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Governing Societies of Brains:

Applications of Neuroscience to Economic Organization and Governance

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Abstract

For centuries we have debated whether good government depends upon better people or better institutions. The debate raged anew among the 18th century political economists, whose work provides a foundation for new institutional economics. Yet today when we think about organizing and governing we typically focus on discovering arrangements that produce efficient outcomes without considering the capacities of the people who are the object of our efforts. Then we attempt to select the “best” fit, create artificial enhancements or reengineer ourselves, institutions, organizations, and networks to achieve efficiency ideals. North (2005) argues that to create adaptive institutions, our minds must evolve. But what if we can’t change our minds or our institutions without changing our brains? This paper summarizes what we know about the biological basis of choice and develops implications for economic organization and governance.

"But what is government itself but the greatest of all reflections on human nature?"
James Madison, *Federalist Papers*, No. 51

Introduction

Madison, one of the founding brains behind the early development of the United States, raises the fundamental problem of government: if government reflects human nature and human nature seeks to govern itself, what does this suggest about the human capacity for government and therefore the most fitting governing institutions? Put somewhat differently, what is the relationship between human nature and government?

Working to create a modern government in the midst of accelerating growth and geo-political adventurism, early Americans were not raising new questions about human nature or government – they were mining centuries of debate for models that were compatible with what they had learned and experienced, and the ideals they aspired to achieve.

The 18th century version of this debate was launched by the moralist Bernard Mandeville (1723).[1] Taking issue with the reformers of the day who railed against the vices and social ills that accompanied rapid growth and urged strict self-governance and virtuous asceticism, Mandeville argued instead for individual liberty and strong, mitigating government. Humans are prone to selfishness and greed and it cannot be eliminated by any means, he reasoned; "To make a great and honest hive. T'enjoy the World's conveniencies, Be fam'd in war, yet live in ease without great vices, is a vain

[1] Originally published in 1705 as *The Grumbling Hive: Or Knaves Turned Honest.* Benjamin Franklin, another founding brain, was introduced to Mandeville in London around the time he began to think of himself as a moralist and engage in the moral debates of the day. He describes Mandeville as: "Dr. Mandevile, author of the Fable of the Bees who had a club there, of which he was the soul, being a most facetious entertaining companion." (Franklin, 1771, pg. 40)

Eutopia seated in the brain."[2] But unleashing human vice stimulates demand for industry and trade, which creates prosperity and promotes the "wealth, glory, or goodness of nations."[3] In Mandeville's view, human nature could be guided to serve the public interest by "lawgivers and other wife men, that have laboured for the establishment of society."[4] And the best form of government combines monarchy, aristocracy, and democracy.[5]

Assailing Mandeville's view of human nature, Francis Hutchison argued that strong government is not needed to achieve virtuous ends because human nature is inherently benevolent and rational. The human capacity for reason was, in his view, sufficient to sustain a commitment to public interest that is "better served by actions that appear to have the most universal unlimited tendency to the greatest and most extensive happiness of all the rational agents to whom our influence extends."[6]

Adam Smith, a student of Hutchison, extended Hutchison's ideas in a theory of human nature and then a model for political economy that included individual liberty, self-regulation, and limited, mitigating government.[7] In Smith's view, human nature, with its apparent capacity for both reason and emotion, is able to balance its own interests with

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[2] Mandeville (1723).
[3] Ibid.
[4] Ibid. Mandeville argues in "An Inquiry into the Origin of Moral Virtue" that the difficult task of breaking the "savage man" has been achieved not by religion nor by philosophy but by "the skilful management of wary politicians" who use flattery to persuade: "… making use of this bewitching engine, they extoll'd the excellency of our nature above other animals, and setting forth with unbounded praises the wonders of our sagacity and vastness of understanding, bestow'd a thousand encomiums on the rationality of our souls, by the help of which we were capable of performing the most noble achievements."
[5] Ibid. p. 401.
[6] Hutchison (1725).
[7] I interpret *The Wealth of Nations* as the logical outcome and final stage of the development of Smith's political economy ideas, which begins with *The Theory of Moral Sentiments*. While some find contradictions between the two works, I believe these contradictions are resolved if one reads his work in the context of the 18th century debate and accepts the biographical evidence that he began with an effort to explain human nature and then built his theory of political economy on this foundation. See for example Cannan (1976) and Raphael & Macfie (1982). For another very interesting perspective on the consistency of Smith's work, see Vernon Smith (1997).

those of others to serve the public interest. However, this is not achieved without both self-regulation and government by others. While he argued that; “Self command is not only itself a great virtue, but from it all other virtues derive their principal virtue,” he also took pains to describe the many ways in which emotions overcome reason and interfere with the capacity for rational self-command.[8] I interpret Smith to have theorized that many of these departures could be checked by the competitive pressures created by free trade and specialization. However, he allowed for limited government that provides that which is under-provided by individuals pursuing their own ends.

But it was the founders of the United States – the first American “brain trust” – who transformed the debate into a working experiment in government and political economy.[9] First hand experience with the excesses of self-government as well as the strong government of the “law givers and other wife men” of 18th century England motivated the American founders to find the contemporary equivalent of a third way.[10] “If men were angels,” Madison argued, “no government would be necessary.”[11] Worried about the potentially corrosive effects of majority factions and reasoning that it was not possible to change human nature; “The latent causes of faction are thus sown in the nature of man,” he argued that the principal challenge was to design a set of governing

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[8] Smith (1776) Part VI, Section III.

[9] In U.S. government, the term “brain trust” is most closely associated with the individuals who advised President Franklin Delano Roosevelt in creating the “New Deal.” Today it is used to refer to any close group of advisors.

[10] Each of them had personally had the occasion to take flight from angry mobs, observed mobs in action, or had friends who had the experience. And as leaders in colonial government, they had first hand experience with the excesses of King George and the English Parliament. Today we typically look to the Plimouth colony or Tocqueville’s observations for an account of early American government, but the first colony, Jamestown, with its extraordinary excesses (including cannibalism) is an equally important though certainly less savory chapter in the American experiment in self-government.

