NEUROLOGICAL IMAGING AND THE EVALUATION OF COMPETING THEORIES

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INTRODUCTION

In recent years, social scientists have begun exploring the neurological foundations of behavior in an attempt to gain a more complete understanding of decision-making in the realms of both politics and economics (see Cacioppo & Viser, 2003; Fowler & Schreiber, 2008; McDermott, 2009; Caplin & Schotter, 2008).

However,[1] it is still unclear to many how an approach focused on the brain's operation can reach beyond a description of the biological process generating some behavior to predicting when and why such behavior occurs. Observing a pattern of brain activity "x" alongside behavior "z" does not in itself give us a better understanding of why "z" happened, or why departures from "z" happen, beyond simply providing a more mechanical description of the process leading to "z." Even if we identify a sequence of connections from neurological activity and environmental stimulation to cognitive and psychological processes to political behavior, we must consider how much each component contributes to the political behavior under investigation. If the neuroscience is not doing any real work, that is,

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generating specific and testable hypotheses that build on and critique our current understanding of political behavior, then it is hard to see how neuroscience informs political science. If neuroscientific data does provide novel insights, or will develop in a way that will, then political science might have much to learn.

There are ample reasons to suspect that neuroscience and related disciplines can help provide a more accurate *and* expansive understanding of choice behavior of interest to political scientists. In line with an earlier article on the topic, I continue to hold a certain sense of caution in how political science proceeds in the use of neuroscience data for several reasons. While neuroscience and related disciplines continue to make significant progress, these fields continue to have considerable conceptual and methodological debates. Researchers should be aware of how unsettled disputes and problems migrate into their own studies. Assuming (perhaps optimistically) that these debates are irrelevant or of subsidiary importance to political science, there is also a critical question of exactly how to best use neurological imaging data. I advocate a particular approach to using neurological data that emphasizes comparative theoretical testing (Clarke, 2007) via the demonstration of particular neurological mechanisms associated with competing theories of political behavior. If different theories developed by political science suggest different neurological mechanisms, then data on which mechanisms are actually operative, and under what conditions, can be used to help test the competing theories. Such practice would be, I believe, an ideal way for political scientists to directly use neurological data.

I structure the remainder of the chapter as follows. First, I review several recent discussions on the use of neuroimaging in economics that helps illustrate the types of debates likely to emerge in political science. The debate will be most helpful if competing theories that make different predictions on what neural mechanisms will be involved are tested. Next, I review a neurological imaging technique, functional magnetic resonance imaging (fMRI),[2] and how it is already being used and published by political scientists and economists today. This motivates a discussion on how particular theories within political science might suggest different approaches to using neurological imaging. I argue that understanding the causal role of particular neural mechanisms can help adjudicate between competing theories of behavior. I provide an example of this usage of fMRI from recent work in neuroeconomics as a template for interested political scientists and review an earlier example from the political science literature.

IMAGING AND NEURAL MECHANISMS IN SOCIAL SCIENCE

Why should social scientists be interested in the activity of the brain? Interested political scientists and economists offer similar rationales (e.g., McDermott, 2004, 2009; Camerer, Loewenstein, & Prelec, 2004). First, many political and economic decisions are made automatically without conscious reflection or calculation. This is important for many reasons, but foremost because it calls into question the decision maker postulated in rational choice models.[3] Second, emotions influence decisions. A number of prominent studies in political science have implicated the affective system in decision-making (e.g., Brader, Valentino, & Suhat, 2008; Marcus, Neuman, & MacKuen, 2000). The common theme here is that many decisions occur at an automatic level until some stimulus is unexpected or novel. The emotional system assists in being able to "turn on" higher-level conscious systems that analyze and deal with the novelty at hand (Marcus et al., 2000; Lieberman, Schreiber, & Ochsner, 2003). Third, the same behavior can be generated by multiple motivations with different neurological mechanisms, which then have different *substantive* implications.[4] In sum, these arguments imply that neurological data can play a role in political science.

