Social Cognition, Vol. 28, No. 6, 2010, pp. 695–716

CAN NEUROSCIENCE ADVANCE SOCIAL PSYCHOLOGICAL THEORY? SOCIAL NEUROSCIENCE FOR THE BEHAVIORAL SOCIAL PSYCHOLOGIST

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Social neuroscience is a young and thriving area of research in psychology that integrates diverse literatures and methodologies to address broad questions about the brain and behavior. But despite the excitement and activity generated by this approach, its contribution to ideas in social psychology is sometimes questioned. This article discusses the ways in which social neuroscience research may or may not contribute to theoretical issues in social psychology. Still a young field, much research in this area has focused on issues of brain mapping and methodological development, with less emphasis on generating and testing novel social psychological hypotheses. The challenges to theoretical advancement, including psychometric and methodological issues, are considered, and a set of guidelines for conducting theoretically-informative social neuroscience is offered. In the final analysis, it is argued that neuroscience has much to offer to social psychology, both theoretically and methodologically, but that like any new approach, these contributions will take time to realize.

The modern field of social neuroscience represents the culmination of nearly a century of research on the interplay of mind and body in social situations, with roots that can be traced to ancient Greek physicians and philosophers (Cacioppo, 1982). Building on interdisciplinary approaches such as social psychophysiology (Cacioppo & Petty, 1979; Rankin & Campbell, 1955) and clinical neuropsychology (Damasio, 1994; Frith, Morton, & Leslie, 1991), the modern social neuroscience approach integrates ideas from multiple research areas in psychology and neuroscience to address questions about social processes in the mind and brain. The emer-

The writing of this article was supported in part by an award from the National Science Foundation (BCS 0847350). The author thanks members of the NYU Social Neuroscience Lab, Jeff Sherman, who served as Action Editor, and two reviewers for their thoughtful comments on earlier drafts of this manuscript.

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gence of Social Neuroscience was recognized in print by Cacioppo and Berntson (1992; see also Cacioppo & Petty, 1983; Carlston, 1994; Leiderman & Shapiro, 1964; Shapiro & Crider, 1969), and later updated to reflect the influences of cognitive neuroscience and neuropsychology in the intervening years (Klein & Kihlstrom, 1998; Ochsner & Lieberman, 2001). The field has since been the subject of several dedicated research conferences, which have grown into the Social and Affective Neuroscience Society, founded in 2008 and the Society for Social Neuroscience in 2010.

In its most recent emergence, the field of social neuroscience elicited much excitement from social psychologists. It promised to stimulate important discoveries about the social mind while achieving new heights of methodological precision. It also offered the cachet of biological science to a field too-often concerned about its caricature as a soft science. As the field of social neuroscience gained its footing, it enjoyed special attention and support from the academic press, in the form of special issues in top journals and the launch of two dedicated journals, along with targeted support from funding agencies (at a time when funding for behavioral social psychology waned). It also garnered special attention from the popular press—with ambivalent approval from social psychologists who, while appreciating the increased public interest, had received far less recognition for behavioral studies of similar phenomena in which the brain's involvement was tacitly assumed. In this context, social psychologists have begun to wonder whether social neuroscience is living up to its fanfare—what, exactly, has it contributed to the field of social psychology? Does one really need neuroimaging methods to test social psychological ideas? Such questions reflect legitimate concerns about both the research goals and the scientific practices of the field.

The goal of this article is to discuss how the social neuroscience approach may or may not contribute to social psychology. To this end, I describe different approaches to social neuroscience and discuss some key psychometric and methodological problems associated with neuroimaging studies of social psychological processes. I also describe the ways in which social neuroscience may be successful in advancing social psychological theory, using examples from the literature. Finally, I present a set of suggested guidelines for conducting social neuroscience research that can inform social psychological questions. The ultimate goal of this article is to make the case to behavioral social psychologists that neuroscience has the potential to make important novel contributions to social psychological theory and research, but that care is required to determine what, when, and how social neuroscience research may serve this purpose.

WHAT IS SOCIAL NEUROSCIENCE?

Social neuroscience means different things to different people. To a social psychologist, it refers to an interdisciplinary research approach that integrates theories and methods of neuroscience (and other biological fields) to address social psychological questions. To a cognitive neuroscientist, it often refers to research on the neural substrates of social processes, such as social emotions and person perception, with a focus on understanding neural function. To an animal behaviorist, it may represent research on the neural and hormonal mechanisms associated with basic social behaviors, such as dominance and affiliation. Broadly speaking, social neuroscience refers to an integrative approach that can be applied to any scientific question concerning social processes and the brain. For the present purposes, it is important to note that much of social neuroscience is not intended to address a social psychological question and, as such, it is not necessarily expected to inform theories of mainstream social psychology. A goal of this article is to assist behavioral social psychologists in determining when and how neuroscience might inform their interests.

WHY SHOULD BEHAVIORAL SOCIAL PSYCHOLOGISTS CARE ABOUT THE BRAIN?

Social psychology seeks to understand the mind and behavior in the context of social and situational factors. Although the approaches and specific questions have changed over the years, contemporary social psychology is especially interested in the mechanisms of the individual's mind. Traditional behavioral approaches—particularly those developed in the social-cognitive tradition, such as computerized reaction-time tasks—are designed to make inferences about the structure and function of these underlying cognitive mechanisms. Although much has been learned to date using behavior-based methods, neuroscience offers new tools and an anatomical guide for exploring the mind. Information about the nature of connectivity among neural systems serves as a useful complement to behavioral methods for advancing theories of the mind and behavior.

