Exploring the Biology of Socialization

MICHAEL I. POSNER, MARY K. ROTHBART, AND GINA GERARDI-CAULTON

Sackler Institute, Department of Psychiatry, Weill Medical College of Cornell University, New York, New York 10021, USA
Department of Psychology, University of Oregon, Eugene, Oregon 97403, USA

ABSTRACT: How will the social sciences take advantage of the revolution that has taken place in biology during the past two decades? Over the last fifteen years, neuroimaging has allowed the study of human cognition and emotion within psychology to achieve close alliances with biology through the development of cognitive and affective neuroscience. There is little doubt that a similar alliance between psychology and biology will occur in the domain of human brain development. In principle, understanding how the human brain is organized by experience (epigenetic rules) and how societies instruct their young could produce a link between natural and social science. The late David C. McClelland sought methods to base the social sciences on psychological ideas. McClelland sought to connect the values of achievement and power as coded from children’s readers and popular ballads to societal economic growth and conflict. These efforts lacked knowledge of brain mechanisms of memory and attention and an understanding of the role of experience in organizing brain circuitry. Understanding of cognitive and brain systems related to knowledge and action may allow a new approach to forging connections between individual minds and social behavior.

KEYWORDS: Human brain mapping; Epigenetic rules; Neuroimaging; Brain circuits, plasticity of; Sociobiology

A convergence has in fact begun. The natural sciences, by their own swift expansion in subject matter during the past several decades, are drawing close to the social sciences. Four bridges across the divide are in place. The first is cognitive neuroscience, or the brain sciences, with elements of cognitive psychology, whose practitioners analyze the physical basis of mental activity and aim to solve the mystery of conscious thought. The second is human behavioral genetics, now in the early stages of teasing apart the hereditity basis of the process, including the biasing influence of the genes on mental development. (E. O. Wilson, Consilience, 192)

In this paper we first outline some of the findings in human brain mapping over the last 10 years. We then apply these findings to the study of human brain development and discuss the developing links between individual differences in behavior and modern genetics. It is through the study of development that Wilson’s ideas of

Address for correspondence: Michael I. Posner, M.D., Professor of Psychology, Department of Psychiatry, Weill Medical College of Cornell University, 1300 York Avenue, Box 144, New York, NY 10021. Voice: 212-746-5755; fax: 212-746-3781.
mip2003@mail.med.cornell.edu

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epigenetic rules can undergo careful empirical examination. Finally, we consider what forms links between human brain development and the social sciences might take.

**BRAIN CIRCUITS**

The mapping of the human genome and the creation of functional maps of the human brain are two impressive events of modern biology. Together they are likely to produce a new understanding of human nature in terms of the commonalities and differences among human brains.

Until late in this century, it did not seem possible that we would be able to see brain areas active while humans performed cognitive tasks. Most of those who entered psychology in the mid-20th century learned from the work of Lashley\(^2\) that cognitive activity was generally a property of the whole brain and not localized in any region. In addition, one of the tenets of cognitive psychology was that cognition was about the programs or software that specified behaviors, and the nature of the hardware that ran these programs was not important.

In the last few years, however, the methods of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have transformed the cognitive landscape.\(^3,4\) Despite previous views of the irrelevance of brain activity to cognition and many very appropriate cautions about the resolution, consistency, and utility of these methods, we find ourselves looking at maps of brain areas active during a variety of cognitive tasks, including reading, listening, searching, learning sequences, comparing shapes or numbers, and many other activities. The accuracy and reliability with which we will be able to visualize this anatomy is bound to improve as new scanners and methods are developed.

What are we to do with these maps? One step that has been taken, however incompletely, is to transform maps into circuits. To do this, it was necessary to see when the specific anatomy involved in the task was active. Because PET and fMRI measured changes in blood flow that lagged behind neuronal activity by a second or so, it is not obvious how to use these methods to measure the time course of mental operations, which are often in the millisecond range. Nevertheless, by relating the generators found in imaging studies to electrical activity recorded from the scalp\(^5,6\) or by depth electrodes,\(^7\) it has proven possible to see when in time many of these brain areas become active. The use, accuracy, and reliability of these methods are almost certain to improve over the next period.

The next step is to examine plasticity in these networks. We already have good examples of how practice in generating particular word associations changes the circuitry involved\(^8\) and how priming tunes the number of neurons involved in a computation. We should be able to observe at the circuit level what educational experiences can do to organize specific brain areas and their order of activation.\(^9\) Another important application will be to study what various brain injuries or pathologic conditions do to the circuitry that supports cognitive processes and how they recover spontaneously or with drug, practice, or insight therapies. We are just at the very start of guiding our therapeutic interventions with imaging methods.