[11] Madison 51 in Cooke (1961).

institutions that would permit individual liberty but check its excesses.[12] "The inference to which we are brought, is, that the *causes* of faction cannot be removed; and that relief is only to be sought in the means of controlling its *effects.*"[13]

Today, in the early years of the 21st century, we observe a wide range of governance models in the global political economy and often quite heated debate about the role of government in human affairs. Only a handful of countries, representing about 6% of global population, practice the Anglo-Scots-American model of political economy.[14] The personal and economic liberties of most of the world's population are much more closely restricted. Most people live in either "nanny states," where citizens have numerous liberties subject to the rule of law but expect democratically elected governments to play a strong role, "authoritarian states," which limit political and economic participation rights or "failed" states that are overrun by conflict and corruption that sharply constrains growth and development.[15]

If government reflects human nature and we observe different forms of government in the world as we know it today, why has human nature produced different types of government, and why hasn't there been more convergence as our interaction with each other has increased through exchange? What does this suggest about similarities and differences in human nature across the world? And for those of us who

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[12] Madison 10 in Cooke (1961). In the view of the American founders, political and economic factions were perhaps the single greatest threat to democratic government.

[13] Ibid.

[14] The most obvious examples are the U.S., Australia, and the U.K., with the U.S. among the most observant among the group.

[15] For example, economic decision making in Canada and the western European social democracies is fairly concentrated and policy makers take a corporatist approach, which balances government, business, and labor concerns.[15] The Eastern European countries and India have long standing socialist traditions and are opening to more limited government in fits and starts with frequent reversals. There are several devoutly communist countries in the system including China, Cuba, and Vietnam. But authoritarianism is perhaps the most common tradition in the global system with some countries ruled by strong individuals, families or theocracies, and other putatively democratic countries cycling between military and civil control.

are interested in the new institutional economics and commercial activity, what are the implications for governing exchange?

Our existing models of human nature, government, and the relationship between the two, rest on rather thin empirical foundations. This is due in part because until fairly recently, we have had limited tools to investigate human nature empirically. But with advances in the neurosciences and analytical technologies, it is possible to begin to examine not only the biological basis of human nature, but that of human choice, which I take to be the principal activities involved in government and exchange.

It seems quite likely that the capacity to develop alternative governing schemes and to choose among them begins in human minds, which regardless of how one approaches philosophy of mind, requires at least a nodding acquaintance with the brain and what we know today about its relationship to the mind and the body.[16] Embodied minds working together (or not) create and enforce the institutions that govern exchange, choose among these institutions, adapt to changing conditions, and suffer or enjoy the consequences. As North (2005) has argued, adaptation requires that the minds of the members of society evolve to solve the problems presented by an ever-changing world.

However, changing our minds may require changing our brains: many neuroscientists argue that there can be no change in our mental state without a change in our brain state. We are first and foremost societies of brains and the first order rules of human order are biological mechanisms. However, the evidence also indicates that our experience in the world plays an important role in structuring our brain. Hence, human

[16] I understand philosophy of mind as the study of the nature of the mind, consciousness, mental events and functions, and their relationship to the physical body. The "mind-body problem" – the relationship of the mind to the body – is one of the central issues in philosophy of mind but well beyond the scope of this paper.

order includes our brains, minds, choices, experience, and the institutions and organizations that we create to order exchange.

This paper examines what we are learning from the neurosciences about the brain, the mind, and choice, and develops some preliminary implications of these findings for developing a better understanding of economic organization and governance. Section One provides a primer on what we know about the biological mechanisms that govern human nature. Section Two examines the nature of thinking and choice. The final section returns to the subject of the relationship between human nature and government and develops implications for self-government.

I. What are the biological mechanisms that govern human nature?

I understand human nature to mean the range of human behavior that persists over long periods of time and across different contexts. The behaviors that are most closely associated with exchange include attending to and assessing the opportunities and constraints arising from meeting one's needs in a particular environment, approaching and becoming acquainted with others, sharing information, estimating intentions, contracting, solving problems, and enforcing agreements. Like most other behaviors, exchange behaviors are associated with observable activity in the brain, which is part of the nervous system.[17]

The nervous system is a bio-electro-chemical signaling and information system that links mental and physical activity at cellular, molecular, neural, and behavioral levels through four mechanisms: 1) voluntary actions of the muscles of the somatic motor

[17] In writing this very simplified overview of the biological mechanisms that govern our choices, I have relied on a number of sources but have drawn most liberally from Nolte (1999), Gazzaniga, Ivry & Mangun (2002), Gazzaniga (1998), LeDoux (2002, 1996), and Damasio (1999). I have also benefited from discussions with colleagues in the Center for the Study of Neuroeconomics at George Mason University.

system, 2) involuntary actions of the smooth muscles, heart, and glands (autonomic systems), 3) the endocrine system, and 4) the immune system.[18] In addition to supporting mental activity, the nervous system plays a key role in maintaining the internal steady state needed to physically adjust to changes in our surroundings and sustain vital functions.

The nervous system is a made up of around 100 billion neurons and perhaps ten times as many glial cells. Neurons, which are the basic signaling and information processing units in the nervous system, help us respond and adjust to internal and external states. They receive information, make a choice about it following some general go/no-go rules, and by changing their activity, pass the information along to other neurons. Glial cells play a supporting function including coping with damaged cells; forming myelin, which enables neurons to signal electrically; and maintaining a barrier between neuronal tissues and the blood (blood-brain barrier), which protects the central nervous system from harmful agents carried in the bloodstream. [19]

Neurons consist of a cell body, and dendrites and axons, which extend away from the cell body. Dendrites are branch-like structures that transport inputs from other neurons. Axons handle outputs from neurons. Most neurons convey information by emitting signals to other neurons through both their dendrites and axons. Neurons may be unipolar (just one axon or one dendrite), bipolar (one axon and one dendrite), multipolar (one axon and a number of dendrites) and pseudounipolar (bipolar neurons whose

[18] The endocrine system includes the system of glands that release hormones directly into the circulatory system, the system of cells along the sympathetic nerves, adrenal glands, and other organs, and the neurons that are specialized to produce and secrete hormones. The immune system includes the organs and cells that defend the body against infection, disease, and foreign substances.

[19] It appears that many types of glia cells communicate with each other and with neurons. Units of communication in the brain may include neuron-glia-neuron loops. Interview with Ira Black, M.D. in Gazzaniga et al. (2002, p. 47).

dendrites and axon have fused). Most neurons in the brain, which is the chief executive officer of the nervous system, are multipolar. Figure 1 shows the major structure of a neuron.

Neuronal activity arises from a combination of electrical and chemical signaling. Signaling, which depends upon mostly involuntary actions in the body, conveys information that generates mental and physical activity. Signals travel in both nerve pathways and in the bloodstream. While neurons signal electrically, the signal is usually transmitted chemically through the release of molecules known as neurotransmitters, which excite or inhibit neuronal activity at specific locations.