The neuroscience approach has been especially useful for discerning the underlying cognitive mechanisms that give rise to observable psychological phenomena. For example, research on learning and memory has been heavily influenced by findings from brain lesion patients and animal neuroscience, and more recently by human neuroimaging. The classic case of HM, whose temporal lobes were resected as a treatment for epilepsy, revealed an important distinction between declarative episodic memory and nondeclarative (implicit) memory processes (Scoville & Milner, 1957). Although other neurological cases have suggested similar dissociations previously, HM's case galvanized a major effort in neuroscience research on learning and memory, which produced a useful taxonomy of memory systems linked to dissociable neural substrates (e.g., Schacter & Tulving, 1994; Squire & Zola, 1996). That is, relating specific memory functions (measured in behavior) to specific neural structures clarified and, in a sense, reified the notion of dissociable mental systems. These advances led to the development and refinement of new theoretical models of memory and behavior, and these in turn influenced the development of dual-process theories of social cognition that are dominant in social psychology today. It is difficult to know whether researchers would have made the same advances in socio-cognitive theorizing without inspiration from early studies of amnesics and other neuropsychological patients. Although similar discoveries about memory dissociations would likely have been made through behavioral experimentation, one could argue that the inclusion of brain-based approaches has provided a more detailed description of the properties of memory systems than would likely have emerged from behavioral studies alone.

Neuroscience also offers an expanded methodological toolkit for testing psychological theories, complementing the traditional tools of self-report and behavioral measurement. Measures of peripheral psychophysiology served this purpose in early social psychology research. In one of the earliest social psychophysiology studies, Rankin and Campbell (1955) measured participants' skin conductance response as they met with same-race and different-race experimenters. Although participants reported similar liking for both experimenters, the skin conductance response—an index of autonomic nervous system activity associated with palm sweating and, presumably, anxiety—suggested greater unease toward the different-race experimenter. This early demonstration of implicit racial bias relied on a physiological assessment of the psychological process of anxiety. More recently, researchers have used measures of brain activity to record online changes in motivational and affective responses that would otherwise be impossible to assess without interrupting a participant's engagement in an experimental manipulation (Amodio, Devine, & Harmon-Jones, 2007; Harmon-Jones & Allen, 1998). Neuroscience methods have also been used to measure theoretically important psychological processes that occur too rapidly for precise assessment using self-report or behavioral methods (e.g., Amodio, Harmon-Jones, & Devine, 2003; Amodio et al., 2004; Ito, Larsen, Smith, & Cacioppo, 1998; Vanman, Paul, Ito, & Miller, 1997).

Finally, neuroscience provides a common denominator for different literatures and research areas in the psychological sciences, given that the ideas proposed in different areas of psychology must all comport with a single model of the brain. Social neuroscience is well-positioned as a critical hub for the integration of information from disparate scientific traditions in psychology. In particular, social neuroscience links social psychology to this hub, facilitating the exchange of ideas between social psychology and the rest of the neuroscientific community.

APPROACHES TO SOCIAL NEUROSCIENCE RESEARCH

As a hybrid field, social neuroscience uses approaches that serve the goals of both neuroscience and psychology, with the latter being more directly informative to social psychology. For the present purposes, the two major approaches may be referred to as *brain mapping* and *psychological hypothesis testing*. A consideration of the goals of each approach will help consumers of this research to determine whether and how social neuroscience can inform their social psychological questions.

BRAIN MAPPING APPROACH

Brain mapping studies ask "where in the brain is _____ [insert psychological construct here]?" Human brain mapping is a cornerstone of modern cognitive neuroscience. It concerns the exploratory mapping of basic psychological processes to particular regions of the brain. In early brain mapping studies, neurosurgeons probed areas of exposed brain tissue while the patient reported his or her experiences. Today, relatively noninvasive neuroimaging measures, such as functional magnetic resonance imaging (fMRI), are used for a similar purpose, albeit with greater sophistication. In cognitive neuroscience, this approach may be used to map relatively low-level psychological processes such as basic forms of sensation, perception, and specific aspects of learning and memory. Because these psychological processes represent relatively low-level mechanisms, they are believed to map more directly onto specific physiological responses than more complex high-level psychological processes.

In social psychology, researchers have attempted to map very high-level psychological processes, such as social emotions, the self-concept, trait impressions, and political attitudes, onto the brain as well. This is where things get trickier. For example, to study the neural basis of romantic love, researchers have scanned participants' brains while they viewed pictures of strangers versus their significant others (Aron et al., 2005). Similarly, to study the neural basis of the self, researchers have scanned the brain while subjects judged whether trait adjectives described them vs. another person (Kelley et al., 2002; Mitchell, Banaji, & Macrae, 2005). Thus, such studies apply the same logic to identifying the neural substrates of very high-level processes as neuroscientists have applied in the mapping of very low-level processes, such as edge detection in vision. A problem with this approach is that high-level constructs, such as the self, are very difficult to define at the psychological level of analysis, and without a clear understanding of one's psychological construct, one cannot begin to make valid inferences about neural mappings (Gillihan & Farah, 2005).

Pure brain-mapping studies are undertaken with few prior assumptions about the psychological function of a brain region—indeed, the point of such studies is to establish ideas about function through the process of induction, across multiple studies using a variety of conceptually-similar tasks and manipulations. This approach can be useful for generating new ideas about links between two otherwise distinct psychological constructs. For example, the observations that social exclusion and physical pain both activate the anterior cingulate cortex has led some to hypothesize that social and physical pain share some common neurocognitive features (Eisenberger, Lieberman, & Williams, 2003; but see Somerville, Heatherton, & Kelley, 2006). Although this approach does not tell us exactly how or why they might be related, simply because the true function of the neural activity is difficult to discern, it nevertheless suggests new testable hypotheses about a potential relationship. In other fMRI research, the observation that two different regions of the brain were activated while participants judged animate vs. inanimate objects might suggest that social vs. nonsocial information is processed via separate cognitive mechanisms (Mitchell, Heatherton, & Macrae, 2002). Importantly, however, brain mapping studies are not designed to test hypotheses about the relationship between two psychological variables or the effects of an experimental manipulation on a psychological variable.

