Social Neuroscience of the Twenty-First Century

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Abstract

Social species are so characterized because they form organizations that extend beyond the individual. The goal of social neuroscience is to investigate the biological mechanisms that underlie these social structures, processes, and behaviors and the influences between social and neural structures and processes. Such an endeavor is challenging because it necessitates the integration of multiple levels. Mapping across systems and levels (from genome to social groups and cultures) requires interdisciplinary expertise, comparative studies, innovative methods, and integrative conceptual analysis.

Social Neuroscience

Social neuroscience brings together a broad variety of scientists, disciplines, and methodologies dedicated to investigating the biological mechanisms of social interaction, and thus represents an interdisciplinary scientific field that dives into the hard problem of the mutual influence of biology and social mechanisms (Cacioppo and Berntson, 1992, 2001) – a problem described by Frith and Wolpert (2004) as one of the major problems for the neurosciences to address in the twenty-first century. Based on the premise that all social behaviors are implemented biologically, this exciting and mature academic field seeks to understand (1) how biological systems implement social processes and behaviors; (2) how social structures that range from dyads, families, neighborhoods, and groups to cities, civilizations, and international alliances impact the brain and biology; and (3) how social and neural structures interact to produce these outcomes. In other words, social neuroscience investigates the interaction between social factors and the central nervous system, their manifestations, and potentially reciprocal influences across levels, from molecules to societies.

Social neuroscience and cognitive neuroscience both focus on the relationship between behavior and brain networks, but the basic perspective of each is distinct and complementary. Cognitive neuroscience views the human brain from the perspective of a solitary computing device capable of complex analyses and computations. Accordingly, attention, perception, memory, and language as an internal representational system are among the topics of interest. Social neuroscience, in contrast, views the human brain as a mobile, broadband computing device connected to others. Among the topics of interest are social learning, hierarchies, imitation, conformity, attraction, empathy, and language as a system for communication with others. According to the social brain hypothesis, the social complexities and demands of primate species have contributed to the rapid increase in neocortical connectivity and intelligence. Consistent with this hypothesis, the evolution of large and metabolically expensive brains in primates is more closely associated with social than ecological complexity (Dunbar and Shultz, 2007; Ott and Rogers, 2010), and the volume of some brain areas, such as the amygdala, correlate with the size and complexity of a person's social networks (Bickart et al., 2011).

Anecdotal evidence for the importance of both social and biological factors on outcomes such as health and well-being has existed for centuries, as the influence of social support on health was apparent even to the ancient Greeks. Hippocrates (460–370 BC) frequently prescribed 'association with friends' as a way to restore the body to its natural state of harmony and cure illness (Hothersall, 2004). In 1848, the case report of Phineas Gage, an American railroad construction foreman, documented his putative changes in personality and social behavior following damage to the ventromedial prefrontal cortex – changes that were sufficiently dramatic that his friends and acquaintances observed he was 'no longer Gage' (Damasio, 1996; Harlow, 1848; Macmillan, 2008).

Empirical evidence for the value of integrating social and biological levels of analysis accrued in animal (e.g., Harlow et al., 1965) and human (e.g., Cacioppo and Petty, 1979; Cacioppo et al., 1982) research, but the emphasis on disciplinary differentiation and specialization presented an active barrier to working across these levels. Most social scientists regarded animal and biological research as having little if anything to contribute to an understanding of suffering and problems that plagued industrialized societies (e.g., Allport, 1947; for a review, see Cacioppo, 2002). On the other hand, most biological scientists believed that social factors were irrelevant to understanding basic biological structures or functions and, even if relevant, were too complicated to be understood in the foreseeable future (e.g., Scott, 1991). It was in this context that Cacioppo and Berntson (1992) proposed the doctrine of multilevel analyses (see below) and the perspective of 'social neuroscience' as a multilevel, integrative field.