Signals transmit information at chemical or electrical synapses, located on neurons. Synaptic transmission binds neurons together in regional clusters or networks that work together to perform specific functions like specialized circuits in an electrical system or networks in a distributed information processing system. Neuroscientists hypothesize that these regional networks are initially built from genetic instructions that specify where particular neurons are located, and then expand and become more complex as we develop, respond to variation in our internal state, and acquire experience by engaging in our external environment. Figure 2 depicts a small biological neural network.

The "headquarters" of our nervous system – the central nervous system – is composed of the brain and the spinal cord (Figure 3). The actions and output of the central nervous system are influenced by incoming sensory information conveyed by the peripheral nervous system, a supporting collection of spinal and cranial nerves. In addition to providing sensory information to the central system, the peripheral system conveys motor commands from the central nervous system to the muscles.

The nervous system begins to form in the third week of embryonic development. The brain and motor nerves begin to form in the fourth week, and reflexes appear between the 8^{th} and 12^{th} weeks. The growth of the cognitive capacities of the brain depends upon massive proliferation and migration of neurons and glial cells, which occurs during the third through fifth months of development, and the formation of neuronal connections, which continues well after birth and perhaps throughout our life.[20]

The brain itself has three components: the cerebrum, the cerebellum, and the brainstem (Figure 3). The cerebrum includes the cerebral hemispheres and the diencephalon, an “in-between brain” located between the cerebral hemispheres and the brainstem. The cerebellum, or “little cerebrum,” which is tucked underneath the cerebrum behind the brainstem, maintains interconnectivity within the central nervous system. And the brainstem, which is located as its name suggests, facilitates motor and sensory communication.

Weighing less than one pound at birth, the brain triples in size as we develop due to the growth of neuronal networks and the addition of myelin. It reaches a maximum average weight of about 3 pounds by age 18, with a range of 2.4 -3.75 pounds, and begins to decline in weight after age 50. Relative to body size, humans have larger brains than most animals. However, it appears that it is complexity rather than size that matters for cognitive function. As compared to other animals, human brains have more complex neuronal interconnections, and the area of certain parts of the cerebral cortex that are believed to be involved in higher-order cognitive functions is larger.

[20] There is some evidence that adult humans are able to produce new neurons throughout life. For an overview of brain plasticity, see Gazzaniga et al. (2002, Chapter 15).

Research on mental activity in the brain is focused on the cerebrum, which includes the neocortex, the mesocortex, and the allocortex, and the subcortical areas of the basal ganglia and the diencephalon. The neocortex or cerebral cortex has two hemispheres composed of layers of neurons that are connected by the corpus callosum. It has four main lobes (frontal, parietal, temporal, and occipital), which are connected to other areas of the brain by billons of axon tracts.[21] The mesocortical and allocortical regions of the cerebrum include the limbic system, the basal ganglia, and the hippocampus. The thalamus and hypothalamus make up the diencephalon. (Figure 4.)

Neuroscientists are only just beginning to understand brain functions and processes. Key functions and processes include attention and sensory perception, learning, emotion, problem solving, memory, and motor control. While major systems of functions can be broadly associated with specific areas or regions in the brain, many functions involve multiple regions and multiple levels of activity involving both cortical and subcortical components. (Figure 5.) For example, frontal, parietal, occipital, temporal, basal ganglia, and thalamus areas are all associated with sensory and motor functions. The limbic system, hippocampus, and hypothalamus are associated with emotional experience. Learning is most closely associated with the limbic system but memory is associated with the limbic system, the basal ganglia, and the hippocampus. Table 1 provides an overview of the functions most closely associated with each anatomical region of the brain.

But our ability to make choices and engage in exchange requires more than bundles of neuronal assemblies. An equally challenging scientific endeavor is to

[21] The cerebral cortex has a high density of cell bodies, which appear to be grey in relation to surrounding areas that are composed mostly of axons, which appear to be paler or white. Hence cell bodies are referred to as grey matter and axon tracts as white matter (Gazzaniga, et al. 2002, p.65).

understand how neuronal systems work together to think and choose, the impact of internal and external stimuli on these processes, and how we can influence the relationship among these variables. We know from studies of brain and other bodily injuries that our brains play an important role in producing and sustaining both voluntary and involuntary activity - our brain mechanisms and our thoughts and choices are inextricably linked.[22] Yet we consistently observe differences among individuals and groups in field studies and in laboratory experiments where we have more control over external stimuli: different people think differently in similar situations. Are we observing differences in brains, experience, or both?

Until we can explain how the brain, thought, and choice are linked or why differences persist despite extensive training and interaction, human nature will remain as black a box as the political economies it has created. An important first step is an empirically based "theory of mind" that can explain our ability to think.[23] That is, we need to understand how we reflect on external events, represent and infer unobservable abstractions such as values, beliefs, dreams, creations, and outcomes for self and for others, to reason and resolve conflicts among mental constructions, and to make choices.

II. What is the biological nature of thinking and choice?

It may be that we have always had theories of how thought and choice emerge from brain activity. However, empirically driven theories didn't emerge until about the middle of the 20th century, in large part because our scientific and technological capacity to know our own minds lagged our desire to do so. As our ability to gather, manage, and

[22] Consider for example, the loss of functionality or personality changes associated with stroke and "brain death," the ability of the brain to control advanced prosthetic devices, or our capacity to reassess our prior experiences and change our beliefs and experience such that we behave differently than we would have without reassessment.

[23] Gazzaniga et al. (2002) attribute the concept of "theory of mind" to David Premack. See interview with David Premack (p. 676-677).

analyze physiology, choice, and behavior developed, two general approaches to theory of mind emerged: connectionist and computational.

The connectionist approach, which can be traced to psychologist Donald Hebb (1949) and economist Friedrich Hayek (1952), conceptualizes mental phenomena as representations of relationships that emerge from the sensory activities of complex, interconnected networks of neural circuits.[24] Hayek argued: "Sensory or mental qualities are determined by the system of connections by which impulses are transmitted from neuron to neuron."[25] Connections, which cluster in networks of neurons (neural networks), develop as a function of experience in the world.

Computational theories of mind can be traced to the work of computer scientists Herbert Simon and Allen Newell (1964), who argued that beliefs and desires can be thought of as information that is represented as symbols to neurons. According to this view, the human brain as an information processing system and thought is a computation performed by the brain.[26] The brain is a kind of digital thinking device somewhat akin to a modern computer that encodes sensory information into binary inputs that feed rule-based programs or routines, which are our values and beliefs "software."

But neither connectionist nor computational theories of mind address the classic mind-body problem or contextual differences. Today the effort to develop an empirical understanding of thinking and choice comes together under the umbrella of cognitive

[24] Donald Hebb (1949) proposed an early and influential model of learning that is still being investigated today.

