Redefining cognitive psychology

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Abstract: Posner & Raichle illustrate how neuroimaging blends profitably with neuropsychology and electrophysiology to advance cognitive theory. Recognizing that there are limitations to each of these techniques, we nonetheless argue that their confluence has fundamentally changed the way cognitive psychologists think about problems of the mind.

In his field-defining book, Neisser (1967) argued that "psychology is not just something 'to do until the biochemist comes'" (p. 6). By analogy, he argued, an economist trying to understand the flow of capital is helped little by knowing about the physical properties of money, its location in banks, its movement from one bank to another, and so on. "Psychology, like economics, is a science concerned with the interdependence among certain events rather than with their physical nature" (p. 7).

Twenty-seven years later, *Images of mind* tells us otherwise. It details the joint value of electrophysiological studies of animals engaged in cognitive tasks, behavioral experiments on normal human subjects, behavioral studies of brain-injured patients, and especially neuroimaging studies of subjects as they engage in psychological tasks. How has the study of neural processes added to the study of mental processes in a way that now earns it a respected place in the armory of the cognitive psychologist?

Posner & Raichle (P&R, 1994) illustrate how research in neuroscience provides real constraints on theories of cognitive processes and helps to adjudicate among competing psychological theories. *Images of mind* (henceforth *Images*) shows that cognitive psychology now has a new set of tools and a new source of evidence at its disposal. There is more than this, though. *Images* reveals that the discipline of cognitive psychology is being transformed in a more fundamental way by the neural sciences. Investigations of the brain offer new insights into the understanding of psychological constructs, including ones that have been the subject of study since the field's inception. This is amply clear in the study of attention, a construct that is the centerpiece of P&R's text.

Consider, for example, the PET study by Corbetta et al. (1991) outlined at the beginning of Chapter 4. This work indicates that focusing attention on particular attributes in the visual world is associated with increased neural activity within brain regions dedicated to processing those sensory attributes. This result reveals how top-down processing can modulate bottom-up processing in a way that is consistent with the neuroanatomy of feedback pathways from higher cortical centers to early processing areas. In fact, this notion of feedback modulating lower-level cognitive operations (reentrant processing) permeates not only the study of attention but also the study of imagery and word reading, as described by P&R. In this way, a biological observation can have significant impact on psychological theory in several domains, thereby providing a fundamentally new insight.

The heart of P&R's discussion about cognitive neuroscience is the use of neuroimaging to study cognitive processes. How is this methodology transforming the study of mind? It is tempting to see neuroimaging as a technique that will simply provide a large database of information about localization. Indeed, it will. However, the usefulness of imaging techniques goes far beyond this, as P&R indirectly observe. Localization is not a destination for the cognitive psychologist; it is a vehicle for reaching a destination. By localizing the structures that mediate task performance, one can dissociate psychological processes: structures involved in one task may not be active in another (and vice versa), suggesting different processes in these tasks. Using this information, one can develop hypotheses about brain circuits that mediate cognitive abilities. There are now several examples of this, including the analysis of words and letter strings, the region-specific effects of selective attention (both described in *Images*), and the dissociation of different types of working memory (Smith & Jonides 1994).

Neuroimaging may have advantages over other cognitive neuroscientific techniques in studying human brain mechanisms and so it is fitting that P&R emphasize imaging results. There are well-documented problems with studies of humans with focal brain damage, for example (Farah 1994). Also, while animal studies of working memory, such as those of Goldman-Rakic (e.g., 1987), provide an important basis for neuroimaging studies of human working memory (e.g., Jonides et al. 1993), caution may be needed when generalizing from animal findings to human cognition. One reason for caution is that the human brain is clearly more lateralized than the brain of any other animal. As described by P&R, this lateralization extends beyond language skills to vigilance, imagery, and various aspects of attentional mechanisms. Thus, there may be important weaknesses in the analogy between the organization of cognitive processes in human and nonhuman brains.

Although the outlook for the place of neuroimaging data in the study of cognition is a rosy one, it is not yet time to dance in the streets. Important problems remain to be solved in acquiring and analyzing neuroimaging data. Even more pressing are issues concerning data interpretation. Questions about subtractive methodology (Sergent et al. 1992) suggest the need for alternative designs. Issues concerning the interpretation of blood flow increases versus decreases in an experimental condition compared to a control condition also need to be addressed. The standard interpretation is that increases reveal heightened brain activity, thereby suggesting heightened cognitive activity in that area. Yet activation increases could sometimes be a sign of greater inhibition of structures downstream. Likewise, decreased activation may reflect the inhibition of some structure and disinhibition of some downstream structure, producing a net increase in activation in some later region. Addressing such issues will require more routine use of sophisticated data analysis techniques, such as path analysis, that may reveal the interdependence of activation levels between areas.

Also, neuroimaging techniques are restricted by their reliance on the activation of large numbers of neurons to reveal a measurable signal. For blood flow studies using PET, these large numbers of neurons must further be active for some 40 seconds to fill a recording interval. So, failing to find a signal in some task is a datum of quite questionable value that should be taken with even greater caution than null results in behavioral studies. The problem is one of duty cycle: obtaining a signal requires that a process and its neural substrate be active during a significant portion of the PET recording interval in comparison to other ongoing processes. Failure to find activation could mean that a brain structure was active for only a small portion of the interval. In such cases, it would be a misinterpretation to argue that the structure in question did not participate in the task (an example may be the discussion of speech production on pp. 118–119 in *Images*).

These caveats aside, there is reason to view the text of Posner & Raichle as a celebration of a new era in the study of cognition. This era goes beyond Roy and Sherrington's (1890) call that "physiology and psychology . . . will find it serviceable for each to give to the . . . other even closer heed than has been customary hitherto." The interdisciplinary study of mind and brain is yielding new methods and new concepts that are redefining cognitive psychology.