# M M : A E S I G N

L K. F [illegible] [1], A S. H b [illegible] [1,2], D A. M [illegible] [1], G S [illegible] [1], S W [illegible] [1,3], D H. W [1]

**Ab**

■ A major thrust of cognitive neuroscience is the elucidation of structure–function relationships in the human brain. Over the last several years, functional neuroimaging has risen in prominence relative to the lesion studies that formed the historical core of work in this field. These two methods have different strengths and weaknesses. Among these is a crucial difference in the nature of evidence each can provide. Lesion studies can provide evidence for necessity claims, whereas functional neuroimaging studies do not. We hypothesized that lesion studies will continue to have greater scientific impact even as the relative proportion of such studies in the cognitive neuroscience literature declines. Using methods drawn from systematic literature review, we identified a set of original cognitive neuroscience articles that employed either functional imaging or lesion techniques, published at one of two time points in the 1990s, and assessed the effect of the method used on each article's impact across the decade. Functional neuroimaging studies were cited three times more often than lesion studies throughout the time span we examined. This effect was in large part due to differences in the influence of the journals publishing the two methods; functional neuroimaging studies appeared disproportionately more often in higher impact journals. There were also differences in the degree to which articles using one method cited articles using the other method. Functional neuroimaging articles were less likely to include such cross-method citations. ■

## INTRODUCTION

Understanding the relationship between human brain structure and function is a major focus of cognitive neuroscience. The methods available to achieve this goal have undergone significant changes over the last 15 years. In particular, functional neuroimaging is rapidly replacing neuropsychological studies of people with brain lesions as the central method in this field.[1] Functional imaging and lesion studies differ in important respects. The nature of the evidence provided by the two is, in principle, fundamentally different, making them complementary rather than competitive techniques. Indeed, no contemporary book or review of cognitive neuroscience seems complete without an introductory paragraph emphasizing the need for studies using converging methods to compensate for their different strengths and weaknesses (D'Esposito & Devinsky, 2004; Farah, 2004; Rorden & Karnath, 2004; Heilma&monly employed for studying structure–function relationships in the human brain. What influence does the method used have on the impact of a cognitive neuroscience study, and has this changed as functional neuroimaging has gained importance over the last several years? If there are method-based differences in

different neural circuits. Indeed, it may even be the case that the same population of neurons can support different cognitive functions. Thus, activity of a region in two or more tasks, or impairment on multiple tasks due to a single, small lesion, might be explained either by a common underlying function or by multiple functions (Duncan & Owen, 2000; Farah, 1994; Shallice, 1988; Rumelhart & McClelland, 1986). Finally, both lesion method and functional imaging share a reliance on ceteris paribus assumptions: that a single variable is being manipulated and all other things are equal. Ceteris paribus assumptions create problems that are method-specific, but the underlying philosophical issue is one that all methods share. For example, in lesion studies, a lack of reorganization is generally assumed: All other neural regions in a lesioned brain are assumed to be performing the same tasks they performed prior to lesion acquisition, and not acquiring the functions of the lesioned area. (This assumption almost certainly does not hold in chronic-stage lesion patients; Farah, 2004.) In functional imaging studies, it is assumed that two tasks that differ theoretically in a single cognitive process do not differentially recruit neural regions for theoretically shared task components (Posner, Petersen, Fox, & Raichle, 1988). (This assumption is also unlikely to hold; Friston et al., 1996.)

In addition to these shared inferential issues, there is an important difference in the kinds of inferences that can be drawn from functional imaging and lesion methods. In contrast to lesion studies, functional imaging studiestc7ids dpar(ly)-35 TDcoer rea(tionas.)3560.5Such.