More recently, the championing of neurological evidence to explain or predict economic decision-making has been challenged by several leading microeconomic theorists. For example, Gul and Pesendorfer (2008) argue that economics is a study of revealed preferences. The process that leads to these preferences simply is not of interest to economics. Insofar as there exist multiple psychological processes that could give rise to the same choice behavior, studying these processes has little bearing on the study of economic choices. This perspective, and various challenges to it, appears in a recently published and fascinating volume that interested political scientists should consult (Caplin & Schotter, 2008). In my experience, there are many political scientists who share Gul and Pesendorfer's position. Others are less willing to ex ante demarcate what political science is or is not, but hold a "proof is in the pudding" mentality. Below I sketch out how neuroimaging studies can test competing theories that each suggests different neurological mechanisms. If adjudication between competing theories using neuroimaging data is successful, proponents of the Gul and Pesendorfer position will likely have fewer adherents in political science.

Given my argument that neuroscience could be useful if it lets us measure the operation of different hypothesized neural mechanisms, I briefly review how fMRI allows us to observe the operation of different neural mechanisms, by relying on the fact that the brain needs oxygen to function. The oxygen is supplied by blood whose level of oxygenization can be measured. *Local* changes in brain activity appear to cause local changes in oxygen use. The dominant method of measuring these changes is to monitor the blood-oxygen-level dependent (BOLD) signal through fMRI, which measures the differences in magnetic distortion of excited hydrogen molecules in oxygenated versus deoxygenated blood. This yields relatively precise spatial and temporal resolution of oxygen use in the brain. Critical to understanding the BOLD signal are the physiological mechanisms that govern blood flow and the establishment of a "baseline" rate of oxygen usage from which to compare changes due to stimulus and selected behaviors. The physiological mechanism that produces changes in blood flow predicts that there will be an initial dip in the BOLD signal, followed by a peak above baseline level as the system overcompensates for oxygen usage before returning back to baseline level (Logothetis, 2003; Heeger & Ress, 2002; Beauchamp, 2002). The fMRI technique is neither foolproof nor universally interpreted, and below I discuss some of these limitations.

The use of fMRI has been much more common in economics than in politics, perhaps leading to the push back led by Gul and Pesendorfer. Questions about concepts like rewards and bargaining (Montague & Berns, 2002; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003), advertising (Wells, 2003; Thompson, 2003), and mentalization (the ability to consider the intentions/perceptions of others; Ramnani & Miall, 2004; Blakemore & Decety, 2001; Bhatt & Camerer, 2005) have been studied using fMRI techniques. Social cooperation (Rilling et al., 2002; McCabe, Houser, Ryan, Smith, & Trouard, 2001) and the role of moral judgment on decision-making (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001), which are relevant to both economists and political scientists, have also been evaluated using fMRI imaging. Similarly, fMRI imaging in experiments on the influence of race on judgment formation (Phelps & Thomas, 2003; for review, see Ochsner & Lieberman, 2001, pp. 720–721) and political sophistication (Schreiber & Iacoboni, 2004) have yielded interesting results.

A recent use of fMRI in economics by Delgado, Schotter, Ozbay, and Phelps (2008) provides a good example of how we might best use fMRI data. A canonical puzzle in economics is the "Winner's Curse," where winners of auctions frequently pay more than they should have in equilibrium (Thaler, 1993). One explanation is that individuals are risk averse. As a result, individuals bid more than they should. A second mechanism is that a "joy in winning" motivates individuals. The joy in beating other individual bidders drives overbidding as opposed to holding a strong desire to avoid the feeling of losing. A final explanation, and the one ultimately supported by the experimental results, is that contemplation over losses in a *social* situation drives overbidding. Key here is that individuals especially want to avoid losing against another person. One way to test these different explanations is to deduce different neurological mechanisms that each explanation would suggest as well as experimental designs that put the appropriate environmental conditions into place, such as whether social competition is present. Earlier work (Knutson, Fong, Bennett, Adams, & Hommer, 2003) suggested that one region of the brain associated with losses and gains is the striatum. In the Delgado experiment, both a lottery and auction task were conducted, with only the latter involving any social competition. The authors found a differential response in the right striatum between lottery losses and auction losses, but no such difference between lottery and auction wins. In explaining their results, the authors write:

> The lack of an enhanced BOLD response in the striatum to wins (in the auction compared with the lottery) suggests that the 'joy of winning' may not be mediating overbidding in experimental auctions. In contrast, the stronger BOLD response to losses in the auction game suggests that a fear of losing a social competition may be linked to overbidding. The fear of losing the social competition of an auction may lead to a striatal response similar to that observed in loss aversion. However, because no actual losses occurred in this experiment, it would appear that the 'fear of losing' the social competition was a factor independent of pure loss aversion. (p. 1851)

While a follow-up discussion on the merits of Delgado paper suggested some doubts in their findings and the novelty of their preferred explanation of contemplation of losses in a social context (Maskin, 2008), the chapter nicely demonstrates ways to use neurological data to adjudicate between social science theories.

COMPARATIVE THEORY TESTING IN POLITICAL SCIENCE WITH NEUROSCIENTIFIC DATA

We have briefly seen how neuroimaging studies can supplement investigations of how people behave politically and economically. Let us now delve into more detail about how different approaches to studying political decision-making suggest different types of neurological evidence.

Camerer et al. (2005, p. 16) suggest a heuristic that sees brain operations explained by whether they are controlled or automatic, and whether they are cognitive or affective (visualized as a 2×2 diagram). Controlled/cognitive behavior is the traditional domain of economic rational choice, where actors consciously attempt to satisfy some utility function that they can explicitly evaluate. For example, one perspective on vote choice assumes that individuals consciously evaluate how a candidate will satisfy their values and material needs. This is a controlled and cognitive process, and, in theory, more likely to activate an executive region of the brain such as the lateral prefrontal cortex (Knight & D'Esposito, 2003). Controlled/affective behavior is what "methods actors" use who consciously elicit emotional reactions. Campaigning politicians who strategically use nonverbal displays (or body language) to elicit emotions provide a concrete example in politics. Automatic/cognitive processes are immediate responses to factual information. Finally, automatic/affective responses include feelings associated with experiences (such as fear or elation) or biological feelings like hunger and sex drive. Quite plausibly, voters might also prefer candidates, in part, because they are physically attractive (Stolberg, 2004; Tingley, 2007; Schubert & Curran, 2001; similarly, see Zebowitz, 1994) or based on other features of a candidate's appearance (e.g., Ballew & Todorov, 2007; Atkinson, Enos, & Hill, 2009). Because each of these categories may implicate different regions of activation in the brain, or patterns of activation across regions, different types of neurological imaging evidence might be necessarily dependent on what is being studied.

C/X and Affective Intelligence Models of Politics

In the Winner's Curse example discussed above, there were rival theories that sought to explain why auction winners often overbid. To adjudicate between the theories, the authors isolated particular neurological mechanisms in conjunction with different elements of the experimental design. In what follows I construct a contrast between two developing literatures: the "reflective/reflexive systems" model (Lieberman et al., 2003) and the "Affective Intelligence" model (Marcus et al., 2000). While these are related, they suggest slightly different approaches to the role of cognition and affect in human political behavior. In what follows I develop these contrasting view and discuss how neurological imaging information can help adjudicate between the competing perspectives. The comparative testing, I believe, represents a key component of a productive research design linking neuroscience and political science.

Reflexive and Reflective Processing: The C/X Model

Lieberman et al.'s (2003) model posits two different neurocognitive systems: the X-system and the C-system.

> The X-system (named for the 'x' in reflexion), consisting of the lateral temporal cortex, amygdala, and basal ganglia, spontaneously and often nonconsciously integrates current goals, context, perceptions, and activated cognition into a coherent whole that guides the stream of consciousness and current behavior. The C-system (named for the 'c' in reflection), consisting of the prefrontal cortex, anterior cingulate cortex, and medial temporal lobes, is recruited when the X-system fails to create coherent outputs from the different sources of input. (p. 689)

According to this model, the X-system guides behavior by incorporating a large range of information (e.g., sensory and motor processing, emotional and social information) until the C-system recognizes a problem in the X-system processes. It then "interrupts" or "overrides" and attempts to resolve the task at hand. In neurophysiological terms that illustrate the complexities of the process, the C-system is monitored by the anterior cingulate, which upon detecting a problem sends a signal to the prefrontal cortex, where a serial processing system resolves the situation.