In research that followed, social species were found to fare poorly when forced to live solitary lives (Cacioppo et al., 2011). Humans, born to the longest period of abject dependency of any species and dependent on conspecifics across the lifespan to survive and prosper, do not fare well whether they are living solitary lives or whether they simply perceive that they live in isolation (e.g., Luo et al., 2012; Perissinotto et al., 2012). In an illustrative study, Caspi et al. (2006) found that perceived social isolation in adolescence and young adulthood predicted how many cardiovascular risk factors (e.g., body mass index, waist circumference, blood pressure, and cholesterol) were elevated in young adulthood, and that the number of developmental occasions (i.e., childhood, adolescence, and young adulthood) at which participants were lonely predicted the number of elevated risk factors in young adulthood. Perceived isolation has also been associated with the progression of Alzheimer's disease (Wilson et al., 2007), obesity (Lauder et al., 2006), increased vascular resistance (Cacioppo et al., 2002a), elevated blood pressure (Cacioppo et al., 2002a; Hawkley et al., 2006), increased hypothalamic pituitary adrenocortical activity (Adam et al., 2006; Steptoe et al., 2004), less salubrious sleep (Cacioppo et al., 2002b; Pressman et al., 2005), diminished immunity (Kiecolt-Glaser et al., 1984; Pressman et al., 2005), reduction in independent living (Russell et al., 1997; Tilvis et al., 2000), alcoholism (Akerlind and Hörnquist, 1992), depressive symptomatology (Cacioppo et al., 2006; Heikkinen and Kauppinen, 2004), suicidal ideation and behavior (Rudatsikira et al., 2007), and altered gene expression including the underexpression of genes bearing anti-inflammatory glucocorticoid response elements (GREs) and overexpression of genes bearing response elements for proinflammatory nuclear factor κB/Rel transcription factors (Cole et al., 2007, 2011). Nonhuman social species from fruit flies to apes also show similar deleterious biological effects of social isolation (e.g., Makinodan et al., 2012; Ruan and Wu, 2008).

The questions posed by the social neuroscience perspective, methodological, and quantitative developments, and the promise of more comprehensive theories inspired a new generation of scientists to pursue a more complex picture of behavior and biological functioning. By its 20th anniversary, social neuroscience had become an active field of research across the globe, fueled by the establishment of societies and journals to advance and foster scientific research, education, and clinical applications.

Doctrine of Multilevel Analyses

Social species are so characterized because they form organizations that extend beyond the individual. The goal of social neuroscience is to investigate the biological mechanisms that underlie these social structures, processes, and behaviors and the influences between social and neural structures and processes. Such an endeavor is challenging because it necessitates the integration of multiple levels. Mapping across systems and levels (from genome to social groups and cultures) requires interdisciplinary expertise, comparative studies, innovative methods, and integrative conceptual analysis (Cacioppo and Decety, 2011). Cacioppo and Berntson's (1992) doctrine of multilevel analyses emphasized the importance of using multilevel analyses to test hypotheses across their different levels of organization and specified three illustrative principles one can use to investigate key questions in social neuroscience along the continuum of organizational levels.

The principle of multiple determinism specifies that behaviors can have multiple antecedents within or across levels of organization. For instance, although immune response was once thought to reflect only physiological responses to pathogens or tissue damage, a more complete understanding of immunity has led to demonstrations of how a person's perceptions of his or her close personal relationships may impact inflammation and immunity (e.g., Kiecolt-Glaser et al., 2010). Psychosocial stress, operating through the brain's perception of the meaning of events, can also increase proinflammatory cytokine production in the absence of infection or injury. Animal research has revealed related findings in mice: exposure of mice to 2 weeks of isolation enhances tumor liver metastasis in part via its suppressive effect on the immune system of the host (Wu et al., 2000). One implication of this principle is that comprehensive theories of social phenomena require a consideration of multiple factors from various levels of organization – e.g., from the biological and individual's level to the social level (Cacioppo and Ortigue, 2011). A second implication is that many-to-many mappings between elements across proximal levels of organization become increasingly complex as the number of intervening levels of organization increases. Accordingly, the articulation of these mappings and mechanisms underlying a given multilevel observation may be simpler when working across proximal rather than distal levels of organization.

The principle of nonadditive determinism specifies that properties of the whole are not always readily predictable by the simple sum of the (initially recognized) properties of the parts (Cacioppo and Berntson, 1992). For instance, the behavior of nonhuman primates was examined following the administration of amphetamine or placebo (Haber and Barchas, 1983). No clear pattern emerged until each primate's position in the social hierarchy was considered. When this social factor was taken into account, amphetamines were found to increase dominant behavior in primates high in the social hierarchy and to increase submissive behavior in primates low in the social hierarchy. A strictly biological (or social) analysis, regardless of the sophistication of the measurement technology, may not have unraveled the orderly relationship that existed.

