our cognitive activities?
10. What is the current state of the empirical findings from brain imaging–cognitive comparisons? Does their lack of reliability and modest correlations justify their use as predictors of performance and abilities? Do they provide a coherent pathway to understanding the mind-brain problem?
11. Are we drawing appropriate interpretations and inferences from the empirical findings that have been forthcoming over the last two centuries in particular?
12. What does the future hold for cognitive neuroscience? Is it reasonable to think of a non-neuroreductive scientific psychology? In other words, can psychological science exist and prosper without neuroscience?
13. What is the likelihood that cognitive neuroscience as we conceptualize it today will be applicable to the many social and medical problems facing humanity?

The goal of this book is to consider some of the many alternative answers that have been provided to some of these questions. The strategy used here is framed in the form of a critical review of both cognitive neuroscience’s past history and its modern developments. A particular interest is considering the possible role of the newest technological development—brain imaging—in studying the relationship between the mind and the body. Unfortunately, the explosive growth of this new mode of research has not been accompanied by a comprehensive and synoptic evaluation of the huge number of studies that have been published in the past two decades. To do so coherently, however, requires that we also consider the history of cognitive neuroscience prior to the invention of modern brain imaging devices, especially functional magnetic resonance imaging (fMRI). This includes consideration of the psychological and more conventional approaches to what used to be called physiological psychology.

My purpose, therefore, is to take a cut at a synoptic synthesis of this substantial body of scientific literature. This is not going to be an easy task; results are varied and numerous, and, as I point out in the body of this book, not only is there a substantial amount of inconsistency in the research findings, but there is also great conceptual confusion about the significance of virtually every one of the multitude of reported experiments.

At the outset I must accept the fact that it is impossible to cover all of the relevant literature. However, by selecting appropriate exemplars, I hope that it will be possible to come to a reasonable conclusion about the current status of what clearly is a time of major developments in cognitive neuroscience. Having no vested interest on my own part with regard

to particular findings or specific theories, I hope what I can offer is an objective evaluation of the state of the field a decade or so into the twenty-first century.

Nevertheless, I also have to acknowledge that I come to this project with a somewhat negative bias. It appears to me that there has been far too much hyperbole and far too little critical analysis of what our experimental outcomes really mean. This has been a major problem throughout the history of cognitive neuroscience and promises to continue to be one well into the current period. I am not now convinced of the validity (defined in its most formal sense) of much of these data and even less so of the interpretations that are often attached to them.

Despite this skepticism, there has been enough empirical progress to support a major transformation in thinking about the role of brain imaging in cognitive neuroscience. That change has been from an almost phrenological orientation in which separate cognitive modules were thought to be localized in narrowly circumscribed locales in and on the brain. Recent research studies, especially those in which the results of many different experiments were combined (meta-studies), have shown that the response to even the most carefully controlled stimulus is much more widely distributed on and in the brain than hitherto thought.

In an older work (Uttal, 2001), I argued against localization on technical and conceptual grounds. In a more recent work (Uttal, 2009), I showed how recent research made this point even more emphatically and led to the conclusion that the modular-localization hypothesis had to be replaced by one that emphasized both widespread distribution of brain representations and a more unified view of psychological mechanisms.

If there is an overarching assumption driving the ideas expressed in this book, it is my focus on the failures of reductionism—both to cognitive modules and to neural mechanisms. I am now convinced that finding support for both cognitive modularism and neuroreductionism is a much more difficult task than hitherto assumed and that we actually know far less in both domains than many think we do.

In my earlier books I tried to identify the pitfalls associated with efforts to proclaim the nature of hypothetical cognitive processes on the basis of behavioral observations. In this present work I emphasize the search for some explanation of the increasing variability of empirical findings with regard to their reduction to neural mechanisms. There is still too much uncertainty about some of the most basic findings from studies that attempt to assign specific functions to specific brain regions (or to systems made up of localized functions) to uncritically accept much of the present literature. This book is a modest effort to resolve some of the present problems generated by mental inaccessibility and neural complexity.

This present work has a somewhat different orientation than the two earlier ones. After introducing my philosophy of mind-brain relations and discussing some of the general problems faced by cognitive neuroscience, I carry out a review of specific brain-behavioral studies to see how well they have informed us in our search for mind-brain relations. Although a major effort will be directed at recent imaging studies, the present situation

becomes understandable only in the context of the history, both psychological and neuroscientific, that has led us to the present situation.

There are a few general points that I should like to make in these introductory comments. First, as a psychologist, I must express the opinion that scientific psychology is at risk in the current context of brain imaging—the newest fad in its long history.¹ An important question is—do neuroscientific findings inform psychology, or does psychological knowledge inform neuroscience? As I progress through the discussions in this book, I have become increasingly convinced that neuroscience is much more dependent on psychology than psychology is dependent on neuroscience and that with the uncertainties of precise cognitive process definitions and the innate problems we have controlling cognitive states, there is substantial reason for caution. Indeed, beyond the sensory and motor systems, neuroscience has done little, in the opinion of many of us, to resolve any of the great questions of psychology. On the other hand, it is virtually impossible to carry out a meaningful experiment in cognitive neuroscience without guidance from psychological findings and theories.

