Epilogue to The Oxford Handbook of Cognitive Neuroscience—Cognitive Neuroscience: Where Are We Going?

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Abstract

This epilogue looks at themes and trends that hint at future developments in cognitive neuroscience. It first considers how affective neuroscience merged the study of neuroscience and emotion, how social neuroscience merged the study of neuroscience and social behavior, and how social cognitive neuroscience merged the study of cognitive neuroscience with social cognition. It also considers how the level of analysis of behavior/appraisal can be linked to psychological process and neural instantiation. It also addresses two topics that have not yet been approached from a cognitive neuroscience perspective, but seem ripe for near-term future progress, namely the study of the development across the lifespan of the various abilities described in the book, and the study of the functional organization of the frontal lobes and their contributions to behaviors (e.g., the ability to exert self-control). This epilogue also explores the multiple methods, both behavioral and neuroscientific, used in cognitive neuroscience, new ways of modeling relationships between levels of analysis, and the question of how to make cognitive neuroscience relevant to everyday life.

Keywords: cognitive neuroscience, emotion, social behavior, social cognition, functional organization, frontal lobes, behaviors, methods, analysis, neural instantiation

Themes and Trends

Here we discuss themes and trends that hint at possible future developments, focusing on those that may be more likely to occur in the relatively near term.

What's in a Name?

It is said that imitation is the sincerest form of flattery. Given the proliferation of new areas of research with names that seemingly mimic cognitive neuroscience, the original has reason to feel flattered.

Consider, for example, the development of three comparatively newer fields and the dates of their naming: social neuroscience (Cacioppo, 1994), affective neuroscience (Panksepp 1991), and social cognitive neuroscience (Ochsner & Lieberman, 2001). Although all three fields are undoubtedly the
products of unique combinations of influences (see, e.g., Cacioppo, 2002; Ochsner, 2007; Panksepp, 1998). They each followed in the footsteps of cog- nitive neuroscience. In cognitive neuroscience the study of cognitive abilities and neuroscience were merged, and in the process of doing so, the field has made considerable progress. In this fashion, affec- tive neuroscience combined the study of emotion with neuroscience; social neuroscience, the study of social behavior with neuroscience; and social cogni- tive neuroscience, the study of social cognition with cognitive neuroscience. All three of these fields have adopted the same kind of multilevel, multivariate methods and convergence approach embodied by cognitive neuro- science (as we discussed in the Introduction to this Handbook). In addition, each of these fields draws from and builds on, to differing degrees, the methods and models developed within what we can now call "cognitive" social neuroscience (see Vol. 1 of the Handbook). These new fields are siblings in a family of fields that have the similar, if not identical, research DNA.

It is for these reasons that Volume 2 of this Handbook has sections devoted to affect and emo- tion and to self and social cognition. The topics of the constituent chapters in these sections could easily appear in handbooks of affective or social or social cognitive neuroscience (and in some cases, they already have, see, e.g., Cacioppo & Berntson, 2004; Toddor et al., 2011). We included this mate- rial here because it represents the same core approach that guides research on the classic cognitive neuroscience in Volume 1 and in the latter half of Volume 2. Our one might wonder whether these related discipli- nes are on trajectories for scientific and popular impact similar to that of classic cognitive neuro- science. In the age of the Internet, one way of quantifying impact is simply to count the number of Google hits returned by a search for specific terms, in this case, "cognitive neuroscience," "affective neuro- science," and so on. The results of an April 2012 Google search for field names is shown in the tables at right. The top table compares cognitive neuroscience with two of its antecedent fields: cognitive psychology (Nisbett, 1967) and neuroscience. The bottom table compares the descendants of classic cognitive neuroscience that were named relatively recently, can be seen, cognitive psychology and neuroscience are the oldest fields and the ones with the most outcomes. By comparison, their descendant, cognitive neuroscience, which describes a neuro- field than of either of its ancestors, is doing quite well, and the third new fields of social, affective, and social cognitive neuroscience, each of which describes fields even newer than that of cognitive neuroscience, also are doing well, with combined hit counts totaling about one-third that of cognitive neuro- science, in spite of the fact that the youngest field is only about one-third of cognitive neuroscience's age.

