21 Evolutionary Cognitive Neuroscience

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Paying homage to the brain is an exercise in futility and understatement, and as such, it is perhaps best approached with humor by the likes of the American comedian Woody Allen who once rhetorically noted, "My brain? That's my second favorite organ." The complexity of the brain in the modern human is certain; there is no need to point out the brain's sophistication to those who even casually study it. At the risk of invoking a second attempt at humor, I can recall one student at the end of an arduous semester of physiological psychology claiming that, "The only thing that made sense in this class was learning on the first day that that the frontal lobes are in the front of the brain."

Each of the three fields invoked by the term evolutionary cognitive neuroscience (ECN) is sufficiently complex on its own. When these three fields are joined togetherin a single systems approach, it quickly becomes obvious that the complexity has expanded exponentially rather than arithmetically. The clear reward of a systems approach is the synergy resulting from melding different subdisciplines and the more integrated overview of what we wish to examine, namely, the organization, function, maintenance, and development of neural systems. The danger of such an approach lies in its very generality, and the consequent danger of losing sight of the contributions of the subdisciplines when studied in isolation. In effect, researchers risk becoming generalists in everything, specialists in nothing.

The tension between a systems approach and studying specifically defined subfields in isolation is reflected daily in discussions among researchers in ECN. We examine the brain and its related systems with the understanding that the brain is derived in part from modularized networks and regions that sometimes provide specific functions, and that these modules do not function in isolation, because they are influenced by both internal and external factors.[1] Similarly, evolution, cognition, and neuroscience are modules of academic study that, like the components of the nervous system, are also part of a larger system. In integrating these fields, we are aware that a meta-process is occurring. The evolution of this new field mirrors the system we study.

The benefit of understanding science from an ECN perspective is that we can consider simultaneously a significant number of variables within any given model, as would occur with a widening of the lens in any combination of fields. The cost is that (like one must exert significantly more energy creating, understanding, and elucidating those models. By allowing for a system that focuses on both proximate and ultimate mechanisms, we derive substantial benefits but incur significant costs as well. As the evolved human nervous system, we assume that the benefits outweigh the costs.

The work of Turhan Canli highlights the benefits of the ECN (Canli et al., 2005). The serotonin transporter gene (5-HTT, SLC6A4) is known to be involved in a number of psychological processes, including affective regulation (the short from of the allele is associated with depression, for example). It is also known that the amygdala modulates affective response, including regulation of prefrontal functioning. Using fMRI, Canli and colleagues found that the carriers of the short-form allele of the 5-HTT transporter gene showed dysfunctional activation in the amygdala during stimuli presentation. In particular, when negative words were presented, there was an increase in activation. However, such an increase in activity was not the whole story. Rather, what was apparently occurring was that carriers of the 5-HTT short-form allele actually demonstrated a blunted activation to neutral words. This lessening of response to neutral words made the activation during the negative word trials seem greater (Canli et al., 2005).

This study demonstrates a number of principles that appear indicative of the future of ECN First, these studies are inherently complex. Even an advanced student of fMRI would be hard-pressed to discover in this work that the increased activation in the amygdala may be due

1 One author (J.P.K.) has previously applied the analogy of the mobile to the brain. The actions of brain modules are dependent on each other, as well as on the function of the entire mobile. Further, the mobile is influenced by its environment, and if we measure any given position of the mobile, it is clearly state-dependent. Further, disruption in one region may influence distal modules, even if the influence is subtle. Although incomplete, this analogy provides a visual image for understanding the brain as an either/or (modular/system) unit.

to a blunted baseline response; only careful manipulation and analysis on the part of the researchers made this finding possible.[2] Second, there is inherent complexity in the interpretation of the research. In this case, examining group differences (based on 5-HTT allele variant) added a level of sophistication, because actual genotyping was performed. Canli's group has since added yet another layer to this line of research that involves an analysis of the components at the behavioral level. Such an increase in complexity is expected to lead to a more complete understanding of the system being examined. We can now speculate on the nature of affective responses from both a genetic and a neural perspective. As an example, we now have the tools to understand and appreciate that the evolution and expression of an affective dysfunction (e.g., depression) may be due in part to a blunted amygdala response that is not based on negative events but instead might be due to tonic reactivity.