HYPOTHESIS TESTING APPROACH

The hypothesis testing approach in social neuroscience is used to test hypotheses about psychological variables. It begins with the assumption that a particular brain region reflects a specific psychological process. In this regard, it does not concern brain mapping, but instead relies on past brain-mapping studies to have already established the validity of neural indicators. For example, a social psychologist who studies intergroup prejudice might hypothesize that implicit racial bias is rooted in mechanisms of basic classical fear conditioning. To test this hypothesis, one might measure brain activity in the amygdala—a structure implicated in fear conditioning in many studies—while a participant completes a behavioral measure of implicit racial bias. In this case, the construct validity of the neural measure of fear conditioning (activity of the amygdala's central nucleus) is already reasonably established (but see Amodio & Ratner, in press), and the question concerns not the meaning of brain activations, but experimental effects among psychological variables. It is the hypothesis testing approach of social neuroscience that is of most interest to social psychologists. Whereas brain-mapping studies typically inform our understanding of the brain, hypothesis-testing studies typically inform psychological theories of the mind.

The greatest power of the hypothesis testing approach is that it establishes a channel of communication between social psychology and other neuroscience-related fields, ranging from cognitive neuroscience to neurology, and to genetics and systems neuroscience, with neuroscience as the common denominator. For example, research linking implicit racial bias to amygdala activity (Phelps et al., 2000; using fMRI), and more specifically, to threat-related activity of the amygdala's central nucleus (Amodio et al., 2003; using startle-eyeblink), suggested that implicit racial bias might reflect a fear conditioning mechanism. Through this link to the neuroscience literature on fear conditioning, researchers could begin to apply the vast body of knowledge on this type of learning and memory to form new hypotheses for how implicit affective racial biases are acquired, expressed in behavior, and potentially reduced (Amodio, 2008).

Other research has applied neuroscience models of response control to questions of how intergroup responses are regulated. Whereas social psychological models had generally focused on deliberative forms of corrective control (e.g., Gilbert, Pelham, & Krull, 1988; Wilson & Brekke, 1994), more recent neuroscience models suggest that control involves at least two separate components—a preconscious component that monitors conflict between one's intention and an impending response error, and a second component representing the top-down correction of the response that is more akin to traditional social psychological models of control (Botvinik, Braver, Barch, Carter, & Cohen, 2001; Miller & Cohen, 2001). Applied to the study of intergroup bias, this neuroscience-based model could address a long-standing question in social psychology: Why do many self-avowed egalitarians often respond unintentionally with racial bias despite their nonprejudiced beliefs? (e.g., Devine, 1989; Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997). Research using an event-related potential (ERP) index of conflict-related brain activity suggested that failures of the preconscious monitoring component, rather than more deliberative corrective processes, accounted for unintentionally biased responses among low-prejudiced people (Amodio et al., 2004; Amodio, Devine, & Harmon-Jones, 2008). Ideas from this social neuroscience model have since been incorporated into recent social-cognitive models of control (e.g., Payne, 2005; Sherman et al., 2008). In this way, the connection to neuroscience can inspire novel theoretical perspectives on classic social psychological questions, which in turn contribute to social psychological theory.

A second powerful aspect of the hypothesis-testing approach is the use of new methods for assessing psychological variables. Once a neural or physiological response has been reasonably validated as reflecting a psychological variable, researchers can use physiological assessments of the response to measure that psychological variable. An advantage of such measures is that they can be assessed online during a psychological task without having to interrupt the flow of a task to have the participant complete a self-report measure. Some physiological measures, such as ERPs are useful for assessing psychological processes that unfold very rapidly in the course of a task response. For example, researchers have used ERP measures to show that pictures of ingroup and outgroup members are distinguished in rapid perceptual processes that may occur before an individual is consciously aware of the stimulus (Amodio, 2010; Ito & Urland, 2003; Walker, Silvert, Hewstone, & Nobre, 2008). In other research, Harmon-Jones and his colleagues have used electroencephalography (EEG) measures of frontal cortical activity to assess online approach-withdrawal orientation, demonstrating that emotional responses are organized in terms of their motivational orientation rather than in terms of their appraised valence (e.g., good vs. bad), at least in behavior and physiology (Carver & Harmon-Jones, 2009; Harmon-Jones, 2003). Other researchers have used ERP and fMRI methods to assess online changes in conflict monitoring activity while participants attempted to regulate intergroup responses (Amodio et al., 2004; Bartholow, Dickter, & Sestir, 2006) or reacted to social exclusion (Eisenberger et al., 2003; Somerville et al., 2006). These examples illustrate how neuroscience methods can provide unique opportunities to address difficult social psychological questions.

PSYCHOMETRIC AND METHODOLOGICAL ISSUES IN SOCIAL NEUROSCIENCE

The promise of the social neuroscience approach is tempered by some serious methodological and psychometric issues. Chief among these is the issue of construct validity. Construct validity refers to the certainty that a psychological variable of interest can be inferred from an observed response (Cook & Campbell, 1979; Cronbach & Meehl, 1955). Construct validity issues have been a perennial concern in psychology—a field that is most interested in mental phenomena that cannot be observed directly, but must be inferred through indirect measures of behavior, self-report, and physiology. In social and cognitive neuroscience, construct validity is the degree to which a particular psychological process can be inferred from an observed pattern of neural activity. Half a century ago, methodologists raised concerns about the validity of personality questionnaires to truly assess specific clinical disorders (Cronbach & Meehl, 1955). In the social cognition literature, similar concerns have been raised regarding inferences of automaticity versus control from reaction-time assessments of intergroup bias (Amodio & Mendoza, 2010; Conrey, Sherman, Gawronski, Hugenberg, & Groom, 2005; Payne, 2001). Today, similar concerns are being expressed regarding neural and genetic indices of psychological processes (e.g., Barrett, 2009; Cacioppo et al., 2003; Risch et al., 2009; Vul, Harris, Winkielman, & Pashler, 2009). Here, I describe what I view as the most pressing issues from the perspective of social and personality psychology.