Essentially this is the same distinction between automatic and controlled processes discussed above (Camerer et al., 2005, p. 16), but with a specification of how and why the brain modulates between the two. In their application of this model, Schreiber and Iacoboni (2004) show that, relative to the unsophisticated, politically sophisticated subjects are more likely to have elements of the X-system activated when asked political questions. This is because political "sophisticates," who have facility with names, dates, or political concepts and have habits of "associative links formed through extensive learning histories" (Lieberman et al., 2003, p. 689), are well accustomed to the processing of political topics. Thus, this model considers the activation/deactivation of reflexive and reflective processes in the brain and how this is mediated by (1) actual familiarity with a set of political topics (which captures the degree of familiarity/novelty of the situation) and (2) emotional feedback that unconsciously provides motivation to "analyze" increasingly unfamiliar situations that generate feelings of unease.

"Affective Judgment"

Marcus et al. (2000) emphasize the role of affect much more centrally. Their approach builds upon Gray's model of behavioral approach and behavioral inhibition.[5] "The Behavioral Approach System gauges the success or failure of recalled actions, contemporary experience, and anticipated activities that fall within the category of previously learned behaviors" (Marcus & MacKuen, 2001, pp. 45–46). Emotions implicated by this system range from enthusiasm to depression, and assist in evaluating the success/failure of strategic action. The behavioral inhibition system "generates moods of calmness and relaxation when the match of incoming sensory signals against anticipated normal execution of plans indicates nothing of concern. It generates moods of increasing nervousness and anxiety when the comparison of environmental information and what would be expected from normal execution of plans indicates a mismatch" (p. 47). The combination of the approach and inhibition systems, which are chiefly constituted by the limbic system of the brain, helps individuals navigate the myriad uncertainties of politics.[6] While the Affective Intelligence approach to my knowledge has yet to utilize neuroimaging techniques like fMRI, the neuroscience literature it builds from has certainly begun to. Because this approach posits a particular set of neurological processes, fMRI and other imaging techniques will provide a better delineation of what these processes are and how they change under various conditions.

Similarities and Differences

The C/X and Affective Intelligence approaches share some significant conceptual similarities. All emphasize the role of habits, automatic responses, and controlled processes. The main difference is that the Affective Intelligence approach more explicitly theorizes the way affective systems modulate and engage controlled decision-making; the approach offered by Lieberman and colleagues is much more focused on information and cognitive processing. Lieberman et al. (2003) do not explicitly theorize how the C system "detects" inconsistencies in the X system beyond specifying that the anterior cingulate is activated. They suggest a combination of (1) logical coherency of the decisions and behaviors being produced by the X-system and (2) dynamic system of feedback with affective processes like anxiety that are generated through interaction with the external environment and mediated through some part of the limbic system. For example, Schreiber and Iacoboni (2004) use this model to explore agree/disagree responses to political and nonpolitical statements. While both models recognize the difference between controlled and automatic processes, cognitive elements modulate the interaction between

the two more centrally in Lieberman et al.'s account, whereas affective systems do much more work for Marcus and colleagues. Both models leave the interaction between cognitive and affective forces relatively unspecified, perhaps because their interaction is not well understood in the neuroscience literature in the first place (LeDoux, 2000, p. 129).

Each also attaches their results to particular conceptions of democratic politics that reflect these differences. Marcus clearly sees the problem of low political participation as a result of too little emotion, the result of a dominant intellectual and cultural perspective that sees "passion as the enemy of reason." "(t)he most serious damage is done by continuing to endorse the normative conception of citizenship as a singularly cerebral reflection on justice and the common good" (2002, p. 135). Of course this is somewhat qualified by a previous statement: "to say that negative campaigns and sensationalized presentations by candidates, activists, and the media create the conditions for reason does not mean that we should automatically endorse *any* use of emotion. The particular circumstances and particular choices must, as with all particulars, be judged on the individual merits" (p. 134). The central theme, nevertheless, is that people do not care about politics not because they lack some sort of cognitive ability or exposure, but instead because prevailing notions of democracy discourage the role of affect.