Studies such as these point to a promising future for ECN. By combining the technologies, methodologies, and the theories of each field, researchers can achieve a deeper understanding of the question at hand. For example, the "Hobbits" of Flores (*Homo floresiensis*) have proved to be somewhat of a mystery. Briefly, the discovery of an apparently isolated group of *Homo* with brains similar in size to the common chimpanzee (*Pan troglodytes*; in terms of overall size, ca. 400 cm^3) came as a surprise, as did the fact that they may have used and made tools. They existed relatively recently (about 15,000 years ago) and have as yet only been found in a single region, an island in Indonesia. The implications of this finding at first appeared tremendous, as researchers had to rethink some common ideas about brain and body scaling in humans, its relation to behavior, and the cyclical role played by cortical expansion, brain size, and body size. However, some rejected the hypothesis that *H. floresiensis* represented a new species that was closely tied to our recent ancestor (*H. erectus*), and it has been alternatively suggested that *H. floresiensis* was a pathological human microcephalic. Employing the most advanced scanning technology, Falk et al. (2005) found it statistically unlikely that the brain of *H. floresiensis* was a miniaturized version of

2 The detection of such subtleties is inherent to the notion of expertise. Familiarity with a technique does provide significant advantages in being a critical consumer. For example, in fMRI, significant activations between conditions may be due to an increase in the firing of inhibitory neurons. Thus, although a researcher may conclude that a region has significantly more activation, she often avoids stating that such activation is due to the firings of excitatory neurons.

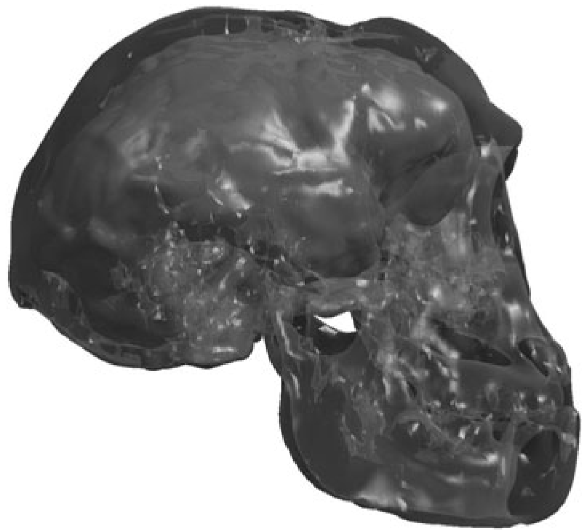

Figure 21.1
The virtual brain of *Homo floresiensis*. Because the brains *Homo floresiensis* are not preserved, a recreated brain was developed derived from skull fossils. *Image by Kirk Smith, Mallinckrodt Institute of Radiology; courtesy of Dean Falk. Used with permission.*

H. erectus or *sapiens*. Instead, it appeared that this species was related to *erectus* but was composed of specific biological traits that did not appear to suggest a "scaled-down" *erectus*. The analysis revealed a set of derived features and evidence that *H. floresiensis* was likely not microcephalic (Figure 21.1). The ability to create "virtual brains" using advanced technology allows us to advance our knowledge in ways previously thought to be impossible.