CONSTRUCT VALIDITY AND LOGICAL INFERENCE

As noted above, social neuroscience has a construct validity problem. That is, a problem with the assumption that a particular pattern of neural activity actually represents a psychological construct of interest. The issue of construct validity is especially important in the field of social neuroscience, in which researchers often wish to infer complex and abstract psychological processes from very low-level and poorly-understood physiological changes in the brain and body. As others have noted, one can never assume a 1-to-1 mapping between a psychological and a physiological variable (Cacioppo et al., 2003). Similarly, one cannot assume that a dissociation in brain activity indicates a dissociation in psychological construct. Thus serious consideration must be given to construct validity in any neuroscience study involving psychological inference.

In the previous section, I described two major approaches taken within social neuroscience—brain mapping and psychological hypothesis testing. Both are clearly important for the scientific advancement of cognitive neuroscience and social psychology and, indeed, each approach contributes to the other. However, these two important steps in the scientific processes must be completed independently; problems arise when one tries to accomplish both in a single step. Brain mapping is an exploratory process of gathering information about the function of particular brain structures. As noted above, the goal of brain-mapping studies in cognitive neuroscience is to build the construct validity of a neural activation so that it can be used to represent a psychological variable in the test of a psychological hypothesis. The test of a psychological hypothesis can only proceed after the process of construct validation is completed.

Reverse inference refers to a form of inference used heavily in social and cognitive neuroscience that blurs the brain-mapping and hypothesis testing approaches (Poldrack, 2006). In studies of brain mapping, the psychological process is manipulated and the resulting pattern of brain activity is observed. The inference that the psychological manipulation produced the brain activity may be described as a forward inference, in that the brain activity follows clearly from the manipulation. The inference is based on the known validity of the manipulation. By contrast, the inference of a psychological process from an observed pattern of brain activity is a reverse inference. In this case, the precise meaning of the brain activity is ambiguous and inductively inferred from other studies that have used a particular manipulation to activate the same area.

The practice of reverse inference becomes increasingly problematic to the extent that the source of inference—in this case, a brain activation—could reflect different psychological processes (Cacioppo et al., 2003; Poldrack, 2006). In studies of low-level vision, reverse inference is a comparatively lesser problem. Retinotopic mapping of stimuli onto primary visual cortex may provide a relatively valid index of low-level visual perception processes. But as psychological variables become more complex, as they do with cognitive and social processes, the mapping between a particular brain region and a psychological process becomes less valid. In these cases, reverse inference becomes a serious problem.

All cognitive and social neuroscience studies rely on reverse inference. That is, to the extent that a brain activation is interpreted as reflecting a psychological process, the use of reverse inference is unavoidable. However, researchers can take steps to bolster the strength of their reverse inferences by enhancing the construct validity of a neural indicator, such as through the careful use of theory, converging evidence from other studies (including animal research), and the use of behavioral tasks that provide valid manipulations of a construct and interpretable behavioral evidence.

ON MIXING BRAIN-MAPPING AND PSYCHOLOGICAL HYPOTHESIS TESTING

In modern psychometric terms, the mixing of brain-mapping and hypothesis testing in a single inferential step conflates inferences of construct validity and internal validity. That is, the process of determining the psychological meaning of a brain activation is confounded with the process of testing a psychological theory, often within a single analysis. Here, I describe examples of two different approaches to testing a social psychological idea with neuroimaging methods: one that establishes construct validity independently and one that does not.

Let's say a researcher wishes to test the hypothesis that generosity in an economic bargaining situation involves greater engagement of the self-concept. The researcher decides to use an fMRI measure of the self-concept, which in past studies has been associated with activity in the medial prefrontal cortex (mPFC; setting aside for a moment the various problems with trying to map a complex psychological variable onto a single brain region, e.g., Gillian & Farah, 2005, and whether fMRI is the best method for addressing this question).

There are two ways the researcher can test this hypothesis. One way is to first identify the specific region of the mPFC that corresponds to one's notion of the self-concept using a well-established task manipulation. This first procedure is designed to establish the construct validity of the neural index of the self-concept. Based on this task, the researcher would identify the specific cluster of voxels associated with self-processes and then use this same cluster to determine the presence of self activity in subsequent studies. Next, the researcher might have the participant complete a bargaining task while brain activity is recorded. Behavior from the task would yield an index of participants' degree of generosity. The degree of Self activation on the bargaining task would be determined by quantifying the activity within the entire region designated as the Self area from the initial self-concept task. The degree of average activity in this predefined self region during the bargaining task (e.g., for a generous vs. selfish response contrast) would represent the degree of self-concept activity in generous bargaining. To test the main hypothesis directly, the researcher would then examine the correlation between this neural index and generosity behavior on the task. Although this approach is not without its problems, it illustrates the preferred way to test a scientific hypothesis—that is, first establish the construct in an initial step, and then test one's psychological hypothesis in a second, independent step.