Among the many lessons learned from approaches to mental processes based on biology is that what seem like unified concepts in behavioral terms may come to rest
on a variety of brain circuits. For example, current views of attention involve several separate circuits. Separate circuits carry out such operations as orienting to sensory information, maintaining the alert state, and resolving conflict between separate brain systems. It will be important to keep in mind that many of our mental concepts will likely turn out to involve a number of underlying circuits involving a widespread anatomy.

DEVELOPMENT

Another important step in examining the plasticity of brain circuits is to observe their development in early childhood. Studying development is a particularly important and obvious way to study plasticity, because learning also changes the brain. When in infant and/or child development do particular circuits come on line? New adaptations of magnetic imaging may be able noninvasively to trace myelination of specific pathways between brain areas. We will then be able to try to predict when particular behaviors should emerge. It is likely that the visual system and particular visually guided eye movements will be studied first, but higher level cognitive activity is sure to follow. We will then have a disciplined approach to understanding when a human brain becomes ready to learn a cognitive skill. In order to develop the ability to perform skills on demand, children need to be able to regulate their own brains in order to switch to the required activity. Attention serves as the vehicle for this form of self-regulation.

Panksepp provides anatomical reasons why the regulation of emotion may pose a difficult problem for infants and young children:

One can ask whether the downward cognitive controls or the upward emotional controls are stronger. If one looks at the question anatomically and neurochemically the evidence seems overwhelming. The upward controls are more abundant and electrophysiologically more insistent: hence one might expect they would prevail if push came to shove. Of course, with the increasing influence of cortical functions as humans develop, along with the pressures for social conformity, the influences of the cognitive forces increase steadily during maturation. We can eventually experience emotions without sharing them with others. We can easily put on false faces, which can make the facial analysis of emotions in real-life situations a remarkably troublesome business. (p. 319)

In early infancy the regulation of negative emotion is a major task of the caregiver. In the first months, holding and rocking are used for soothing, but even from the start there is a strong role for orienting to the caregiver. Beyond three months, caregivers in our society use orienting to external events as a means of distracting the child from distress. Drawing attention to an external event produces conflict with the expression of distress, leading to a form of soothing, although the distress often reappears when orienting stops. The caregiver trains the infant to regulate distress at least in part by distraction. This form of regulation is definitely influenced by cultural factors. In the United States, parents often use visual engagement with the infant to direct attention to objects in the environment. In Japan, similar experiences are used to share emotion, directing the child's attention to sharing emotional experiences with others. Even in adults, it has been shown that the ability to control attention relates to reduced reports of negative affect. We believe that the brain system involved in this self-regulation lies along the midline of the frontal lobe and
works in conjunction with lateral brain areas and the underlying basal ganglia as a circuit involved in the regulation of emotion.\textsuperscript{15,16}

As the child matures, closely related brain systems become involved in detecting and resolving cognitive conflicts. The first precursor of the control of conflict is found in late infancy and appears to involve the dorsolateral prefrontal cortex.\textsuperscript{17} In A-not-B tasks, children are trained to reach for a hidden object at location A, and then tested on their ability to search for the hidden object at a new location B. Children younger than 12 months of age tend to look in the previous location A, even though they see the object disappear behind location B. After the first year, children develop the ability to inhibit the prepotent response toward the trained location A and successfully reach for the new location B.

During this period, infants develop the ability to resolve conflict between line of sight and line of reach when retrieving an object. At nine months of age, line of sight dominates completely: If the open side of a transparent plastic box is not in line with the side in view, infants will withdraw their hand and reach directly along the line of sight, striking the closed side.\textsuperscript{17} In contrast, 12-month-old infants can simultaneously look at a closed side while reaching through the open end to retrieve a toy.

The ability to hold two things in mind can be traced developmentally through sequence-learning paradigms. Infants as young as 4 months can learn patterns of looking to locations that involve unambiguous associations.\textsuperscript{18} In unambiguous sequences each location is invariably associated with another location (e.g., 123123). Because the location of the target is fully determined by the preceding item, there is only one type of information to attend to, and therefore no conflict to resolve (e.g., location 2 is always followed by location 3). Adults can learn unambiguous sequences of spatial locations implicitly even when attention is distracted by a secondary task.\textsuperscript{19}

Ambiguous sequences (e.g., 1213) require attention to the previous item in addition to the context in which that item occurs (e.g., location 1 may be followed by location 2, or by location 3). Ambiguous sequences pose conflict because for an association there can exist two strong candidates that can only be disambiguated by context. Ambiguous associations were not learned by infants until 18 months or later.\textsuperscript{18}