[25] Hayek (1952, Section 2.49, p. 53).

[26] A strong proponent of the computational theory of mind and stalwart critic of the connectionist approach his cognitive neuroscientist Steven Pinker. He argues that the mind is what the brain does. It is a "system of organs of computation designed by natural selection to solve the problems faced by our evolutionary ancestors … in particular, understanding and out-maneuvering objects, animals, plants, and other people." (1997, p. 21). The brain processes information, and the mind or mental activity is a kind of computation that "makes us" see, think, feel, choose, and act in unique ways, and to reflect on our thoughts and activities as well as those of others.

neuroscience, which is a concerted amalgam of investigators in multiple disciplines including artificial intelligence, computer science, economics, law, medicine, philosophy, physics, and psychology.

For example, Posner and Raichle (1997) argue that "measuring the mind" requires five levels of analysis: 1) cognitive system or the functional requirements of everyday life such as reading, writing, and planning, based on verbal reports; 2) mental operation or the sets of operations that make up the tasks associated with functions such as scanning, finding, or placing, which are studied with computer simulations of logical sequences (computational models); 3) performance or the neural pathways involved in actually performing a mental operation, which is studied with computer simulations of neural networks (connectionist models); 4) neural systems or changes in neural populations, which are studied using neuro-imaging methods such as functional magnetic resonance imaging (fMRI) or Positron emission tomography (PET); and 5) individual cell or how cells respond in mental activity. The individual cell is studied using invasive methods such as microelectrode recordings, which cannot easily be applied to humans but is used extensively in animal studies.[27]

Social cognitive neuroscientists broaden the analysis of thinking to include how minds influence each other through interaction. In an overview of conclusions drawn from non-verbal, bi-directional studies that address a number of questions including exchange, Singer, Wolpert, and Firth (2003) argue that to understand the mind in a social setting, we must investigate interactions arising from three levels of analysis: 1) the social level or the motivational and social factors that influence behavior and experience, 2) the

[27] Conturo, et al. (1999) report progress in non-invasive neuronal fiber tracking for use in humans. They argue that their technique makes it possible to track neuronal connections between brain regions, which is the key to understanding higher level cognition.

cognitive level or the "information processing mechanisms" that are associated with social level phenomena, and 3) the neural level.

Putting Posner and Raicle, and Singer et al. together suggests that thinking and choice are better thought of as emergent properties of a complex adaptive system than as the computable output of the type of static equilibrium models that dominate social science analysis. While the brain is necessary for thought, it is not sufficient and in some cases it may not even be necessary. It may take a whole body – including the brain – to think and choose.[28] Moreover, we are adapted to specific environments hence our thinking and choices are probably contingent upon the (experienced) exigencies of our immediate environment. All of which suggest that the ability to form and update values, goals, beliefs, alternatives, and intentions, estimate the intentions of others, consider the consequences of outcomes, and make an adaptive choice, is more likely to be a homeodynamic process situated in a very specific context than an abstract computational process situated in an encoded repertoire of algorithms situated in neural networks in the brain.

But how would we measure homeodynamic choice? As I imagine it, homeodynamic choice is influenced by the interaction among individuals whose bodies and brains are responding to excitatory and inhibitory cues in the choice environment. Cues in the choice environment produce state changes in the bodies and brains of participants, some of which may be transmitted to each other, which may produce further internal and brain state changes at the individual level.

[28] We have probably all had the experience of responding to something or someone viscerally, which is one obvious example of how our bodies take in and respond to our environment without obvious reference to thought. For more detailed arguments that support this notion, see for example Damasio (1999) and LeDoux (2002, 1996).

Consider the following example of critical thinking and choice in the field. Foreign troops are posted to an installation in an area that has been surveyed and determined to be safe but that is located in an area with a history of insurgency. As they move in, one of the troops notices that a number of local inhabitants are swiftly leaving and reports this to the commanding officer (CO). The CO attempts to collect a wider range of observations from his troops. There is no apparent danger yet the commander orders his troops to fall back. Reporting his choice to headquarters as his troops are moving out, he says: “Something is going on - I don’t know what. It doesn’t feel right. People are leaving. We are getting out of here now.”

As the CO choice example suggests, homeodynamic choice has three potentially overlapping state components at the individual level: 1) external, 2) internal, and 3) brain state. The extent to which state components overlap is an empirical question: the overlap may vary depending upon a number of factors including the type of individual, individual capacities and experiences, type of choice, or choice environment. One may ask for example, whether personal exchange involves more external state cues than impersonal exchange and if these differences are reflected in biological processes and performance. For illustration, I will assume each component affects the other in equal measure and choice emerges from the convergence of signaling activity generated in each of the three states. Figure 6 depicts the concept.

An individual’s external state is the choice environment within which the individual and a choice are situated. Institutional economists have many tools for analyzing this environment, which typically includes physical, economic, social, organizational, and institutional opportunities and constraints.[29] In the above choice example, the CO's external state cues may include geo-spatial maps of the area, intelligence reports on insurgent activity, visual observations of population movements and other sensory inputs, knowledge of host country organizations and institutions, a tactical plan, military codes of conduct, and other organizational rules and routines.

Institutional economists are less accustomed to analyzing the internal states of the individuals in a choice environment. Yet internal state is a critical component in thinking and choice. Citing Pasko Rakic's eloquent description, Gazzaniga (1998) reminds us that the brain is situated in a "dynamic physiochemical milieu." Operating in this milieu is a largely automated set of physiological activities that maintain homeostasis or the internal steady state needed to adjust to changes in our surroundings. These activities include changes in temperature, blood oxygen concentration, and pH levels. Homeostasis is regulated by the nervous, endocrine, and immunological systems and affects motor, autonomic, and brain functions. We have all had direct experience with homeostatic adjustment in one form or another and can attest to its impact on thinking and choice. Similarly, as our illustrative CO is responding to his environment and making his choice, changes in his internal state influence his functionality.

The final state component in homeodynamic thinking and choice is the brain. Thinking and choice are information intensive and involve integrating different brain functions. Exchange is a good example of a cognitive system that is both information and integration intensive. And indeed, the cumulative evidence suggests that exchange

[29] For more detailed analytic frameworks for choice environments see Polski and Ostrom (1999), E. Ostrom, Gardner, and Walker (1994), and V. Smith (1982). Tools used in institutional economics include analytical narratives and other field studies, laboratory and field experiments, econometrics, decision analysis, game theory, and legal and contract analyses.

involves most brain functions including perception, attention, the ability to “mirror” the actions and states of others, emotion, memory, planning and executing movements, and in some cases learning and somatosensory processing. Moreover, we know from research on split-brain patients, that even though the brain is made up of a large number of specialized functions that “talk” to each other, thinking and choice cannot be subdivided.[30] So while one day we may be able to describe the neural pathways in the brain that are associated with making particular choices in specific environments, this still may not tell us much about individual and group differences in thinking and choice.

