aps ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Perspectives on Psychological Science
5(6) 772–775

DOI: 10.1177/1745691610388781
http://pps.sagepub.com
SAGE

Bridging Psychological and Biological Science: The Good, Bad, and Ugly

Arthur P. Shimamura
Department of Psychology, University of California, Berkeley

Abstract

Revolution or the new phrenology—the advent of functional neuroimaging has led some psychologists to address issues of structure-function relations that only two decades ago would have been relegated to science fiction. Others, however, are skeptical of recent bridges between psychological and biological science and consider these advances as misguided and leading us astray. With any new advancement comes problems and pitfalls, and constructive criticisms help to sharpen the research program. Here I offer commentary on the state of the art and identify both advances and concerns in bridging psychological and biological science.

Keywords

cognitive neuroscience, functional neuroimaging, localization, reductionism, biological psychology

The 1990s was proclaimed by the Library of Congress and National Institute of Mental Health as the "Decade of the Brain." In 1994, the Cognitive Neuroscience Society was founded by a group of scientists interested in bridging psychological and biological science. Just as the mid-20th century has been viewed as the era of the cognitive revolution (Gardner, 1985; George Miller, 2003), I am convinced that the 1990s will be viewed as the beginning of the cognitive neuroscience revolution. Mid-century cognitive psychologists revolted against the tyranny of behaviorism and considered mindful events, whereas cognitive neuroscientists revolted against insular views of the mind and considered brain activity.

Attempts at bridging psychological and biological science over the past two decades have certainly advanced our understanding of the mind and behavior. Of course, every science is fraught with ill-conceived motivations, poorly designed experiments, and overzealous claims, and cognitive neuroscience has its share of errant contributors. In this issue, Gregory Miller (2010, this issue) admonishes both scientists and science writers about the dangers of faulty inferences and inaccurate phraseology (see also Beck, 2010, this issue). Poldrack (2010, this issue) offers an analytic approach that attempts to dissuade us from naive attempts at localizing complex psychological phenomenon to rather circumscribed neural tissue, and, similarly, Gonsalves and Cohen (2010, this issue) highlight the benefits attained by careful analysis of functional neuroimaging data.

The cognitive neuroscience revolution is most significantly marked by advances in functional neuroimaging, particularly functional magnetic resonance imaging (fMRI), which has been an incredibly accessible and exciting means of relating brain activity to psychological function. Colorful brain images and colorful claims about the neural underpinnings of psychological function have been presented in both scientific journals and in the popular press. The excitement and popularity of neuroimaging research has led appropriately to criticisms about claims made by the field's most ardent advocates. Indeed, it has frequently been suggested that the cognitive neuroscience revolution is instead the new phrenology (see Uttal, 2001). Such criticisms need to be addressed with the hope that they can be resolved and advance the field. I believe that most critics of the field appreciate that there is worth in bridging psychological and biological science, yet conceptual blunders must be avoided. With these points in mind, I describe briefly the good, bad, and ugly of the approach.

Reductionism, Localization, and Other Metatheoretical Orientations

Gregory Miller warns us from accepting naive reductionism—the simplistic notion that complex psychological functions, such as object recognition, episodic memory, and fear, can be

Corresponding Author:
Arthur P. Shimamura, Department of Psychology (MC1650), University of California, Berkeley, 3210 Tolman Hall, Berkeley, CA 94720-1650
E-mail: aps@berkeley.edu

attributed to rather circumscribed brain regions, such as the fusiform gyrus, hippocampus, or amygdala. Such one-to-one mappings of function to structure is certainly simplistic and should be avoided. Miller's point echoes those of Dennett (1995) who described the problem of *greedy reductionism*: ''But in their eagerness for a bargain, in their zeal to explain too much too fast, scientists and philosophers often underestimate the complexities, trying to skip whole layers or levels of theory in their rush to fasten everything securely and neatly to the foundation'' (Dennett, 1995, p. 82).

