

AMAZING PAPERS IN NEUROSCIENCE

Cognitive Neuroscience and Single-Word Processing

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Early neuroimaging research on language-related function is useful for teaching cognitive neuroscience. In these studies, researchers used relatively simple experimental designs in an attempt to break down complex cognitive processes. In addition, the hypotheses tested in these studies were based on models derived from non-imaging observations, such as lesion studies. Thus, students at all levels may find the research accessible in its simplicity and engaging in its attempt to test existing theories in novel ways. Raichle (1996) describes a series of such studies that used what were, at the time, novel applications of relatively young imaging methods to measure brain activity related to single-word processing. In a short, readable

article, he places the studies in their historical context (i.e., models of language function based largely on case studies of patients with brain lesions) and describes the methods and designs used in the research. He summarizes the results and the main takeaways from the research and its practical implications for research and medicine in the future. This paper touches on many important features of cognitive neuroscience, as well as psychology and neuroscience more broadly. It can serve as a springboard into discussion of many topics in many course contexts.

Key words: Cognitive neuroscience; language; fMRI; PET; neuroimaging; experimental methods.

Beginning in the 1980s, Marcus Raichle and his team at Washington University in St. Louis conducted a series of studies in which they used non-invasive imaging methods to examine brain activity related to processing single words. This work included some of the earliest applications of human neuroimaging to the study of psychological processes (thanks, in part, to the involvement of psychologist, Michael Posner). In his typical, engaging style, Raichle (1996) gives the main take-home messages from this research, placing it within a historical context—looking forward, as well as back.

Raichle (1996) begins with the lesion-based case studies of Paul Broca and Carl Wernicke from the late 1800s, each of which involved identification of a language processing area that now bears the discoverer's name (i.e., Broca's area, Wernicke's area). Raichle immediately points out the limitations of lesion studies that have nevertheless given rise to models of language processing in the brain. He quickly moves to the late 1900s, when non-invasive studies of brain structure and function became possible. He gives a brief but informative summary of positron emission tomography (PET; specifically ^{15}O labeling) and functional magnetic resonance imaging (fMRI) as each is used in functional brain imaging, followed by the use of the subtractive method—first in purely behavioral studies, then in experimental functional neuroimaging research on cognitive processes.

On these historical and methodological foundations, Raichle (1996) proceeds to the meat of the paper, in which he summarizes a series of PET and fMRI studies of brain activity related to processing single words (specifically nouns). He focuses specifically on visual processing, although the group also conducted studies with words presented aurally. The research involved four conditions:

(1) watching a small fixation cross (from which activity during eyes-closed rest was subtracted), (2) silently viewing words, (3) reading words aloud, and (4) generating a verb to go with each noun. Some findings were not surprising: All conditions involved the activation of visual areas, and motor areas became active when the participants spoke. However, there were also unexpected findings: First, based on lesion studies, reading aloud was expected to elicit activity in Wernicke's and Broca's areas. It did not. These areas became active only during the verb-generation task. Second, the cerebellum was more active during the verb-generation task than the reading-aloud task, suggesting involvement in cognitive aspects of the task (since motor activity was similar in both tasks). Finally, reading aloud elicited bilateral activity in the insular cortices within the Sylvian fissure. This activity was not seen in the verb-generation condition unless the task was made less effortful through practice.

Raichle (1996) summarizes their findings with a two-route model of single-word processing: (1) A more automatic one seen in the read-aloud task and when participants were very familiar with the words in the verb-generation task, and (2) one that meets the demands of novelty (possibly including inhibition of the other route) and includes Wernicke's and Broca's areas. He then concludes by addressing the limitations of various cognitive neuroscience methods alone, and giving examples of the benefits of combining methods (e.g., lesion studies and functional neuroimaging studies). These benefits apply in both research and clinical settings.

VALUE

Although published in a relatively obscure journal, this paper is a wonderful resource for faculty teaching cognitive neuroscience at all levels. It is short, well written, and

provides a springboard for discussion of many important points in cognitive neuroscience—and more generally in neuroscience and psychology. These points include organizational principles in the brain (e.g., networks vs. isolated areas, plasticity with learning), limitations of various methods in science and in medicine and benefits of using multiple methods, the process of developing and testing hypotheses, and advancements in neuroimaging methods (e.g., more sophisticated comparisons, event-related designs and analysis). A video is available that depicts some of the research described in the paper (Module 8: Language Processing in the Brain, in Vattano, et al., 2000; http://www.learner.org/vod/vod_window.html?pid=1615). Engaging activities in numerous courses can be built around this video (e.g., see Sable, 2015).

AUDIENCE

For me, this paper has inspired class activities in courses ranging from general psychology to graduate seminars and in topical contexts ranging from an introduction to the psychology of language to the opening day of a seminar in cognitive neuroscience. In lower-level classes, I do not assign the paper to read, instead focusing on the video and

details that are relevant to the topic (using the paper as a resource for myself). However, in more advanced undergraduate and graduate courses, the paper may be an excellent reading assignment.

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