How Do We Link Levels of Analysis?

A theme running throughout this Handbook concerns the different ways in which we can link the levels of analysis of behavior/experience, psychological process, and neural basis of the neuroscience (and in some cases, they already have, see, e.g., Cacioppo & Berntson, 2004; Toddor et al., 2011). We included this mate- rial here because it represents the same core approach that guides research on the classic cognitive neuroscience in Volume 1 and in the latter half of Volume 2. Our one might wonder whether these related discipli- nes are on trajectories for scientific and popular impact similar to that of classic cognitive neuro- science. In the age of the Internet, one way of quantifying impact is simply to count the number of Google hits returned by a search for specific terms, in this case, "cognitive neuroscience," "affective neuro- science," and so on. The results of an April 2012 Google search for field names is shown in the tables at right. The top table compares cognitive neuroscience with two of its antecedent fields: cognitive psychology (Nisbett, 1967) and neuroscience. The bottom table compares the descendants of classic cognitive neuroscience that were named relatively recently, can be seen, cognitive psychology and neuroscience are the oldest fields and the ones with the most outcomes. By comparison, their descendant, cognitive neuroscience, which describes a neuro- field than of either of its ancestors, is doing quite

in Volume 2, only recently has it become clear that more molecular mappings are possible. This is because for at least some of the Volume 2 topics, behavioral research before the rise of the cognitive neuroscience approach had not developed clearly articulated process models that specified explicitly how information is represented and processed to accomplish a particular task. This limitation was perhaps most evident for topics such as the self, some aspects of higher level social cognition such as mental state inference, and some aspects of emotion, including how emotions are generated and regulated. Twenty years ago, when functional neuroimaging burst on the scene, researchers had proposed few if any process models of these molecular phenomena. Hence, initial functional imaging and other types of neuroscience studies on these topics had more of a "let's induce an emotional state or evoke a behavior and see what happens" flavor, and often they did not attempt to test specific theories. This is not to fault these researchers; at the time, they did not have the advantage of decades of process- oriented behavioral research from cognitive psychology and vision research to help guide them (see, e.g., Ochsner & Barrett, 2001; Ochsner & Gross, 2005). Researchers had to develop process models on the fly.

However, times have changed. As attested by the chapters in the first two sections of Volume 2, the incorporation of brain data into research on the self, social perception, and emotion has been very use- ful in developing increasingly complex, "molecular" theories of the relationships between the behav- ior/experience, psychological process, and neural instantiation. Just as the study of memory moved beyond single-memory systems and toward multiple-system models (Schacter & Tulving, 1994), the study of the self, social cognition, and emotion has begun to move beyond simplistic notions that single brain regions (such as the medial prefrontal cortex or amygdala) are the seat of these abilities.

Looking Toward the Future

Without question, progress has been made. What might the current state of cognitive neuroscience research auger for the future of cognitive neuro- science research? Here we address this question in four ways.

New Topics

The most obvious idea that recurs in the chapters of this Handbook is that the cognitive neuroscience approach is a general-purpose scientific tool. This approach can be used to ask and answer ques- tions about any number of topics. Indeed, even within the broad scope of this two-volume set, we have not covered every topic already being fruit- fully addressed using the cognitive neuroscience approach.