In psychological science, issues of naive reductionism are interwoven with issues of *naive localizationism*. Long before the advent of fMRI, Alexander Luria, the noted neurologist, warned us against a ''narrow ''localizationist view in which one uses data from brain-injured patients to map specific disorders onto specific brain regions (Luria, 1973). Thus, Broca's aphasia should not be attributed simplistically to Broca's area. Naive localizationist views harken to the view of the phrenologists and thus encourage critics to make comparisons between those who linked bumps on the head to psychological functions to those who link bright spots on neuroimaging scans to psychological functions. Luria, however, was a reductionist and argued for a more sophisticated analysis of the neural circuits or systems involved in complex psychological functions. By analogy, the heart is an essential component of the circulatory system, but it is not the only structure involved in this system. Clearly, a full explanation of mindful events requires a consideration of broad neural circuits and the interaction of many neural processes. Yet these points do not belie the fact that there is some degree of functional localization in the brain. Indeed, damage to certain brain regions can reliably cause rather discrete problems in psychological function, including problems in language, memory, and emotional regulation. In neuroimaging studies, mindful events are often reliably correlated with activity in specific brain regions. Thus, it is important to consider a more sophisticated view of neuroimaging and neuropsychological findings that involves the identification of neural mechanisms contributing to psychological function (for an attempt to overcome narrow localizationist views in the analysis of episodic memory, see Shimamura, in press).

With respect to reductionism, Gregory Miller does not suggest any direction to follow. In fact, he never explicates what a nonnaive reductionist view would look like. He even rejects views that consider psychological functions as highly complex, though in principle reducible to brain activity. If one rejects such a view, one harbors very close to a *mentalist view*, which argues that there is something unique about the mind that cannot be explained by matter (i.e., the brain). I suspect that most scientists adopt a *materialist view*, in which only matter exists, and thus it is essentially the brain (or the body taken as a whole) that gives us the experience of psychological events, such as thoughts, feelings, and memories. From a materialist view, it is assumed that brain activity does underlie these mindful events, and thus the usage of such phrases as *neural underpinnings*, *neural basis*, or *underlying biological substrate* is perfectly reasonable. Of course, one's behavior or psychological experience can influence biological processes, as we often engage in a number of behaviors, such as overeating, overdrinking, excessive fear, and exercise, that could influence brain processes. Yet these influences are assumed to affect the body and ultimately impinge on later psychological events. Finally, it seems that some critics of the cognitive neuroscience revolution fear that psychological science will be rendered obsolete. Yet I thoroughly agree with Gregory Miller that ''Working out the biology will not make psychology obsolete'' (p. 735). Basic research in behavioral science is essential in characterizing the nature of psychological events. Indeed, it is only by careful analysis of behavioral tasks that those who use neuroimaging techniques can more succinctly characterize structure–function relations.

What Functional Neuroimaging Can (and Cannot) Do For You

Functional neuroimaging is a correlational method in which neural activity is linked to psychological events. Thus, one could assess the neural correlates of such psychological phenomena as fear, remembering, or daydreaming. Such analyses would indicate where and perhaps when brain activity occurs when confronted with a mindful event. Unless one induces neural activity and observes psychological or behavioral consequences, as is done in animal models using electrical stimulation or in humans using transcranial magnetic stimulation, one is left with correlative data that link regional activity to psychological processes. Yet the analysis of correlative data has been extremely valuable in both psychological and biological arenas. Virtually all human aging studies and studies of clinical pathologies (e.g., depression, schizophrenia) are correlational in that the primary interest centers on an analysis of a subject variable. A psychologist cannot randomly place a subject in a 70-year-old group or a schizophrenia group. Despite this restriction, such correlational analyses have been extremely useful and have advanced our understanding of psychological phenomena.