Marcus Raicle, who is an expert in neuro-imaging, argues that “spontaneous intrinsic activity” in the brain may be more important in thinking and choice than processing external inputs.[31] While the brain represents on average just 2% of human body weight, it consumes over 20% of total energy. Raicle reasons that running at a high metabolic rate is indicative of cycling glutamate. Hypothesizing that glutamate cycling is associated with neurons talking to each other to sustain system balance, he estimates that maintaining system balance expends 60-80% of the brain’s total energy. This sharply limits the brain’s capacity for handling external inputs. Citing evidence that brain activity decreases from a physiologic baseline, he argues that research suggests a default mode of brain function, which is indicative of system behavior.[32] Similarly, Damasio (1999)

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[30] Split-brain refers to individuals whose corpus callosum (connects the two hemispheres of the brain) has been severed in order to interrupt the “electrical storms” associated with epilepsy. This treatment innovation was pioneered by Roger Sperry, who found in post-operative testing that subjects showed no obvious functional impairment. More detailed testing, which isolates visual input to one of the two hemispheres of the brain, reveals functional specialization in the brain. Gazzaniga, who worked with Sperry as a student and has continued to investigate these questions, has reported extensively on the capacities of split brain subjects.

[31] Marcus Raicle, “Image of the Mind Update,” talk presented at the Decade of the Mind Symposium at George Mason University, May 22, 2007.

[32] See Raichle, et al. (2001). The authors provide evidence of an organized, baseline default mode of brain function that is suspended during specific goal-directed behaviors.

argues that our brains "… preserve and expand (our) ability to sense (our) internal state, to hold know-how in disposition, and to use these dispositions to respond to changes in the surrounding environment." And Gazzaniga (2005) argues that the brain is a rule-based device that interacts with its environment in a way that allows it to learn rules to govern how it responds.

Synthesizing, it occurs to me that rather than thinking of the brain as an information processing or computational production system, it may be more useful to think of it as a governance system that governs our mental and physical responses to our environment. But if the brain is a governance system, how does it govern? And are we capable of self-government or do we require Mandeville's "wife-men?"

III. Implications for Self-Government

As we have seen, similar networks in the brain may perform very different functions, the same networks may participate in different functions at different times, and while there is specialization, if functionality is lost in a particular network, other networks may develop compensatory functions. Brain areas are also interconnected at different levels of order. Based on the available evidence, the brain appears to be a polycentric system composed of specialized but overlapping regions with "jurisdiction" over attention, perception (sight, smell, hearing, sensation), motivation (desires, goals, beliefs), emotions, memory, language, learning, and problem solving.

If one accepts my argument for homeodynamic choice, than we must view the brain as a sub-system in a larger polycentric system that includes internal and external state systems. In this formulation, human nature is governed by the convergence of external, internal, and brain state events. The influence of the brain system on human nature is an empirical question: it may be a dominating system in some or all choice situations – the governor who governs the governors. Or it may have considerably less influence than we would like. If we are governed by spontaneous order as Hayek proposed, which is a kin to classical market contracting in an economy, than we may be as likely to be ruled by what Keynes' dubbed "animal spirits" as we are by utilitarian logic.

Unfortunately, we know as little about how polycentric systems work as we do about human thinking and choice. Vincent Ostrom (1972) attributes the first reference to polycentric systems to Polyani, who drew a distinction between deliberate or directed order and spontaneous order.[33] Extending Polyani and his own work with Tiebout and Warren, Ostrom argues that polycentric systems are an example of spontaneous order that is self-generating and self-governing.[34] He identifies a number of examples of polycentric systems that have relevance for exchange-related thinking and choice including markets, coalition formation, and the selection of political leadership. Ostrom argues that polycentric systems as distinct from hierarchical or codified systems, have many centers of decision making that are formally independent of each other but operate under the same general system of rules, which provides a framework for ordering relations within the system. Ostrom theorizes that polycentric systems have no center, no central or dominate power, no coordinator and no integrator. However, these are empirical questions that have not to my knowledge been systematically examined.

[33] Ostrom cites Polyani (1951) *The Logic of Liberty.* Note that Polyani and Hayek were close colleagues and the complementary nature of this work by Polyani and Hayek's work on sensory order (1952).
[34] See Ostrom, Tiebout and Warren (1961). The authors are concerned with those situations in which a metropolitan region has emerged that is not a legal entity, has no general instrument of government, and where its affairs are governed *de facto* by a group of separate and independent governing entities including state and federal agencies, counties, cities, and special districts.

And so we return to the dilemma that confronted Madison: to govern ourselves in a way that is true to our natures, we must focus equally on understanding the capacities and processes of human nature and systems of (polycentric) government. This begs the question of our biological capacity for self-government. We have many examples of neurobiological (internal state and brain state) differences that potentially affect impulse control and social behavior such as brain lesions, autism, schizophrenia, and anti-social personality disorder. These phenomena suggest that some people may not be capable of self-regulation. By implication, if enough similarly ordered people associate in groups, or a few strong individuals succeed in dominating a group, some groups may not be capable of self-regulation.

Gazzaniga (2005) is skeptical. Citing evidence that the brain is active before we become consciously aware of a thought, he argues that our conscious minds (which are enabled by brain functioning) have potential "veto power" over choices that emerge from involuntary processes and hence the capacity for self-regulation.[35] In his view, further research is needed to determine how much and what kind of impairment is necessary to so completely shutdown inhibitory functions that self-regulation becomes impossible or requires the aid of others, including government. Moreover, he argues that responsibility for choice is something that happens when people interact: it is fundamentally a social construct involving what I have labeled external state cues. And indeed, there is strong evidence that our choices are influenced by both our own homeodynamic choice set-up as well that of those with whom we interact. This influence appears to be enabled by systems of "mirror neurons" that allow us to recognize and "mirror" the observed actions and emotional states of others.

[35] Gazzaniga (2005, chapter 6).

