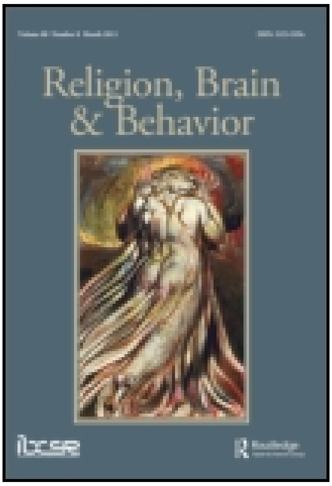

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Religion, SCAN, and developing standards of inquiry

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EDITORIAL

Religion, SCAN, and Developing Standards of Inquiry

Social, cognitive, and affective neuroscience (SCAN) names a spectrum of integrative approaches grounded in cognitive neuroscience, itself an integrative field that emerged in the 1980s and that united perspectives from cognitive psychology and neuroscience. SCAN uses cognitive neuroscience to understand social, emotional, and behavioral aspects of thought. It hopes to enrich both neuroscience and social science by integrating models of how the mind works with models of how societies function. Cognitive neuroscience has changed continually since its origins over 35 years ago, widening the integrative reach of its inquiries and refining its methods, particularly in relation to neuroimaging. The emergence of SCAN is a neat illustration of the bi-directional influence between social science and neuroscience.

Methods for measuring and analyzing the brain once fashionable in the 1980s, 1990s, and up to 2008 or so, have not survived critical scrutiny of first principles and statistical rigor. Looking ahead, a key challenge to the quality of SCAN is developing reasonable strategies for scientific inference. Many neuroscience journals have responded to this challenge by developing new standards. For instance, the Society for Neuroscience and its flagship journal, the *Journal of Neuroscience*, have adopted new standards for reporting to augment the quality and assessment of research by the increasing numbers of fields and scholars drawn to neuroscientific inquiry. The editors of *Religion, Brain & Behavior* are assessing these shifts with the goal of producing detailed guidelines for publication that will help its readers and prospective authors apply a uniform set of best practices when targeting the brain's important functions in religious cognition and behavior. A future editorial will introduce these new standards.

While uniform standards are crucial, default standards are a poor replacement for balanced reflection on the valuable contributions and inevitable limitations of any study. An important challenge in any scientific enterprise, particularly a recently emerging area such as SCAN, is to develop policies that combine rigor with commonsense recognition of the distinctive challenges that every study must navigate.

Rather than offering a final word, we hope to improve our assessment by inviting readers to comment. Letters in response to this editorial (up to 500 words and submitted to rbbsubmit@ibcsr.org) will be considered for publication in a subsequent edition of RBB. In the years ahead, we will be reviewing our assessment of this highly productive area, and we hope the journal will continue to benefit from the collective wisdom of its readership.

In what follows we aim to describe widespread misunderstandings about the promise and perils of SCAN for addressing basic questions about how religion works. We hope that readers will take away a sense of the excitement and potential that SCAN brings for understanding how religious minds and groups elaborate each other, while at the same time understanding the practical limitations on inference in this young but growing area of science. We briefly cover four broad, but critically important, cautionary principles for presenting and interpreting neuroimaging data that often go unrecognized. Highlighting these best practices will assist readers wanting a surer set of perspectives from which to assess papers, and authors wanting greater rigor in marshalling evidence from the existing literature.

First, functional magnetic resonance imaging (fMRI) does not directly measure neural signals. Rather, fMRI indexes the heightened metabolic demands in the brain arising from those signals. Most optical imaging is similarly dependent on metabolic demands. fMRI and optical imaging help researchers localize brain activity but inferring the underlying electrical signaling in the neurons is not straightforward. Metabolic signals are slow in comparison to electrical signals, requiring several seconds to develop. In fact, their relationship to neural signals is not well understood. So the activation patterns of fMRI and optical imaging do not directly measure the extent and timing of neural activity in relation to a set of mental functions. That is, a single brain region may include neural networks coding diverse mental functions, but if those networks are similar in metabolic demand, it may be impossible to distinguish them via fMRI. Identical fMRI activation is not a guarantee of identical neural coding. Additionally, because fMRI and optical imaging are metabolic rather than electrical proxy signals, they may fail to measure neural activity that is critically important to some set of mental functions that is not sufficiently metabolically demanding. Absence of fMRI activation in a neural network cannot be taken as definitive evidence of an absence of that network in the function of interest.

Second, electro-encephalography (EEG) and magneto-encephalography (MEG) measures arise from combinations of many electrical sources in the dendrites of the brain as they influence electrical or magnetic sensors on or near the scalp. Inferring the location of those electrical sources in the brain requires high density arrays of sensors and sophisticated computational methods, most of which only became widely available over the last five to ten years. EEG/MEG signals provide temporal sensitivity in the range of milliseconds and can provide insight into rapid neural changes underlying mental function. But the location of an EEG or MEG sensor on or above the scalp provides no direct measure of the neural signals underneath. A "temporal" or "parietal" EEG electrode derives its name not from the area of brain it accesses, but instead from the portion of the skull it rests above, a convention that is often obscured by EEG/MEG papers published prior to just a few years ago. The introduction of dense arrays of EEG and MEG sensors (128 sensors or more) and of Bayesian source inference algorithms has made possible much greater spatial sensitivity from EEG/MEG. However, studies using extracranial EEG/MEG require at least 64 sensors and must include sophisticated source inference algorithms to yield information about where in the brain the EEG/MEG signals arise. This rule is important to accurately assess brain localization from studies using EEG/MEG methods.

Third, it is impossible to assign mental function from neural measures alone. Any association of neural measures with mental functions of interest requires careful assessment of a study's task design and behavioral measures. For example, a study of the neural codes for managing cognitive conflict must use a task that directly contrasts conditions of cognitive conflict, such as the Stroop task. Such studies routinely identify regions in the rostral cingulate zone. This routine association between cognitive conflict tasks and the rostral cingulate zone does not support the claim that "anytime this neural region is activated in a study – no matter the task design – it is evidence of cognitive conflict management." Such a claim is known as reverse inference, or affirming the consequent. Though such practices were routine in the early years of neuroimaging, they are now recognized as violations of the standard logic of scientific inquiry in SCAN.

The fourth cautionary principle related to neuroimaging applies not to dynamic signals of brain function but to static signals of brain structure in relation to impaired or preserved mental functions following a lesion to the brain. This is especially relevant to the challenge of using naturally occurring brain lesions to assign mental functions to neural tissues. In lesion-deficit mapping (LDM) of mental functions onto neural regions, for example, preserved mental function in the presence of a brain lesion does not by itself determine that the lesioned region is unimportant to the mental function in healthy brains. Over the last 15 years or so, a growing awareness of brain plasticity has resulted in a greater awareness that a mental function requiring a given neural network in healthy brains can, following a lesion to that network and time for healing and retraining, be carried out by other networks. LDM is extremely important in assigning mental functions to localized regions whose lesions result in impaired function. However, LDM provides much more limited insight into the function of healthy brains in cases where lesions occur without loss of function.

New advances in the theory and methodology of inquiry in SCAN continue to require attention by the authors, readers, and editors of this journal. Just in the last year or two, brain connectomics has exploded, yielding an array of measurement, analysis, and inferential approaches that are showing us how limited is the view that seeks only the modular localization of mental function. As SCAN develops and RBB along with it, keeping these four cautionary principles in mind will only help to improve our models of how to relate religion, brain, and behavior.

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