We have learned in introductory psychology courses that a correlation does not imply a causal relationship. As important as this homily is, it does not mean that scientists should ignore the possibility of a causal relation between two correlated variables. Many would argue that smoking causes lung cancer in humans, yet tobacco companies are correct in stating that there is no scientific evidence demonstrating a causal link between smoking and lung cancer in humans. Clearly, it would be unethical to consider such an empirical investigation, which would include a long-term study involving randomized groups, in which one group is forced to smoke for an extended period. Yet strong correlations between smoking behavior and lung cancer have been observed, and animal models have demonstrated causal links between the two. Such findings, taken together, offer important evidence to conclude that smoking causes cancer. Similarly, one could observe in an fMRI study an area in the brain in which activity is reliably correlated with a mental event, such as remembering. Such findings, along

with lesion studies in animal models and neuropsychological studies of memory impairment in patients, could be convincing evidence to suggest that the brain area contributes to remembering in a causal fashion, though of course not in a narrow localizationist manner. When Gregory Miller states that ''To date, no fully developed demonstration of a mechanism by which psychology or biology affects the other has been offered'' (p. 716), he seems precariously close to making the same kind of assertions that tobacco companies make about their products.

At the moment, there are three general methodologies used in functional neuroimaging. The first and most widely used method is the (usually pairwise) comparison of conditions within a task. For example, in an fMRI study, one might assess brain regions as being active when a subject recognizes a test item as ''old'' compared with trials when the subject identifies an item as ''new.'' In this subtractive method, one can assess the neural correlates associated with one condition (i.e., remembering) in comparison with another baseline condition (i.e., not remembering). Most functional neuroimaging studies assess such within-task activations. A second method is to consider cross-task or cross-function analyses in which two very different tasks are presented during the same scanning session to determine the degree of overlap in activity between the tasks (see Cabeza et al., 2003). This method is also considered by Poldrack in his analysis of various tasks that might activate the same brain region. Cross-task analyses highlight more complex structure-function relations as two diverse mental events might activate the same brain region. In such instances, one cannot claim a simple one-to-one mapping between structure and function. A third method involves functional connectivity analyses in which multivariate models are used to address activity across large-scale neural networks (see Rogers, Morgan, Newton, & Gore, 2007). All of these methods are correlative in nature, though each offers important clues to the biological bases of psychological processes.

Cognitive Neuroscience: "What?", "Where?", and "How?"

Poldrack (this issue) identifies ''where'' and ''what'' strategies when conducting neuroimaging research. I would like to suggest a broader usage of these questions as they are important for cognitive neuroscience and thus critical in bridging psychological and biological approaches. When one asks a ''What?"-question, such as ''What is remembering?'' or ''What is depression?'', it is essential to describe mental events in terms of psychological processes and how they are affected by task variables. Experimental psychologists, sans neuroscience, focus on such ''What?'' questions. Indeed, the cognitive revolution demonstrated how information processing approaches could help in describing psychological phenomena (see Gardner, 1985). Even today, it is common and useful to refer to psychological concepts such as executive control or bottom-up processes when describing psychological phenomena. As mentioned above, it is certainly a worthy enterprise to conduct behavioral analyses that describe the nature of psychological events without referring to brain processes. Indeed, one could still be a materialist but nevertheless solely be interested in psychological conditions or variables that influence behavior.

"Where?'' questions attempt to define the neural correlates of psychological phenomena. Such questions address the neural underpinnings of psychological phenomena, as it is assumed that brain activity is the basis for psychological events. Functional neuroimaging studies, as well as studies of brain-injured cases, address the ''Where?'' question. As such, these studies help define brain regions that contribute to psychological events. It is important to note that the psychological tasks used to study ''Where?'' questions are critical, and thus analyses of brain-oriented issues depend upon knowledge gained from addressing ''What?'' questions. In other words, worthy functional neuroimaging findings are based on careful descriptions and behavioral indices of psychological phenomena.