For example, Buccino, et al. (2005) find that when individuals observe an action, an internal replica of that action is automatically generated in their premotor cortex. In the case of object-related actions, a further object-related analysis is performed in the parietal lobe, as if the subjects were indeed using those objects. Similarly, imitation and observation of emotions activate a similar network of brain areas. Carr et al. (2005) argue that we understand what others feel by a mechanism of action representation that allows us to experience empathy and modulates emotional content. The insula plays a fundamental role in producing emotional contagion, acting as a relay from action representation in the superior temporal and inferior frontal cortices to the limbic system.[36]

Yet social interaction can be a double edged sword. In a review of the literature on the physiological correlates of human traumatic experience, Kendall-Tackett (2000) finds evidence that chronic hyperarousal of stress response may alter the sensitivity of the brain to threats, leading afflicted individuals to misinterpret and overreact to external stimuli. Chronic hyperarousal, which produces abnormal levels of stress hormones, may permanently alter brain structures such as the hippocampus. For example, damage suffered by child soldiers, or other young victims of violent conflict, torture, or abuse, may lower intelligence, reduce brain substance, or interfere with semantic memory, which diminishes cognitive capacity. Or it may permanently alter feedback to the central nervous system, which can distort perception, sleep, and mood in ways that affect cognitive and social functioning.

While interaction among individuals with different homeodynamic choice set-ups can influence thinking and choice in important ways, there is also evidence that we can and do use our cognitive capacities to transform our experience. For example, Ochsner et

[36] For additional evidence, see Firth and Wolpert, eds. (2003).

al. (2005) find that reappraising highly negative scenes reduces subjective experience of negative affect.

Summing up, the evidence regarding human nature and the capacity for self-government is mixed. At present, it looks like the form of government that fits human nature is a polycentric system that includes self-regulation, voluntary regulation through interaction with others, and in a default mode, involuntary regulation by Mandeville's "lawgivers and other wife men." If thinking and choice are homeodynamic, than developing an empirically-based profile of individuals and the general system of rules for how they labor together is an important question for both institutional economics and cognitive neuroscience. To my mind this provides a strong rationale for collaboration between the two disciplines.

Table 1: Functional Anatomy of the Brain

Anatomical Division	Function
Frontal Lobe	Planning and executing movements
Parietal Lobe	Somatosensory processing: touch, pain, temperature sense, limb position
Occipital Lobe	Visual activity
Temporal Lobe	Auditory activity
Association Cortex	Volume of neocortex that is not specifically sensory or motor. These regions receive inputs from one or more areas
Limbic System, including the amygdale	Emotions, learning, & memory
Basal Ganglia	Controlling movement, short-term memory, & executive functions
Hippocampus	Emotions & memory
Thalamus	Relaying primary sensory & attentional activities
Hypothalamus	Autonomic, endocrine, homeostasis, & emotional activities

Figure 1: Neuronal Structure

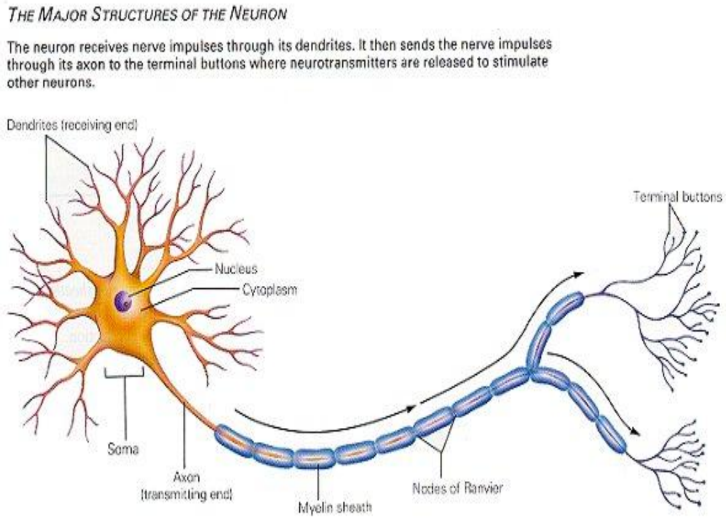


Figure 2: Biological Neural Network

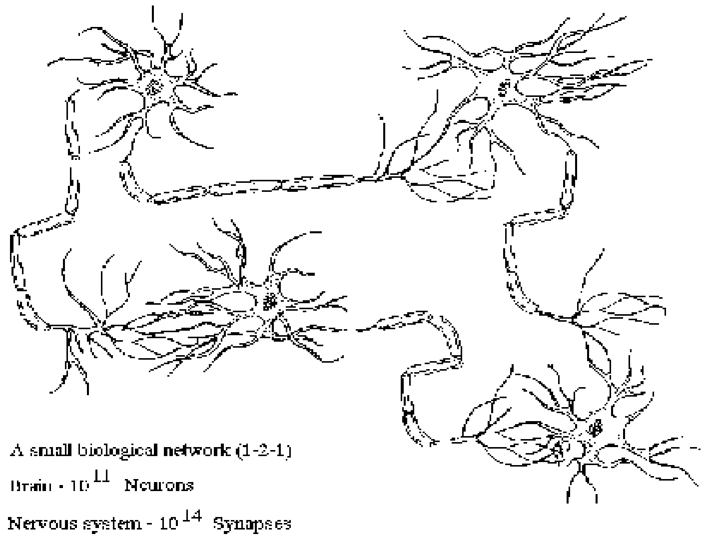


Figure 3: The Central Nervous System

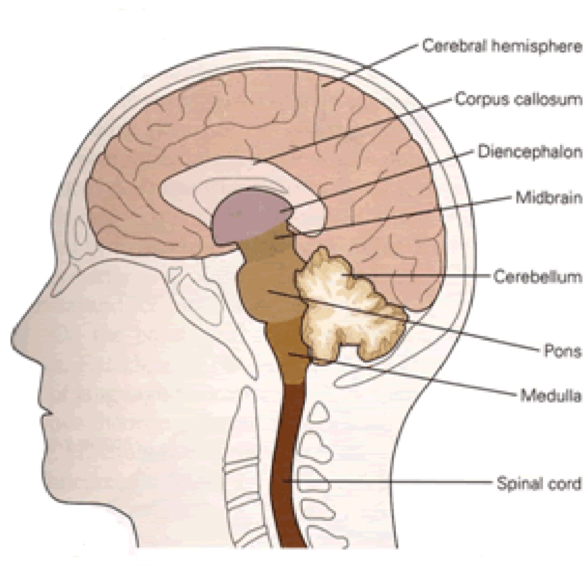
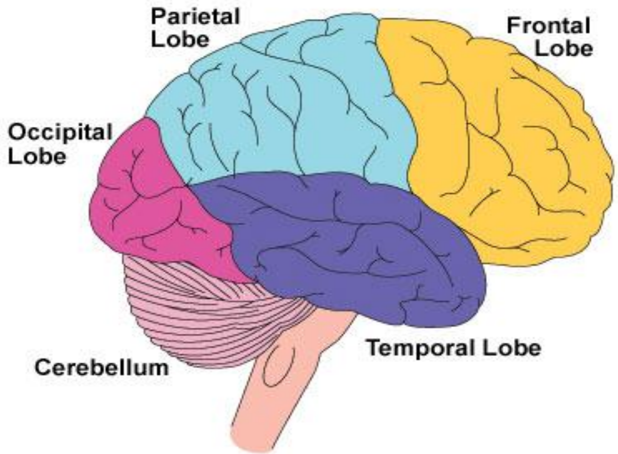