This is quite different from the story Schreiber (a co-author of the Lieberman et al.'s paper) tells. Political novices need "models of how experts connect their values to policy choices" (Schreiber & Iacoboni, 2004, p. 8). That is, novices need exposure to the way people familiar with politics, from armchair Sunday morning junkies to D.C. policy makers, connect what they value to how they participate democratically. Thus, political novices "are not at recess" when thinking about politics beyond their immediate social context, and what is needed to help them is some way to familiarize themselves with the cognitive components of the political process.[7]

A Comparison, A Test?

A comparative theory approach to testing these models would examine a particular political choice and record localized neural activity in the brain. The "Affective Judgment" perspective predicts that anxiety is increased when actors are in an unfamiliar context. This anxiety is then postulated to motivate conscious, rational, decision-making, and "considered judgment." The cognitive nature of the C system in the Lieberman's model suggests that the role of emotion is less important in the actual "override" process. The brain's focus, during the override process, is on resolving the cognitive details of the decision task at hand, and thus difficulty in resolving these details is what drives the "override" process. An example of a study that contrasts the approaches taken in the "Affective Judgment" and "reflective/reflexive" (C/X) models is Pochon et al. (2002) who investigate reward systems in the brain and the cognitive difficulty of a task. They suggest that with increasing cognitive complexity, the limbic system (which controls affective processes) is "gated," possibly so as not to interfere (distract) the operation of higher level cognitive areas like the dorsolateral prefrontal cortex. "We suggest that a dynamic interplay is created between activated cognitive areas necessary to maintain a high level of cognitive performance (the network for WM (working memory) and attention) and affective areas deactivated because they may process counter productive signals interfering with performance" (p. 5673). The evidence suggested by Pochon et al. is that a gating mechanism occurs to reduce interference from the paralimbic system on cognitive systems like the dorsolateral prefrontal cortex. This gating process is related to the cognitive complexity of the task and the stakes at hand. The "override" process is initiated by emotional disturbance but then is gated and regulated depending on the cognitive demands of the task. Such a result fits the contours of the C/X model more clearly than it does in the Affective Intelligence perspective, which sees motivation for cognitive reasoning coming from the limbic system. A more defined comparative research program would be needed to more concretely test the theories. The results also suggest need for theorizing about the interrelationship between the *stakes* and the *complexity* in decision environments.

LIMITATIONS ON COLLECTING AND INTERPRETING NEUROSCIENTIFIC DATA IN POLITICAL SCIENCE

The previous section argued that different "social" science theories could suggest different patterns of neurological activation and highlighted potential shortcomings in current neuroscience models. While the ability to use neurological imaging to discriminate between competing social science theories is exciting, it is important to be cautious about limitations in both the technology and the current state of consensus in the neuroscientific disciplines. In other words, "conceptual problems (can) migrate" between academic disciplines (Johnson, 2002). A more exhaustive discussion is contained elsewhere (Tingley, 2006) and so I provide only a short summary here.

Modular versus Distributed Information Processing

Within neuroscience, there is a continuum of research perspectives on the question of modular (specific functions–specific brain modules) or distributed (specific functions–many brain regions) processing in the brain. While many studies focus on finding the functional properties of distinct neuroanatomical regions, there is conflicting theoretical and empirical evidence of their existence (Cohen & Tong, 2001; for how this surfaces in in vivo and in vitro neurological studies, see Steriade, 2001; Kurzban & Haselton, 2005; Uttal, 2001; for debates regarding the role of the amygdala [of interest to several political scientists], see Adolphs, 2003, p. 169; Baxter & Murray, 2002; Ochsner & Lieberman, 2001, p. 726). A more multifaceted view would study the *various* functions of specific brain regions, such as the amygdala. Indeed debate about modularity has a very long history (Star, 1989).