A different way the researcher might test this hypothesis is to first note that the self-concept has been associated with activity in the mPFC in previous studies. However, as with many brain regions linked to social processes, the mPFC includes a large area of cortex, and the specific location of Self activity varies quite a bit from study to study (e.g., Amodio & Frith, 2006; Kelley et al., 2002; Mitchell et al., 2005; Ochsner et al., 2005). Thus, one cannot be sure exactly where within the large mPFC region that the self-concept might be represented—a first strike against good construct validity. Nevertheless, the researcher conducts a single study in which participants complete the bargaining task while their brains are scanned. To test the main hypothesis that generosity involves the self, the researcher might first compare brain activity associated with generous vs. selfish responses. This contrast might reveal brain activity in several parts of the mPFC, as well as in other brain regions. Because the mPFC is a large region, how can the researcher know which part of the mPFC really represents the self? Activations in the mPFC during such tasks often activate multiple clusters of activity, each composed of hundreds of voxels. The researcher might simply conclude that because there was greater mPFC activity on trials where generous responses were made, the self is indeed involved in generosity. The problem here is that one cannot know whether these activations truly represent self-concept activation or some other concurrently-activated process.

To probe the data further, the researcher might correlate the behavioral measure of generosity with subjects' degree of mPFC activity during the task. Sometimes, the neural index of the self is the average brain activity in the mPFC cluster. More often, however, researchers will use activity from individual voxels within the cluster for correlation analysis. This often involves hundreds of independent correlation tests—one for each voxel in the cluster that passed a pre-defined statistical threshold for the generous vs. selfish contrast on the bargaining task. Often, researchers focus on the voxel or cluster that is most strongly correlated with behavior (in this case, generosity behavior). From this correlation, the research might conclude that (a) since these specific voxels were correlated with generosity behavior, they must represent the true Self area and (b) given the significant correlation, the self is indeed involved in generosity, supporting the psychological hypothesis—an example of circular logic. In this case, a single analysis is used for brain-mapping the self and for testing the hypothesized relationship between the self and generosity.

As illustrated in the example above, the use of a single-step analysis to test a psychological hypothesis with neuroimaging data skips the critical step of establishing construct validity. Not only does this seriously threaten the internal validity of the experimental inference, it also leads to artificially-inflated correlations because the brain-based predictor variable (e.g., the self) becomes defined in terms of the criterion variable (generosity behavior), instead of being defined a priori in an independent test. In other words, the construct is defined by the inferential test. When the predictor is defined by the outcome (i.e., affirming the consequent), the test is tautological. This practice is what produces the inflated *voodoo correlations* described by Vul et al. (2009). It is important to note that this problem is rooted in the conceptual logic of validity and scientific inference and cannot be fully addressed through statistical corrections or improvements in measurement reliability (Barrett, 2009). These concerns are of special relevance to the field of social neuroscience because in this field, the psychological constructs tend to be most abstract and thus most difficult to operationalize in the brain.

Ultimately, social neuroscience relies on the combination of brain mapping and hypothesis testing studies. The initial brain mapping research is needed to establish the function of neural structures so that they can later be used to inspire and test theoretical hypotheses, which in turn will raise new questions about brain mapping. Thus, there will always be give and take between these approaches. However, it is critical for scientists to recognize the different functions and limitations of these two approaches, along with the challenges involved in bridging between them.

EFFECTS OF NEUROIMAGING ENVIRONMENT ON PSYCHOLOGICAL PROCESSES

In addition to the psychometric concerns discussed above, physiological and neuroimaging measures sometimes introduce important limitations to the scope of experimental methods normally employed by social psychologists. Beyond issues of cost and training, the recording equipment is sometimes invasive or otherwise constraining, and these factors have direct implications for the manipulation and measurement of psychological variables involved in hypothesis testing. For example, fMRI recording requires that a participant lie very still on a narrow scanner bed with his or her head and upper body ensconced in the narrow scanner bore (i.e., a plastic tube). A bite bar or other means of immobilizing the participants' head is often used. During scans, the room is usually darkened, and the participant wears earplugs to attenuate the loud buzzing and whirring noises from the pulsing scanner. This environment places important limitations on the type of research that may be conducted. Experimenters must contend with the participant's anxiety and distractibility during the study, which may interfere with experimental manipulations. Experimenters must also design tasks that can be implemented with stimulus presentation through LCD goggles (or a back-reflected LCD monitor) and/or responses made on a button box that is usually held in the subject's right hand.

Beyond these obvious limitations, a recent study found that immobilization in the supine position may significantly reduce the psychological engagement in approach motivation (Harmon-Jones & Peterson, 2009). That is, in line with recent research on embodiment and situation cognition (Smith & Semin, 2004), constraints on a participant's body (as in the fMRI scanner) have important effects on emotion and cognition, especially as they pertain to action. Other common social neuroscience methods, such as EEG/ERP, are less constrictive, but still present limitations that require special considerations concerning technical and psychological issues.

NOT ALL BRAIN ACTIVITY IS PSYCHOLOGICAL

Psychologists, by design, are interested in psychological processes, such as emotion and cognition. Cognitive (and social) neuroscientists study the brain as a way to understand these psychological processes, on the assumption that all mental activity arises from the brain. However, the reverse is not true—not all neural processes relate to psychological processes. Indeed, much of the brain's activity at a given moment is devoted to nonpsychological (or extremely low-level psychological) processes involved in regulating and maintaining physiological systems in the body, such as homeostasis, respiration, balance, etc. When a psychologist examines a brain scan from an experimental task, some of the activations likely correspond to the psychological properties of the task, but other activations that may covary with the task may have little to do with psychological processes per se. Nevertheless, there is often a tendency to interpret all of the brain activations in terms of psychological functions. This practice may lead to misinterpretations of neural activations, which further threaten the construct validity of neuroimaging measures and, at a broader level, may add confusing and conflicting information to the field's base of knowledge. A consideration of neural anatomy and function from nonhuman literatures may be informative when interpreting how particular patterns of brain activity might relate to a psychological process.