Evidence for developmental changes in executive function and control of conflict during the 24- to 36-month age range comes from a study using a Stroop-like spatial conflict task.\textsuperscript{20} Because children of this age do not read, location and identity rather than word meaning and ink color served as the dimensions of conflict. Children sat in front of two response keys, one located to the child’s left and one to the right. Each key displayed a picture, and on every trial a picture identical to one of the pair appeared on either the left or right side of the screen. Children were rewarded for responding to the identity of the stimulus, regardless of its spatial compatibility with the matching response key. Reduced accuracy and slowed reaction times for spatially incompatible relative to spatially compatible trials reflect the effort required to resist the prepotent response and resolve conflict between these two competing dimensions. Children 24 months of age tended to perseverate on a single response, while 36-month-old children performed at adult accuracy levels, responding more slowly and with reduced accuracy to incompatible trials. The ability to handle this spatial conflict task is correlated with the ambiguity resolution in sequence learning. Thus it appears specific events in the period between two and three years lead to the ability to resolve conflicts in a variety of situations.
It was also found that the cognitive measures of conflict resolution discussed above were related to aspects of children's self control in naturalistic settings. Children relatively less affected by spatial conflict also received higher parental ratings of temperamental effortful control and higher scores on laboratory measures of inhibitory control, such as the ability to withhold responding to wait for a reward. Individual differences in effortful control are strongly related to some aspects of metacognitive knowledge, such as theory of mind (i.e., knowing that behavior is guided by their beliefs, desires, and other mental states). Inhibitory control and theory of mind share a similar developmental time-course, with advances in both domains between the ages of 2 and 5 years. Moreover, tasks that require the inhibition of a prepotent response correlate with theory of mind tasks even when other factors, such as age, intelligence, and working memory are factored out.

Executive control also continues to develop during later childhood, a period more amenable to study using neuroimaging methods. In children aged 5 to 16 years, there is a significant correlation between the volume of the right anterior cingulate and the ability to perform tasks requiring focal attentional control. In a functional MRI study, performance of children ages 7–12 and adults was studied in a go/no-go task. In comparison with a control condition in which children responded to all stimuli, the condition requiring inhibitory control activated prefrontal cortex in both children and adults. The number of false alarms in this condition also correlated significantly with the extent of cingulate activity.

These findings suggest the importance of effortful control to the child's emotional, cognitive, and social development. Evidence from twin studies suggests that effortful control is heritable. However, there is also evidence that higher level aspects of socialization depend on parental skills. Empathy is related to effortful control, with children high in effortful control showing greater empathy. Effortful control may support empathy by allowing the individual to attend to the thoughts and feelings of another without becoming overwhelmed by their own distress. Consistent with its influence on empathy, effortful control also appears to play a role in the development of conscience. The internalization of moral principles appears to be facilitated in fearful preschool-aged children, especially when their mothers use gentle discipline. In addition, internalized control is facilitated in children high in effortful control. Two separable control systems, one reactive (fear) and one self-regulative (effortful control) appear to regulate the development of conscience.

Wilson says "people expect from social sciences—anthropology, sociology, economics, and political science—the knowledge to understand and control their future." (p. 181) He argues that medical and social sciences both have important questions to answer, but that medicine appears to be making rapid progress based on a shared biological knowledge base while the social sciences progress less rapidly.

SOCIAL SCIENCES

Is there a prospect for resting the social sciences on a biological base? There have been two general approaches to the analysis of social science in biological terms. One is based on the general principles of evolution and sees sociobiology as providing the perspective for human behavior. A rather different approach is more similar
to neurobiology in seeking to explore the structure of the human brain and its growth and development as an important perspective for unifying sociology, economics, and political science. The two are not mutually exclusive. For example, neurobiology does not deny evolution as the organizing principle for biology, but builds on it by means of empirical methods to determine how brains are constituted. The cognitive neuroscience and human brain development perspective we have been describing extends the experimental approach of neurobiology to understanding the more complex emotional and cognitive regulation of humans. Wilson has summarized this combined role of culture and genetics as the development of epigenetic rules.

We will now consider what Wilson means by epigenetic rules and how they might serve to connect cognitive and affective neuroscience with the social sciences. Epigenetic rules refer to largely unconscious heuristics that are the results of culture and genetics and that operate to determine the way people filter or explore their environments. At the most elementary level are things like the restricted portions of the electromagnetic spectrum that influences our visual system. This selection is built in as part of the genetic basis of the human visual system. It limits the range of information to which we are sensitive. Even these limits can be overcome by inventions like radotelescopes, which extend our sensory capacity. Selection of information by attention involves more complex epigenetic rules that select information based on both an automatic and a voluntary basis. The tendency to automatically orient to visual motion is a good example. Because changes in many scenes are accompanied by real or apparent motion, we believe that we have knowledge of the full scene, whereas experimentation shows that we have information only about the restricted parts of the scene to which we attend.\textsuperscript{27} We can also use effortful control, which as we have seen combines genetic control and socialization by parents, to switch attention and thus process other aspects of the scene.