(Illusory) Images

Obtaining a clean fMRI measurement of neural processes is difficult even with multimillion dollar equipment. Researchers should be cautious in a couple of ways. The measurements of decreases or increases in the BOLD signal are all compared to a "baseline" level that assumes a lack of direct activation from external stimulus. This poses a difficult problem for several reasons. First, it appears that the "baseline" level of neurological activity "is already tuned to interpreting and categorizing the world as social" (Adolphs, 2003, p. 174). Thus, isolating the effect of neural activation must consider how the "background" activities of other regions also contribute to the process at hand. Establishing this "baseline" can be complicated not only by how an experiment is actually set up (in terms of the behavioral category selected as the "baseline") but also by "task-independent" deactivations of particular regions by precise mechanisms that are not fully understood (Gusnard & Raichle, 2001, similarly see Overgaard, 2004). This is exacerbated by the typically small level of fMRI-captured BOLD signals over the baseline (Raichle & Gusnard, 2002; e.g., see Schreiber & Iacoboni, 2004, p. 7). Furthermore, to argue, as some theorists do, that emotions modulate sensory information before the details of political information are processed, Marcus et al. (2000, chap. 4) make an assumption about a baseline level of monitoring that changes depending on feelings of enthusiasm or anxiety. Unfortunately, such theories of politics do not then specify what normal "everything makes sense" functioning in response to social stimuli looks like versus nonnormal "this is not what is expected to be happening" functioning. Without a better understanding of the contribution of "baseline" activity to normal human functioning in response to diverse situations and types of information, investigations of neural activations will be necessarily vague in terms of what they imply.

The BOLD response may vary due to normal aging processes, moreover, complicating the interpretation of results that use subjects that span age groups or extrapolation of studies from one age group to another (D'Esposito, Deouell, & Gazzaley, 2003). Even effects of common substances like caffeine can complicate inferences (Laurienti et al., 2002). Individual variations in brain anatomy pose a challenge for functional location in the brain (Brett , Johnsrude, & Owen, 2002). While significant steps have been made in permitting better localization, a better understanding is required of the functional properties of parts of the brain that are being localized. This becomes increasingly acute as localization moves to higher order functions beyond the primary motor and sensory cortical areas (Way, 2003). Finally, fMRI does have a somewhat limited degree of time resolution, usually between 1 and 4 seconds, due to signal/noise problems that emerge. Additionally, higher temporal resolutions have revealed nonlinearities in the BOLD signal and the normalization of the BOLD signal takes between 16 and 20 seconds, creating similar temporal resolution problems (Pfeuffer, McCullough, Van de Moortele, Ugurbil, & Hu, 2003). While other imaging techniques with better temporal resolution can be used in conjunction with fMRI, such as event-related potential (ERP) measurements, a number of practical issues emerge due to the use of strong magnetic fields. Additional issues include the appropriate statistical procedures to use (Lee, Yoon, Chung, Song, & Park, 2004), analysis design for acceptable statistical significance calculations (Editorial, 2001), and necessity of lesion studies or transcranial magnetic stimulation to rule out spurious relationships in imaging data (Adolphs, 2003, p. 6; Camerer et al., 2005). It warrants restating that these methodological problems can migrate into the evaluation of social scientific theories. Regardless, vast conceptual and technological improvements in the recent past point to similar progress in the future.

CONCLUSION

The possibilities for interesting interdisciplinary work between political scientists and neuroscientists are immense. For example, the study of coalition formation, with theories ranging from individualistic rational choice to institutional effects, has long been a principal focus for political scientists. Accessing the neurological and psychological dimensions of coalition formation would be a welcome avenue of research. What are the neurological substrates of screening potential partners? As coalitions become more salient, are there changes in how the brain monitors possible disruptions/deviations? Is the decision by someone with political experience to join a coalition identical in process to what a political novice would use? More generally, the prospect of social cooperation (such as in the prisoner's dilemma) is a central theme in political science. The political decision-making underlying coalition formation and cooperation involves (to name just a few) trust, monitoring, reputation, reciprocation, evaluation of the intentions of others, and estimation of payoffs/rewards. Neuroscientific work that probes these traditionally central concepts is illustrated by a recent study of altruistic norm enforcement (de Quervain et al., 2004). Both political scientists and neuroscientists stand to gain from working together to better explicate many crucial features of modern political science, just as increasing numbers of economists have begun to explore neuroscientific methods. But such collaborations will be most fruitful if they are done in an environment that tests theories comparatively. If competing explanations of political behavior suggest different neurological mechanisms, then fMRI will be particularly useful.