GUIDELINES FOR USING SOCIAL NEUROSCIENCE TO INFORM SOCIAL PSYCHOLOGY

Despite some serious challenges and caveats, social neuroscience remains an exciting and generative force in the field of social psychology, and in the broader psychological and neural sciences. As reviewed in the section on hypothesis-testing approaches above, theoretically-oriented research has already used neuroscience models and methods to gain new ground on classic social psychological questions. In this section, I outline a set of guidelines for conducting social neuroscience research that can inform theoretical issues in social psychology.

1. START WITH A SOCIAL PSYCHOLOGICAL QUESTION

This first guideline seems obvious. But although social neuroscience studies almost always involve social variables, only a subset ask social psychological questions. As a general rule, a social psychological question is posed in psychological terms, and ideas and methods from neuroscience are incorporated to assist in measuring and interpreting the evidence for the psychological hypothesis. To the extent that one's question is not couched in psychological terms, it is less likely to inform social psychological theory.

2. ASK YOURSELF WHETHER YOU REALLY NEED A NEUROIMAGING MEASURE TO TEST YOUR IDEA

Social psychology has come a long way without neuroimaging methods. Indeed, most questions about a social psychological process can be tested using purely behavioral methods, without the need for neural measures. Obviously, simply showing that a brain was involved does not constitute a major theoretical advance. The inclusion of unnecessary neuroimaging measures can invite an exploratory and speculative analysis of brain activations that may blur the line between brain mapping and hypothesis testing. Given the ambiguities of interpreting patterns of brain activity (especially with fMRI), behavioral tests of social psychological ideas often provide cleaner and more straightforward conclusions.

A powerful but less obvious use of the social neuroscience approach is to generate hypotheses from neuroscience models and then test them with behavioral methods. Although this approach to social neuroscience may seem less glamorous, it can be more rigorous and have greater potential to inform social psychological theory. For example, social psychologists who study prejudice have wondered why reaction-time measures of implicit racial bias are not always good predictors of behavior. To address this issue, my colleagues and I considered how implicit racial associations might be represented in the brain, and how these neural processes might in turn relate to behavioral expressions of bias. We noted that neuroscience models of learning and memory distinguish between implicit associations based in affective processes and those based in semantic processes (e.g., Gabrieli, 1998; LeDoux, 2000; Squire & Zola, 1996). These models have linked affective and semantic forms of memory to different regions of the brain, which in turn influence different aspects of behavior. On the basis of neuroscience research, we found it useful to think of implicit racial biases in terms of these different underlying memory systems (e.g., Amodio, 2008; Amodio et al., 2003), and we suggested that if one considers the different properties of these underlying systems, one could observe a stronger link between measures of implicit bias and intergroup behavior. We then tested this neuroscience-based hypothesis in a series of behavioral studies and found that, as expected, a consideration of affective vs. semantic forms of implicit bias led to better prediction of intergroup responses (Amodio & Devine, 2006).

Hence, a consideration of neuroscience models of psychological processes can inform one's thinking on an issue, which may then inspire new hypotheses that can be tested with traditional behavioral methods. By connecting their behavioral research to neuroscience on a theoretical level, social psychologists will also make their work accessible to a broader audience, inviting further connections to other literatures and theoretical ideas.

3. THE BRAIN IS A MECHANISM VARIABLE, NOT AN OUTCOME

Indeed, the brain *is* a mechanism—a key component of the organism in the S-O-R chain that mediates the effect of a stimulus on behavior. Whereas the goal of brain-mapping studies is to examine brain activations that result from a manipulation, the goal of most psychological studies is to understand the psychological mechanisms that produce a response. As such, measures of brain activity provide a useful outcome variable in brain-mapping studies, but are more appropriately treated as a mechanism variable in psychological hypothesis-testing studies in which behavior is the outcome. Conceptualizing the brain as a mechanism (or process) variable will serve two purposes. First, it will encourage the inclusion of behavioral tasks that provide psychometrically valid measures of a psychological variable, which in turn will improve one's ability to infer the psychological meaning of observed brain activity. Second, at a broader level of analysis, it will keep the research questions framed by a theoretical model in which the outcome is behavior. The practice of treating neural measures as mechanism variables will aid in the translation of social psychological theory into hypotheses that can be tested using neuroimaging methods.

4. FOCUS ON NEURAL INDICATORS WITH REASONABLY WELL-ESTABLISHED CONSTRUCT VALIDITY

To inform social psychological theory, it is important to focus on neural indicators that have already been established as reflecting your psychological variable of interest. When selecting a neural indicator, carefully decide whether activity in a particular structure can be used as a valid measure of your psychological construct. The task that a neuroscientist used to manipulate a psychological construct might not be considered appropriate from a social psychologist's perspective, or it might just not relate well to your particular theoretical question.

It is important to read widely, within and outside of one's primary literature. The same part of the brain may be described as reflecting different processes by different researchers and in different literatures. A case in point is the striatum, a region of the basal ganglia. Historically, the striatum has been associated with basic motor processes, with its degradation being implicated in Parkinson's disease (Meynert, 1871). Over a century later, the striatum was seen as a key substrate of procedural memory (also, habit learning), with an emphasis on its behavioral implications (Alexander, DeLong, & Strick, 1986; Knowlton, Mangels, & Squire, 1996; Yin & Knowlton, 2006). More recently, researchers interested in the cognitive process of economic decision-making have interpreted the striatum activity as reflecting the computation of value or the appraisal of error signals in reinforcement learning (Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Montague & Berns, 2002). Thus, different researchers from different fields may interpret the same pattern of striatum activity in very different ways. All may be partially correct. But to the extent that there are multiple plausible psychological interpretations, construct validity for the measure is low, and it is more difficult to infer support for a particular psychological hypothesis. Furthermore, the way a particular brain activation is interpreted within a particular field can become reified over time if the interpretations receive little input from other fields, creating an echo chamber. Reading widely across literatures will serve to strengthen one's understanding of neural function.