Figure 4: Anatomy of the Brain



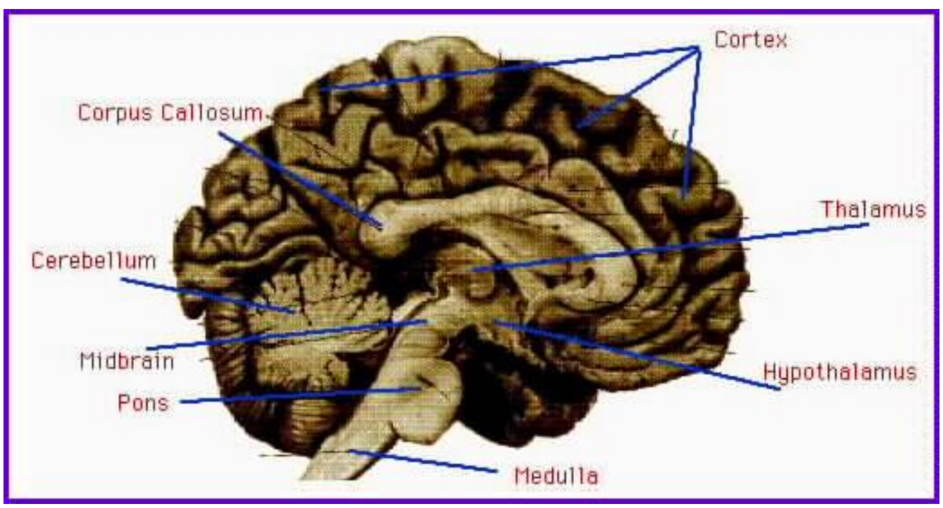


Figure 5: Brain Functions

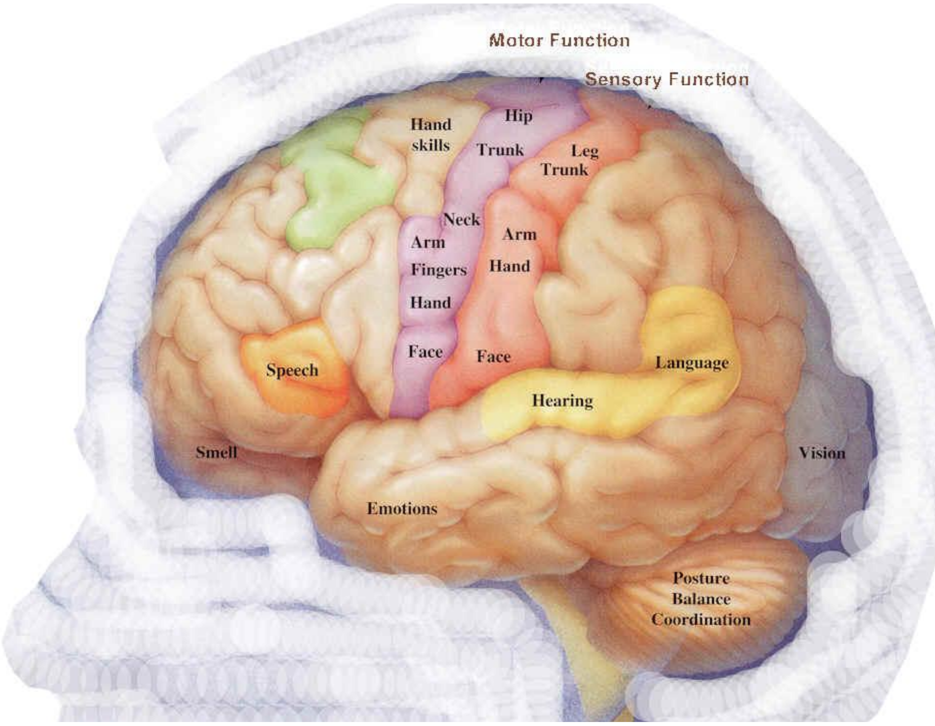
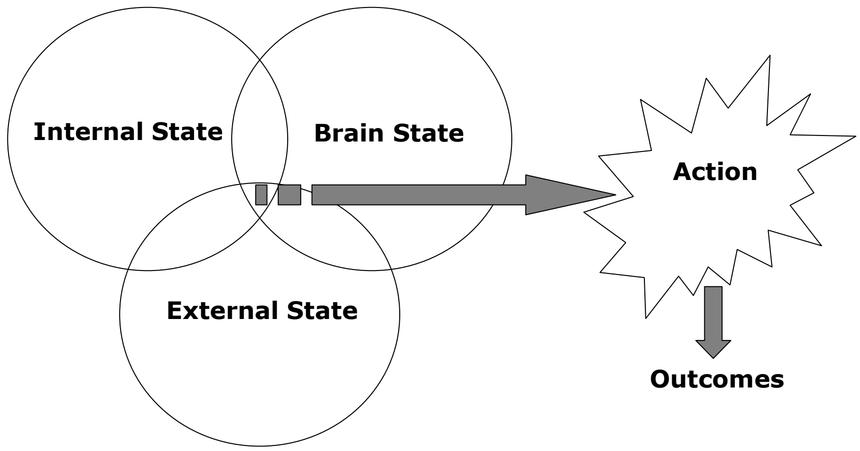


Figure 6: Homeodynamic Choice



References

Buccino, G., F. Binkofski, G.R. Fink, L. Fadiga, L. Fogassi, V. Gallese, R.J. Seitz, K. Zilles, G. Rizzolatti, and H.J. Freund. 2005. “Action Observation Activates Premotor and Parietal Areas in a Somatotopic Manner: An fMRI Study.” In Cacioppo, John T. and Gary G. Bernstson, eds. 2005. *Social Neuroscience.* New York, NY: Psychology Press.

Cannan, Edwin. 1976. “Editor’s Introduction.” In Smith, Adam. 1976. [1776]. *An Inquiry into the Nature and Causes of the Wealth of Nations.* Chicago, IL: University of Chicago Press.