Our understanding of the human brain, and its relation to higher levels of explanation in the study of humans, will come from *both* the development of theory and the collection of evidence. fMRI and related technologies give political scientists and economists an expansive new source of raw data. However, just as a failure to focus on conceptual, as opposed to empirical, progress undermines political science "pre-neuropolitics" (Johnson, 2002, 2003), similar problems apply to the development of "neuropolitics." To this end, political scientists, economists, and neuroscientists need to work with each other in ways that explicitly acknowledge limitations in their conceptual framework and measurement techniques and hence preventing alarms about the role of neuroscience in the study of politics (e.g., Wahlberg, 2004; Editorial, 2003, 2004).

Given that political science is currently discussing the merits of different "scientific" approaches to political science, such as rational choice theory, neuroscience may be able to provide fresh perspectives on seemingly incommensurable research traditions. Lupia's (2002) efforts to bring formal modeling of psychological processes into political explanation, Bueno de Mesquita and McDermott's (2004) recent statement on prospect theory, and

Blank's (2003a) discussions on public policy all suggest that the ground is fertile for novel approaches to inquiry in political science. Politics offers an incredibly rich source of information about human emotion, cognition, and behavior: alliance formation, provision of public goods, use of force, and partisanship, to name just a few. Further scientific exploration of these and other political behaviors should tread slowly yet surely.

NOTES

1. A substantially earlier version of this chapter appears in Tingley (2006).

2. I do not focus on other imaging technologies, such as positron emission topography (PET), because of the growing frequency that fMRI is being used (PET requires the administration of a radioactive substance into the bloodstream) and because many of my general arguments will cross apply.

3. Of course, rational choice theory does not specify that people must be "conscious" or in "control" of their decision-making process in order to be rational, or even modeled as being rational (Ordeshook, 1995, p. 178). However, rational choice theory often used in explanations where the posited actors *are* conscious and acting intentionally. This stems from the intentionalist form of explanation being used (Tingley, 2007; Elster, 1983). Of course, the neuroscience program explored here is trying to build those mechanisms instead of relegating them to the black box that rational choice theorists purportedly try to avoid (Boudon, 1998).

4. Camerer (2003a, 2003b), citing Romer (2000), give the example of two people who do not eat peanuts. One person likes the taste of peanuts but consciously does not eat them because of an allergy. The other person had an adverse experience with peanuts but can still eat them; not eating peanuts is a habit formed from a harsh memory. Each method of explaining not eating peanuts suggests different economic consequences like differences in price elasticity. Darren Schrieber and colleagues suggest a similar example from political science: responses to political questions can be habit based due to a high degree of familiarity with the issue (sophistication) or the result of a highly conscious effort to construct a response, given a very low level of familiarity with the subject (Lieberman et al., 2003; Schreiber & Iacoboni, 2004).

5. Interestingly, Marcus and MacKuen (2001) find that the third piece of Gray's model, relating to "fight–flight"-type interactions, is "of limited application" to the study of politics, presumably because of the primitiveness that such a situation involves (p. 44). Morikawa, Hanley, and Orbell's (2002) analysis of cognitive requirements in "hawk-dove" games paints a more central picture for "fight-flight" situations in political interaction.

6. Another well-developed theory, which I do not cover here only for simplicity's sake, is known as the "hot-cognition" model. It argues, among other things, that political concepts are stored in memory with effective associations attached to them. Thus, exposure to these concepts generates automatic affective impressions upon recall (Morris, Squires, Taber, & Lodge, 2003; Lodge & Taber, 2000). For a general review of the role of emotions in politics, see Marcus (2000, 2002, 2003).

7. Schreiber acknowledges that such a reading of his work is plausible, though he maintains more of an agnostic stance here: both effective and cognitive forces can plausibly modulate responses to political "facts" and arguments. Further, how both of these systems do this is not well understood, largely because much of the study of effect in relation to politics is too oriented toward the study of disaffiliative effect like fear and anxiety (Schreiber, personal conversation).

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