Given the construct validity problems associated with neuroimaging measures of high-level psychological variables, it is often advisable to interpret brain activity in terms of lower-level psychological processes that then contribute to the higher-level processes that are typically of interest to social psychologists. For example, activity of the amygdala is more accurately described as being involved in autonomic activation or vigilance than the high-level concept of fear. Furthermore, if a researcher interprets a neural activation as if it has a one-to-one mapping with a psychological process, little can be learned about the nature of the process from the pattern of neural activity. For example, activity in the mPFC has been interpreted as reflecting theory of mind and the process of thinking about other people (Mitchell et al., 2005; Saxe & Kanwisher, 2003). With this interpretation, the brain activity is simply used as an indicator of the psychological variable. But if one considers the function of this same region in lower-level terms—such as an important hub for integrating information about one's own actions with one's goals and expectancies, as a means to regulate behavior (Amodio & Frith, 2006)—then observations of mPFC activity can enrich one's ideas of how theory of mind relates to other processes.

5. USE A CONSTRUCT-VALID BEHAVIORAL TASK THAT YIELDS AN INTERPRETABLE DEPENDENT MEASURE

Given the issues of construct validity described above, it is critical to use psychologically valid behavioral tasks in conjunction with neuroimaging. That is, when measuring brain activity, a researcher must be sure that the participant is engaged in the psychological process of interest. Ideally, the behavioral task will not only engage this process, but also yield a clear behavioral index to be used as an outcome variable as well as a means to corroborate one's interpretation of the associated brain activity.

To illustrate this issue, consider research examining the control of intergroup responses toward Black people by White Americans. Much previous behavioral research has shown that stereotypes of African Americans (e.g., as dangerous) come to mind automatically, and that controlled processing is needed to override the influence of stereotypes on one's behavior (Devine, 1989; Fazio, Jackson, Dunton, & Williams, 1995; Payne, 2001). For example, in Payne's (2001) weapons identification task, a Black or White face is presented briefly as a prime, followed by a picture of either a handgun or handtool. Because Blacks are often stereotyped as dangerous, controlled processing is required to respond correctly on certain trials, such as when a Black face appears before a tool, but is not required to respond correctly on other trials, such as when a Black face appears before a gun. Therefore, this task is designed to engage participants in control on some trials, but not others. The task also yields clear behavioral assessments of controlled processes, such as error rate data and mathematically-modeled process estimates (e.g., Jacoby, 1991). Thus, the task has construct validity as an elicitor of controlled processing, and it yields valid indicators of the engagement of successful control. Researchers interested in the neural mechanisms of control can use this task to identify brain activity that is specifically associated with the engagement of control by comparing neural responses from trials requiring control with trials that do not require control. One's interpretation of this brain activity can be further validated through its association with behavioral indicators of control. In my own research, I have used this approach to demonstrate the roles of the PFC and the anterior cingulate cortex in proactive and corrective forms of control over racial stereotypes, respectively (Amodio, 2010; Amodio et al., 2004; Amodio et al., 2007, 2008).

When a scanner task has little construct validity, one cannot be sure that the observed brain activity is actually related to the process of interest. For example, many social neuroscience studies have used passive face-viewing tasks to elicit brain activity in an effort to study prejudice and prejudice control. In such studies, a participant might simply view faces of Black and White people with the goal of making some arbitrary judgment, such as whether the picture appeared on the left or right side of the screen. Because such judgments are not known to require any special control or bear any relation to racial associations, this type of task has little if any construct validity, nor does it provide any interpretable behavioral data. Although such tasks frequently elicit brain activity in a variety of brain regions, including areas of the PFC linked to control in past studies, data from passive viewing tasks cannot be interpreted in terms of psychological concepts such as control. Further problems arise when researchers explore correlations between brain activity and other measures of racial bias, such as self-reports or behavioral measures of implicit bias, and then choose to interpret only the activations where correlations arise as ad hoc evidence for the brain's involvement in control. This practice can result in spurious or otherwise uninterpretable findings. Therefore, if one's goal is to draw psychological inferences from the resulting brain activity, it is critical to select a task that is psychologically valid.

6. CONSIDER NEUROANATOMY WHEN DEVELOPING HYPOTHESES AND INTERPRETING RESULTS

The social neuroscience approach is most powerful when one uses models of neuroanatomy, as well as the neurochemical systems that interact with neural structures (e.g., Amodio, 2009, 2010), to inform one's hypotheses about socio-cognitive mechanism. In this way, models of the brain may be used to refine or otherwise constrain psychological theory and hypotheses. Problems arise when neuroscience models are not considered in the interpretation of neuroimaging data.