Unfortunately, many cognitive neuroscientists consider the endpoint of their endeavor as discovering where brain activations occur for a particular psychological event. That is, one might say, ''I have found the brain region that is most highly active during a fear-induced condition.'' As important as this finding is, cognitive neuroscience must go further in characterizing the neural mechanisms or circuits that underlie particular structure–function relations. In other words, theories must address ''How?'' questions: ''How does a brain region contribute to a fear response?'', ''How does the hippocampus contribute to remembering?'', etc. Without addressing ''How?'' questions, the field is subject to criticisms of naive reductionism and narrow localizationism. To answer ''How?'' questions, it is necessary to consider broader neural circuits and develop theoretical frameworks that might even encompass whole-brain interactions. To go beyond ''What?'' and ''Where?'' questions, it is often necessary to consider computational models that define *how* neural circuits operate.

Some have criticized functional neuroimaging for failing to contribute anything new to our understanding of psychological phenomena. Some suggest that neuroimaging studies have only replicated or confirmed what has already been discovered by animal models or studies of brain-injured cases. It would be rather disturbing if neuroimaging data did not confirm extant findings of structure–function relations. Indeed, the fact that neuroimaging studies have often corroborated findings from animal and neuropsychological studies provides further evidence for causal links between brain activity and psychological phenomena. Despite these criticisms, neuroimaging investigations have provided new and important scientific discoveries. As Gonsalves and Cohen assert, the importance of the posterior parietal cortex in episodic retrieval is a finding that was discovered only by functional neuroimaging research. The role of the anterior cingulate gyrus in conflict monitoring is another prime example (see Botvinick, Cohen, & Carter, 2004). When considering criticisms of the field, it is hoped that most everyone believes that there has been progress and that at least the cup is filling up and may even be half full. Criticisms that pertain to overzealous inferences in data interpretation or suggestions

that some practitioners act as if the cup is nearly full are useful and help drive more sophisticated analyses.

Declaration of Conflicting Interests

The author declared that he had no conflicts of interest with respect to his authorship or the publication of this article.

References

Beck, D.M. (2010). The appeal of the brain in the popular press. *Perspectives on Psychological Science*, *5*, 762–766.

Botvinick, M.M., Cohen, J.D., & Carter, C.S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Science*, *12*, 539–546.

Cabeza, R., Dolcos, F., Prince, S.E., Rice, H.J., Weissman, D.H., & Nyberg, L. (2003). Attention-related activity during episodic memory retrieval: A cross-function fMRI study. *Neuropsychologia*, *41*, 390–399.

Dennett, D.C. (1995). *Darwin's dangerous idea: Evolution and the meanings of life*. New York: Simon & Schuster.

Gardner, H. (1985). *The mind's new science*. New York: Basic Books.

Gonsalves, B.D., & Cohen, N.J. (2010). Brain imaging, cognitive processes, and brain networks. *Perspectives on Psychological Science*, *5*, 744–752.

Luria, A.R. (1973). *The working brain: An introduction to neuropsychology*. New York: Basic Books.

Miller, George A. (2003). The cognitive revolution: A historical perspective. *Trends in Cognitive Science*, *3*, 141–144.

Miller, Gregory A. (2010). Mistreating psychology in the decades of the brain. *Perspectives on Psychological Science*, *5*, 716–743.

Poldrack, R.A. (2010). Mapping mental function to brain structure: How can cognitive neuroscience succeed? *Perspectives on Psychological Science*, *5*, 753–761.

Rogers, B.P., Morgan, V.L., Newton, A.T., & Gore, J.C. (2007). Assessing functional connectivity in the human brain by fMRI. *Magnetic Resonance Imaging*, *25*, 1347–1357.

Shimamura, A.P. (in press). Hierarchical relational binding in the medial temporal lobe: The strong get stronger. *Hippocampus*.

Uttal, W.R. (2001). *The new phrenology: The limits of localizing cognitive processes in the brain*. Cambridge, MA: MIT Press.