Finally, the principle of reciprocal determinism specifies that there can be mutual influences among biological and social factors in determining behavior (Cacioppo and Berntson, 1992). For example, maternal behavior can alter expression of genes through a process of DNA methylation, and genes altered in this way then can affect subsequent maternal behavior (Zhang and Meaney, 2010). One important implication is that comprehensive accounts of human behavior cannot be achieved if the biological, cognitive, or social levels of organization are considered unnecessary or irrelevant.

Social neuroscience also flourishes because of an increasing number of sophisticated methods and techniques that have been developed in the past two decades. This point is discussed next.

Techniques Used in Social Neuroscience

To investigate the mutual influence of biological and social mechanisms, social neuroscientists, ranging from physicists to psychologists, epidemiologists to neurologists, philosophers to neurobiologists, and entomologists to zoologists, have begun to work together in interdisciplinary scientific teams using animal models, patients studies, and research on healthy individuals. These interdisciplinary collaborations have capitalized on a variety of methods and techniques ranging from behavioral studies of implicit processes in lesion and split-brain patients to volumetric and neuroimaging studies across scales of neural organization in chimpanzees or healthy humans to cellular and molecular techniques in genetics and epigenetics. Even developed techniques such as meta-analyses and electroencephalography have seen upgrades that, for instance, permit investigations of the source and chrono-architecture of the neural substrates of social processes (e.g., He et al., 2009; Ito et al., 2004; Ortigue et al., 2010). Importantly, the development of experimental manipulations of neural processes in humans through, for instance, the use of transcranial magnetic stimulation and neurotransmitter agonists and antagonists has also helped determine the causal significance of specific neural regions in social cognition, emotion, and behavior. Finally, increases in computational speed and capacities are increasingly simplifying the problem of addressing questions across levels of organization that involve large datasets and/or previously computationally prohibitive simulations or analyses.

Prospects

Interdisciplinary collaborations are a cornerstone of social neuroscience endeavors. A decade ago, the field was characterized by some as correlating social and cognitive functions with regions of brain activation using functional neuroimaging. The field has always had a broader foundation, however, and social neuroscience is now recognized as drawing on research on animals and humans, with phenomena at multiple levels of organization measured and/or manipulated to go beyond the specification of association across levels to specify the mechanisms operating at and between each of the levels of organization pertinent to an association. The manifold disciplinary expertise for such multilevel investigations is increasingly beyond the reach of individual scholars, so interdisciplinary teams of scientists are increasingly common.

Furthermore, the twenty-first century presents its own unique array of questions. For instance, the development and accessibility of the Internet have transformed major aspects of the social environment, including how and where people study, meet, shop, and interact. Understanding how online interactions are similar to and different from face-to-face social interactions and how they might best be performed to benefit users across the lifespan is of particular relevance to a world growing more and more dependent upon the Internet and social networking sites for social interactions. And the century is still young. What the short history of social neuroscience has shown is that the number of social neuroscience papers that appeared in multidisciplinary science journals nearly doubled in the first decade of the field's existence and that the field has attracted some of the best and the brightest scientists across a wide range of scientific disciplines, with high rates of citation of social neuroscience articles in their dominant disciplinary journals (Matsuall et al., 2011). By bridging the gap between animal and human studies, social neuroscience has contributed to the understanding of the mechanisms by which the social world (and its disorders) impacts health, well-being, and longevity. The successes that social neuroscience has already met in its first two decades of existence suggest a promising future as it opens a critical avenue for a better understanding of the biology of connected minds. A multilevel integration of the social, biological, and cognitive factors known to determine behavior could also provide scientists and practitioners with new therapeutic interventions to address acute and chronic individual, communicative, and social disorders such as autism, psychopathy, and social phobias (e.g., see reviews by Cacioppo et al., 2007; Cacioppo and Ortigue, 2011). The road ahead is not only replete with conceptual challenges and methodological issues, but also promises exciting scientific discoveries. In short, the twenty-first century is an exciting time in which to be a social neuroscientist.

See also: Bayesian Models in Neuroscience; Cerebral Cortex; Cognitive Neuroscience; Electroencephalography: Basic Principles and Applications; Embodiment Theory; Emotion, Neural Basis of; Empathy: A Social Neuroscience Perspective; Functional Brain Imaging of Language Processes; Neural Foundation of Morality; Neuroeconomics; Neuroesthetics; Neuroethics: Ethics of Science and Science of Ethics; Neuromarketing; Neuroscience of Education; Placebo Effect; Psychopathy; Self and Brain.

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http://www.s4sn.org/ – Society for Social Neuroscience.

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