For example, early notions of emotion regulation hearken back to the Freudian and Cartesian ideas of inner conflict between *passion* and *reason*, and the belief that cognition (i.e., reason) must be invoked to directly down-regulate emotion (i.e., the passions). The idea that cognition directly down-regulates emotion is still pervasive today (as reviewed by Ochsner & Gross, 2005). On the basis of prior research linking cognitive control to the prefrontal cortex and other studies linking negative emotion to the amygdala, some researchers have proposed that emotion regulation must involve the inhibition of the amygdala by the PFC. However, anatomical research on these brain regions shows that there are actually very few connections between these regions and, of those sparse connections, most run from the amygdala to the PFC (Ghashghaei, Hilgetag, & Barbas, 2007). Research on the macaque brain suggests that PFC signals primarily target structures involved in sensation, perception, and motor control, but not structures believed to be emotional, such as the amygdala (Fuster, 2001). Indeed, in a fMRI study where participants' behavior (i.e., eye gaze) was measured while they attempted to regulate their negative emotion, the correlation between activity in the PFC and the amygdala was accounted for by participants' tendency to look away from aversive stimuli (Van Reekum et al., 2007). That is, the PFC was involved in regulating one's behavioral response to the aversive stimulus rather than directly down-regulating the amygdala. Hence, neuroscience models can constrain theories about emotion regulation to suggest that the Freudian inner conflict model may not be correct. Just as a consideration of neural models can inspire useful new psychological theories, ignoring such models may lead to mischaracterized psychological theories.

7. BE PREPARED TO UPDATE INTERPRETATIONS OF BRAIN ACTIVATION

Neuroscience is a young and rapidly advancing field, and changes in our understanding of neural function are inevitable. Researchers will need to keep themselves apprised of developments and then update interpretations of past work accordingly. For example, the amygdala was once interpreted as the fear center, and often as the locus of emotion broadly. However, it is now understood to represent a diverse set of processes involved in attention, vigilance, memory, and the coordination of both autonomic and instrumental responses (Whalen, 1998; Killcross, Robbins, & Everitt, 1997). Thus the notion that the amygdala represents negative emotion is too simplistic and no longer tenable. Furthermore, the amygdala comprises multiple nuclei associated with different functions, connected within an inhibitory network (Barbas & Zikopoulos, 2007). These subnuclei cannot be differentiated with current neuroimaging methods, and thus it is very difficult to infer the specific meaning of an amygdala activation using fMRI (although other methods, such as startle eyeblink, can provide indices of activity of specific nuclei; Davis, 2006). As our understanding of amygdala structure and function advances, past research that has interpreted amygdala activity as a fear index will likely need to be revised.

Another issue concerns the broader meaning of blood oxygen-level dependent (BOLD) activity in the brain. fMRI signals reflect changes in blood flow in a particular region of the brain. In the past, it was assumed that increased blood flow to an area meant that the specific area had just been highly active and had signaled other connected regions (i.e., reflecting presynaptic neural activity). For example, BOLD increases in the PFC are often interpreted as reflecting the engagement of control on other regions of the brain. However, more recent studies of BOLD activity suggest that it reflects an increase in the inputs to a particular region from other areas of the brain (i.e., postsynaptic neural activity; Lauritzen & Gold, 2003; Viswanathan & Freeman, 2007). According to this view, activity in the prefrontal cortex might suggest that other neural structures are attempting to recruit controlled processing, independent of whether control is actually implemented. Changes in our understanding of brain function and neuroimaging data are inevitable as the science advances. Although they cannot be avoided, the impact of such changes can be mitigated though careful experimentation and interpretation and keeping oneself apprised of advances in functional neuroanatomy.

THE FUTURE OF SOCIAL NEUROSCIENCE IN SOCIAL PSYCHOLOGY

Not long ago, some psychologists worried that neuroscience was poised to swallow the fields of personality and social psychology, and that social neuroscience was the harbinger of social psychology's demise. But I think the opposite has happened—instead, social neuroscience has introduced the broader field of neuroscience to the rich theoretical and methodological traditions of social and personality psychology. In this way, social neuroscience has helped to elevate the disciplines of social and personality psychology in the eyes of other scientific fields.

Social neuroscience has also helped to increase the exposure of social and personality psychology in the popular media. Sometimes, this attention may be bittersweet, such as when a brain imaging study that simply replicates a well-known behavioral effect receives coverage in the *New York Times*. Similarly, high-profile criticisms of neuroimaging methods that were inordinately (and perhaps inappropriately) aimed at social neuroscience, as opposed to the broader neuroimaging field (e.g., Vul et al., 2009), have not benefitted social psychology. Yet the publicity of social neuroscience findings have, over time, increased the public's interest in basic behavioral social psychology.

Finally, as the field of social neuroscience has matured, the approach is beginning to contribute substantive advances to the fields of social and personality psychology. For this reason, social neuroscience has begun to gain credibility and respect from social psychology purists, as well as broader acceptance in the mainstream literature. As social and personality psychologists become increasingly familiar with neuroscience ideas and methods, more and more behavioral researchers are incorporating neuroscience ideas into their work. Neuroscience is also playing a larger role in graduate training programs. Given the state of contemporary psychology and neuroscience, it is critical for new social psychologists to have basic knowledge of the brain and neuroscience methodology. At the very least, these students will come into contact with social neuroscience research in their future careers. At best, they will incorporate neuroscience approaches to complement and enhance their research on social psychological questions. Just as social cognition became fully integrated into mainstream social psychology after a period of skeptical segregation, social neuroscience is turning the corner toward full integration as well.

CONCLUSIONS

The emergence of social neuroscience is a good thing for social psychology. The promise this new field holds for making substantive contributions to social psychological theory and research far outweighs the growing pains it is currently experiencing. The goal of this article was to describe how neuroscience models and methods can be used constructively to advance social psychological research, while also describing the major limitations of this approach. A consideration of these issues will help the researcher who wishes to apply the neuroscience approach to address social psychological questions. It will also help the consumer who needs to understand the limitations of neuroimaging research to discern its value for their own work. Although debates about the role of neuroscience in social psychology will surely continue, one thing is certain: neuroscience has arrived in the field of social psychology and it is here to stay. It is now up to the social psychologist to take advantage of what it has to offer.

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