It is one thing to recognize that genetics and environment both contribute to epigenetic rules and another thing to develop models of how both support such rules. In recent years genes that contribute to higher level cognition such as the personality trait of sensation seeking\textsuperscript{28} or the ability to orient to sensory stimuli\textsuperscript{29,30} are beginning to be identified. We are a very long way from working out the complete genetics of how the selection of environmental events for conscious perception takes place and still further from understanding the joint effects of genetics and socialization. Nonetheless, the swift advance of knowledge in the natural sciences makes it reasonable to consider what the consequences of such knowledge might be for the unity of science.

Societies have different goals for socialization that are reflected in child-rearing methods. For example, the goals may be for independence, as in our culture, or they may emphasize the importance of group solidarity, as in Japan. As we have seen, these goals appear to result in different techniques of socialization. The consequences must be epigenetic rules that differ somewhat from culture to culture and govern sampling and labeling of the physical and social environment. Thus the development and deployment of attention serves as a mediator between the full complexity of the environment and those aspects that will serve as the basis of perceptions, actions, and memories (see, e.g., Ref. 27).

The ability to alter brain structure does not end in infancy. Elsewhere, we have described such mechanisms of plasticity as changes in attention, priming and devel-
opment of new epigenetic rules that produce changes in brain systems over many time scales. These mechanisms make it perfectly possible that socialization early in life or specific experiences, even in adulthood, might both lead to differential epigenetic rules expressed as patterns for sampling the environment.

Can an understanding of human brain development provide a basis for the social sciences? There are examples of how this might be accomplished. One effort to examine the consequences of socialization for economics and political science is in the work of David McClelland. In his book The Achieving Society, McClelland argued that the economic achievement of nations could be predicted from an understanding of the way those countries socialized their young to develop strong motivation for economic success. McClelland coded elementary school readers for examples of instructing the young in the importance of individual success and showed that the coding of need for achievement was correlated with a later rate of economic growth, as measured by such measures as gains in electrical power or number of patents awarded. McClelland coded aspects of the need for power from popular songs and ballads and suggested a relation between the regard for power compared to affiliation and the propensity of that society to conduct wars.

The original studies were conducted within a psychoanalytic framework in which early childhood exposure related to economic success or power was seen as primary in the development of particular motivations. Later, however, McClelland argued that a brief workshop in thinking in terms of achievement motivation was sufficient to influence the propensity to start businesses and other aspects of successful business activity. Nearly every aspect of McClelland's empirical effort to link economic growth to childhood experience has been subject to critiques. Most critical was the finding that reports of economic growth from more recent times were unrelated to his achievement motivation measure. In addition many argued that his methods for coding need achievement were problematic (see also Ref. 37). It is not our goal to argue for or against the success of McClelland's effort. Instead we want to indicate that his work suggests that, in principle, understanding how the human brain is organized by experience and how societies instruct their young could provide a link between natural and social science.

Simon distinguished between two kinds of science, natural and artificial. Natural science is concerned with "what is," whereas artificial science requires a specification of value: "what ought to be." Simon argues that artificial science involves producing the designs that are needed to achieve those values.

Wilson goes a step further than Simon in arguing that even values will be constrained by a deeper understanding of the human brain. Given the progress that has been made in understanding the neural basis of thoughts and feeling, why not relate them to values? Although Wilson's argument is persuasive, he may not take seriously enough the plasticity of value to environmental influences. It remains to be seen how greater understanding of general values will emerge from knowledge of human nature and socialization.

On the first reading of Consilience, its theme appears to be unlikely. Indeed, the sciences seem to be ever more fragmented, technical, and difficult to read and absorb. Where is the unity? As we began to prepare this paper, however, Wilson's goal of unifying social and natural science seemed more reasonable. There are already many signs that efforts of this type are under way. Political and economic psycholo-
ergy have joined social and evolutionary psychology in efforts to link areas of the social sciences to the cognition and emotion of individuals. Advances in genetics are even providing a new kind of empirical basis for our understanding of human history. It is now possible to use DNA in order to trace the migration of groups well before the dawn of recorded history and to study how languages evolved. History is arguably the most humanistic of the social sciences, and yet even here scientific developments are having an impact. These various linking fields should eventually produce empirically validated analyses of behavior in social settings that relate to the values a culture seeks to convey to its members. As we decode the circuits that control these activities and understand their joint genetic and environmental basis, new opportunities to support the connections between the epigenetic rules of individual cognition and emotion and the underlying biology are likely to emerge.

REFERENCES