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methods used in the articles that had cited the articles in our index group, and counted how many such citations were ''within method'' and how many were ''across method.'' In other words, when an article in our subset was cited, how often was it cited by an article that shared the same method, and how often by an article that used the other method? We found that within-method citation occurred 417 times in the 12 selected imaging studies, and 139 times in the 12 selected lesion studies. Across-method citations occurred 48 times in imaging studies, and 30 times in lesion studies. An ANOVA of these data revealed a significant main effect of the within/across-method factor on citation count [$F(1,22) = 5.2,$ $< .05$]. Notably, there was also an interaction of this factor with the lesion/imaging method factor [$F(1,22) = 5.8,$ $< .05$], indicating a greater bias away from across-method citations in the functional imaging literature.

## DISCUSSION

& Zilles, 2003; *J al f Ne cie ce*: Raichle, 2003). Some theorists have raised the bar still higher, arguing that mere convergence between two methods is insuf-

The results of the automated searches were hand-reviewed by two investigators independently to identify the articles that met the three criteria listed above. The same investigators then classified the selected articles, according to the principle method used, as one of the following: (1) lesion study; (2) functional imaging (including functional magnetic resonance imaging, positron emission tomography, and single-photon emission computed tomography); (3) electrophysiological (event-related potentials, electroencephalography, magneto-encephalography, intracranial recording); (4) neurochemical-level studies (pharmacological agents, Parkinson's disease, genetic studies of receptors, etc.); (5) combinations of these; and (6) other. The results of this independent selection and classification were compared, and differences were resolved by consensus between the two reviewers. The present work focuses solely on lesion and functional imaging studies. A total of 91 articles published in 1993 and 178 articles published in 1997 formed the dataset on which further analyses were performed.

### I A

In keeping with common practice, citation counts were used as a marker of the impact of each publication. Citation counts, tracked by year, were obtained from the ISI Citation Indexes (http://isi6.isiknowledge.com/portal.cgi) from each article's publication date through September 2003. To explore the possibility that the journal of publication might have an independent influence on citation rate, we also included journal impact factor (as of September 2003, drawn from the ISI website: http://isi6.isiknowledge.com/portal.cgi/jcr) as a variable in the analysis.

### E g M b C P

In an effort to examine the use of converging evidence, we examined the extent to which a subset of our pool of articles was cited by articles using other methods (''across-method citations''). Twelve articles from 1993 and 12 articles from 1997 were randomly selected from the original pool of 269 articles, with the constraint that half of this subsample were lesion studies and half were functional imaging studies. The articles that cited each of these 24 articles were identified using the ISI Citation Indexes, and were classified as lesion, functional imaging, or other study. The number of times that each of the 24 articles was cited by articles in these three categories was then determined.

### S A

The dependent variables were all positively skewed, and so were log-transformed prior to being submitted to parametric analyses.

## APPENDIX

### A. B N G N M S MEDLINE

1. brain.mp. or exp BRAIN/
2. exp NEURONS/
3. cerebral.mp. or exp CEREBRAL CORTEX/
4. (frontal adj lobe).mp. [mp = title, abstract, cas registry/ec number word, mesh subject heading]
5. exp Frontal Lobe/
6. (temporal adj lobe).mp. [mp = title, abstract, cas registry/ec number word, mesh subject heading]
7. exp Temporal Lobe/
8. (parietal adj lobe).mp. [mp = title, abstract, cas registry/ec number word, mesh subject heading]
9. exp Parietal Lobe/
10. exp PREFRONTAL CORTEX/ or prefrontal.mp.
11. (prefrontal adj cortex).mp. [mp = title, abstract, cas registry/ec number word, mesh subject heading]
12. Broca.mp.
13. Wernicke.mp.
14. cerebellum.mp. or exp CEREBELLUM/
15. exp Basal Ganglia/
16. (basal adj ganglia).mp. [mp = title, abstract, cas registry/ec number word, mesh subject heading]
17. amygdala.mp. or exp AMYGDALA/
18. exp Hippocampus/ or hippocamp$.mp.
19. thalamus.mp. or exp THALAMUS/
20. exp Thalamic Nuclei/ or exp Gyrus Cinguli/ or cingulate.mp.
21. (nucleus adj accumbens).mp. [mp = title, ab-

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30. (functional adj magnetic adj resonance adj

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