Carr, Laurie, Marco Iacoboni, Marie-Charlotte Dubeau, John C. Mazziotta, and Gian Luigi Lenzi. 2005. “Neural Mechanisms of Empathy in Humans: A Relay from Neural Systems for Imitation to Limbic Areas.” In Cacioppo, John T. and Gary G. Bernstson, eds. 2005. *Social Neuroscience.* New York, NY: Psychology Press.

Conturo, Thomas E., Nicolas F. Lori, Thomas S. Cull, Erbil Akbudak, Abraham Z. Snyder, Joshua S. Shimony, Robert C. McKinstry, Harold Burton, and Marcus E. Raichle. “Tracking Neuronal Fiber Pathways in the Living Human Brain.” Proceedings of the National Academy of Sciences. Applied Physical Sciences/Neurobiology. 96:18:10422-10427. August 31.

Cooke, Jacob E., Ed. 1961. *The Federalist.* Middletown, CT: Wesleyan University Press.

Damasio, Antonio. 1999. *The Feeling of What Happens: Body and Emotion in the Making of Consciousness.* New York, NY: Harcourt Press.

Franklin, Benjamin. 1771. *Autobiography.* In Shaw, Peter. Ed. 1982. *The Autobiography and Other Writings of Benjamin Franklin.* New York, NY: Bantam Books.

Frith, Christopher D. and Daniel M. Wolpert, Eds. 2003. *The Neuroscience of Social Interaction: Decoding, Imitating, and Influencing the Actions of Others.* Oxford, England: Oxford University Press.

Gazzaniga, Michael S. 2005. *The Ethical Brain.* New York, NY: Dana Press.

_____. 1998. *The Mind’s Past.* Berkeley, CA: University of California Press.

Gazzaniga, Michael S., Richard B. Ivry, and George R. Mangun. 2002. *Cognitive Neuroscience: The Biology of the Mind.* Second Edition. New York, NY: W.W. Norton and Company.

Hayek, Friedrich A. 1952. *The Sensory Order.* Chicago, IL: University of Chicago Press.

Hebb, Donald M. 1949. *The Organization of Behavior: A Neuropsychological Theory.* New York, NY: John Wiley & Sons.

Hutcheson, Francis. 1725**.** *An Inquiry into the Original of our Ideas of Beauty and Virtue; in Two Treatises.* London: J. Darby. Yale University Library Collection.

Kendall-Tackett, Kathleen A. 2000. "Physiological Correlates of Childhood Abuse: Chronic Hyperarousal in PTSD, Depression, and Irritable Bowel Syndrome." Child Abuse & Neglect. Vol. 24, p. 799-810.

LeDoux, Joseph. 2002. *The Synaptic Self: How Our Brains Become Who We Are*. New York, NY: Penguin.

_____. 1996. *The Emotional Brain: The Mysterious Underpinnings of Emotional Life.* New York, NY: Simon and Schuster.

Mandeville, Bernard. 1723. *The Fable of the Bees; Or, Private Vices, Publick Benefits.* London: E. Parker. Yale University Library Collection.

Ochsner, Kevin N., Silvia A. Bunge, James J. Gross, and John D. Gabrieli. 2005. "Rethinking Feelings: An fMRI Study of the Cognitive Regulation of Emotion." In Cacioppo, John T. and Gary G. Bernstson, eds. 2005. *Social Neuroscience.* New York, NY: Psychology Press.

Nolte, John. 1999. *The Human Brain: An Introduction to Its Functional Anatomy.* Fourth Edition. St. Louis, MO: Mosby.

North, Douglass C. 2005. *Understanding the Process of Economic Change.* Princeton, NJ: Princeton University Press.

Ostrom, Elinor, Roy Gardner, and James Walker. 1994. *Rules, Games, and Common-Pool Resources*. Ann Arbor, MI: University of Michigan Press.

Ostrom, Vincent. 1972. Polycentricity. Presented at the Annual Meeting of the American Political Science Assocation, Washington, D.C., September 5-9. Reprinted in: McGinnis, Michael, ed. 1999. Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis. Ann Arbor: University of Michigan Press.

Ostrom, Vincent, Charles M. Tiebout, and Robert Warren. 1961. The Organization of Government In Metropolitan Areas: A Theoretical Inquiry. The American Political Science Review. Vol. 55, Issue 4, pp. 831-842. December.

Pinker, Stephen. 1997. *How the Mind Works.* New York, NY: W.W. Norton.

Polski, Margaret M. and Elinor Ostrom. 1999. “An Institutional Framework for Policy Analysis and Design.” Workshop in Political Theory and Policy Analysis Working Paper W98-27. Indiana University, Bloomington, IN.

Posner, Michael J. and Marcus E. Raichle. 1997. *Images of the Mind.* New York, NY: Scientific American Library.

Raichle, Marcus E., Ann Mary Macleod, Abraham Z. Snyder, William J. Powers, Debra A. Gasnard, and Gordon L. Shulman. 2001. “A Default Mode of Brain Function.” Proceedings of the National Academy of Sciences. Inaugural Article Neurobiology: 98:2:676-682. January 16.

Raphael, D.D. and A. L. Macfie, Eds. 1982. “Introduction.” In Smith, Adam. 1982 [1759]. *The Theory of Moral Sentiments.* Indianapolis, Indiana: The Liberty Fund.

Simon, Herbert A. and Albert Newell. 1964. “Information Processing in Computer and Man.” American Scientist. 52:281-300.

Singer, Tania, Daniel Wolpert, and Chris Firth. “Introduction: The Study of Social Interactions.” In Frith, Christopher D. and Daniel M. Wolpert, Eds. 2003. *The Neuroscience of Social Interaction: Decoding, Imitating, and Influencing the Actions of Others.* Oxford, England: Oxford University Press.

Smith, Adam. 1759. *The Theory of Moral Sentiments.* Printed for A. Millar in the Strand and A. Kincaid and J. Bell in Edinburgh, Scotland. Reprinted in Smith, Adam. 1982. *The Theory of Moral Sentiments.* Indianapolis, Indiana: The Liberty Fund.

_____. 1976. [1776]. *An Inquiry into the Nature and Causes of the Wealth of Nations.* Chicago, IL: University of Chicago Press.

Smith, Vernon. L. 1997. “The Two Faces of Adam Smith.” Southern Economic Association Distinguished Guest Lecture, Atlanta, George. November 21.

_____. 1982. “Microeconomic Systems as an Experimental Science.” The American Economic Review. 72:5:923-955.