Am I biased? Of course, I am. I am coming at the problems of cognitive neuroscience from a perspective that may be unusual among my colleagues. Where they seek affirmation of their findings and theories, I seek negation; I challenge the empirical outcomes and interpretative theories. Where their work is based on a set of usually implicit assumptions, I seek to make the assumptions explicit and in doing so often find contradictions at the most basic level of understanding.

Despite some who would read this criticism of cognitive neuroscience as a generalized attack on both experimental psychology and neuroscience, I hope I can make it clear to my readers that I am a strong and positive proponent of the kinds of empirical research that I discuss in this book. Much of the data, the findings, and the results obtained over the last century are relatively solid scientific facts that provide us with a picture of human nature that was not possible in the speculative periods that preceded it. As I show throughout this book, however, there is somewhat less assurance that PET or fMRI images are reliable and valid indicators of psychologically meaningful patterns of brain activity. The difficulty is in large part with the theories that have proliferated over this same time period—theories that have been proposed to explain psychological processes with neural mechanisms. I argue that most of these theories cannot be discriminated from each other for a number of reasons. First, the anatomic structures to which they refer are rarely adequately demarcated, and their activities are, to a degree not yet fully realized, unreliable and unreplicated.

Second, the data are complex, and the systems involved not adequately simplified by assumptions such as “pure insertion”—the idea that the removal of one portion of a complex process leaves all of the other components in their original state.

Third, none of the neuroscientific theories so far proposed is sufficiently quantitative or precise to account for the vagaries of the data. Indeed, most psychological theories do not have identifiable neural postulates that can be tested. Therefore, at the same time, they all

permit too much leeway in accommodating contradictory information and do not constrain our theories when opposing discoveries occur. Furthermore, without specific neural postulates, it is rare, indeed, when psychological controversies can be resolved by neurophysiological techniques. The major exceptions to this generalization occur in the sensory and motor domains where the research issues are of neural transmission codes rather than of the neural equivalents of our cognitive processes. In general unless a psychological theory has specific neurophysiological postulates, it is neutral with regard to underlying mechanisms. By “neutral” I mean that it is underdetermined; that is, it does not contain sufficient information to discriminate between plausible neural mechanisms. Underdetermination also plagues any reductionist approaches using behavior and mathematical models as well.

Fourth, there is a lot of cherry picking exhibited in the field; references are selected to provide support for arguments that on close inspection are only a small part of the relevant literature. I must admit that I cannot avoid this problem; my strategy is also to select a few particularly salient reports and deal in depth with each of them for each of the topics considered here. My bibliography will happily be shortened to the hundreds from the tens of thousands by this selective approach; however, more important is the fact that a detailed dissection of a few studies will often uncover hidden design flaws, internally inconsistent findings, and illogic that might have otherwise been overlooked.

This then brings me to a highly personal admission. Whenever one attempts to survey such a broad and complex field of science as cognitive neuroscience, it is very difficult to be sure that one has interpreted all of the reports within the frame of reference intended by the authors. I am sure that there may be discrepancies between their stated conclusions and my own evaluations of their findings. In some cases, I am probably to blame, but in others I am convinced that some investigators have read far too much into what are variable and inconsistent results. In some cases I am sure that differences in initial assumptions may also account for differing interpretations. I also apologize in advance to all of those authors whose publications are overlooked because of the sheer volume of the literature, as well as to those who may feel I have not expressed their point of views correctly.

Obviously, when one samples from such a broad literature, the selection may be unbalanced. I am aware of that problem and admit that I have often sought out articles and reports (the number of which is growing every week it seems) that were critical or that illustrated the variability or uncertainty of the empirical findings. However, the huge variety of stimuli, analytical methods, and experimental conditions makes the results far more variable and complex than anticipated. Indeed, if one examines the literature very carefully, there is a remarkable absence of real replication. This problem is exacerbated by the fact that very small changes in experimental protocol can produce very large changes in results. This problem is even further compounded by the complexity of the brain itself. An emerging generalization is that even the most peripheral parts of the brain are so heavily interconnected with higher levels that it is often difficult to tease out their separate roles.

Finally, another personal note: I am fully aware that the strongly critical approach I take in this book will not be well received by many of my fellow cognitive neuroscientists. However, I am becoming increasingly aware that the field in which we labor is heavily contaminated with both our hopes and our implicit, a priori assumptions. This does not mean that the study of behavior or brain anatomy, chemistry, and physiology will not continue to lead to understanding about their respective fields. It is the current failure to establish robust links between the cognitive and neural domains that is the problem.

If the analysis I present here provides the basis for a more realistic, constructive, and conservative evaluation of what we have accomplished in cognitive neuroscience, or even stimulates some discussion about the possible flaws in traditional and modern research, I will feel that the effort has been worthwhile. With these caveats in place, I now turn to the task at hand—a critical appraisal of the field of cognitive neuroscience in the twenty-first century.