We envision similar discoveries in the future, and as each discovery occurs, we will probably have to rethink our ideas about ECN. Further, we suspect that each discovery will spur debate among colleagues, and that such debate will foster new discoveries. Although this is the hallmark of many fields, we look forward to ECN expanding as the disciplines within the field gain in popularity and importance.[3]

3 The political climate in the United States is not conducive to pursuing some of the ideas presented in this field. In particular, the "evolution" question has become, almost inconceivably, an educational issue in our schools. Although this book is not the appropriate forum for discussing the matter, the future of this

John Huglings Jackson (1835–1911) is one of the most interesting figures in the history of neuroscience. Like the nervous system he studied, his theories were complex and organized in a manner that make them difficult to condense. That he never produced a final treatise of his work is another point of comparison with neural systems, as there never was (or will be) a final product. More than a century ago, Jackson speculated about the evolution of the nervous system in terms of function and structure. He thought that the brain functioned as a sensorimotor assemblage, and that even at the highest levels of consciousness, there was sensorimotor integration. The brain was a structure that was divided into different regions with the "lowest, middle, and highest" each indicating different evolutionary levels (p. 41). Current views, particularly on scaling, often mirror his postulations that different networks reflect differences in evolution and that there is communication between regions that establishes higher-order cognitive abilities. It is this view that leads one down a usually fruitful but sometimes fatal path, as one is tempted to assume that there are general trends in brain complexity that lead to behavioral flexibilities *without exception*. Although our general principles are typically reliable, they are, in fact, incomplete, as Jackson seemingly assumed. As Lori Marino once asserted, "There is more than one way to evolve an intelligent species." This is an important idea to remember. As modularized as we may think the brain is, the evidence from the hemispherectomy literature leads us to understand that plasticity and adaptiveness are equally strong players, and one must consider these influences as well when considering cognition and evolution. Further, we must understand at some level the global function of the brain (Gray, Konig, Engel, & Singer, 1989) and come to terms with a significant number of issues, such as the problem of consciousness (Samsonovich & Ascoli, 2005), if we are to describe in any completeness the evolution of cognitive neural systems. Because general principles in ECN are difficult to establish and because those that exist have exceptions, there is always room for interpretation. That is why we assume a cautionary approach. Although allometric scaling applies well in primates, the correlation coefficients are never perfect, and we must be sensitive to error variance.

and many other fields depends on the education of students in the fundamentals of science and scientific theory. As we integrate these principles into classroom teaching and study, we must be sensitive to the role that the external environment plays inot only in teaching evolutionary principles but in applying them as well (a case in point is working with, stem cells).

This book has demonstrated that, as in all disciplines, the simplest questions may lead to complex answers. Genetic markings may help to provide an answer in some cases, new technology in others. Some of these questions are best addressed using animal models, and others can only be answered using a shovel, a pick axe, and a brush. By bringing together a truly diverse set of techniques, we can elaborate and expand on such "simple" questions "Are chimpanzees right-handed?" or "Does adding more neurons geometrically expand the number of neuronal connections?" The future of ECN lies in addressing questions such as these, but more important, in addressing the questions that are generated by this research As teachers and researchers, we are excited by these possibilities: our students and their students will assuredly answer questions that we never thought could even be addressed, much less resolved.[4]

From stem cells to neural implants, ECN will provide practical and clinical applications. The ideas generated by this field do not live only in academic tomes but instead can have impacts beyond scholarly debate. Further, the techniques invented and refined by researchers in ECN will continue to have a significant impact in medical, educational, and clinical arenas. Obvious examples include the development of neuroimaging techniques and psychoneuroimmunology advances. However, there are more subtle applications, such as taking an ultimate perspective in our approach to studying human behavior. For example, we can determine how the brain may have evolved in creating and maintaining a disorder such as autism (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004) and how even in nonautistic populations, such brain differences may be involved in maintaining current selection pressures (Kanazawa & Vandermassen, 2005).

The future of ECN is both promising and exciting. We hope that this book will inspire and encourage researchers in the field. We also hope that tomorrow's students will continue to pass on this field to their students, perhaps with modifications that are derived from competitive forces, such that ECN continues to evolve.

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4 The editors of this volume are all at institutions that value teaching and research equally, and as such, we are particularly sensitive to issues involving classroom teaching.

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