That said, of the many topics that have not yet been approached from a cognitive neuroscience per- spective, do any appear particularly promising? Four such topics seem ripe for near-term forward progress. These topics run the gamut from the study of spe- cific brain systems to the study of lifespan develop- ment and differences in group or social network status, to forging links with the study of mental and physical health. The first topic is the study of the functional orga- nization of the frontal lobes and the contributions they make to behavior such as the ability to exert self-control. At first blush, this might seem like a topic that already has received a great deal of atten- tion. From one perspective, it has. Over the past few decades numerous labs have studied the relation- ship of the frontal lobes to behavior. From another perspective, however, not much progress has been made. What is missing are coherent process models that link specific behavior to specific subre- gions of prefrontal cortex. Notably, some chapters in this Handbook (e.g., those by Badre, Christoff, and Silvers et al.) attempt to do this within specific domains. But no general theory of prefrontal cortex has yet emerged that can link the myriad behaviors in which it is involved to specific and well-described processes that in turn are instantiated in specific portions of this evolutionarily newest portion of our brain.

The second topic is the study of the development across the lifespan of the various abilities described in the Handbook. Although some Handbook sections include chapters on development and aging, many do not—precisely because the cognitive neuroscience pic- ture of lifespan changes in many abilities has only just begun. Clearly, the development from prefrontal to parietal to limbic and then to frontal, social, and affective abilities is crucially important, as is the way in which these abilities change as we move from middle adulthood into older age (Casey et al., 2005; Johnson et al., 2012). The multilevel approach that characterizes the cognitive neuroscience approach holds promise of deepening our understanding of such phenom- ena. Toward this end, it is important to note that new journals devoted to some of these topics have
New Methods

How are we going to make progress on these questions and the countless others posed in the chapters of this Handbook? On the one hand, the field will undeniably continue to make good use of the multiple methods—both behavioral and neuroscientific—that have been in our tool kit for the past decades. As noted in the Introduction, certain empirical and conceptual advances were only made possible by technological advances, which enabled us to measure activity with dramatically new levels of spatial and temporal resolution. The advent of positron emission tomography, and later functional magnetic resonance imaging (20-30 years ago), were major breakthroughs.

On the other hand, these functional imaging techniques are still limited in terms of their spatial and temporal resolution, and the areas of the brain they allow researchers to focus on reflect the contributions of many thousands of neurons. Other techniques, such as magnetoencephalography and scalp electroencephalography, offer relatively good temporal resolution, but their spatial localization is relatively poor. Moreover, they are best suited to studying cortical rather than subcortical regions.

We could continue to bear the drum of the use of converging methods: What one technique can do, another can, and by triangulating across methods, better theories can be built and evaluated. But for the near term of game-changing methodological advances to be realized, even current technologies will need to undergo a transformation that enables them to combine spatial and temporal resolution in new ways or new techniques that have better characteristics will need to be invented.

New Ways of Modeling Relationships between Levels of Analysis

All this said, even the greatest of technological advances will not immediately be useful unless other systems are in place. For example, new variables like changes in disease, or social connection vs. isolation, can boost or diminish physical health. Such an effect would arise via interactions between the immune system and brain systems involved in emotion, social cognition, and other areas (Etcoff et al., 2012; Eisenberger & Cole, 2012). This is an area of future growth that we expect to be represented in this Handbook in the future.

Perception, emotion, and so on. We break these modularities into more molecular parts and characterize them in terms of their automatic or controlled operation, what the mental representations are relational, and so on. Surely, however, the computations performed by specific brain regions did not evolve to instantiate our folk-psychological ideas about how best to describe the processes underlying behavior.

One possible response to this concern is that the description of phenomena at multiple levels of analysis allows us to sidestep this problem. One could argue that at the highest level of description, it’s just fine to use folk-psychological terms to describe behavior and experience. After all, our goal is to map these terms—which prove extremely useful for everyday discourse about human behavior—onto precise descriptions of underlying neural circuitry by reference to a set of information processing mechanisms.

Unfortunately, however, many researchers do not rest assuredly understanding folk-psychological terms to describe behavior and experience, but also use such terms to describe information processing itself. In this case, process-level descriptions are not likely to map in a direct way onto neural mechanisms.

Marx (1983) suggested a solution to this problem: Rely on the language of computation to characterize information processing. The language of computation characterizes what computers do, and this language often can be applied to describe what brains do. But brains are demonstrably not digital computers, and thus it is not clear whether the technical vocabulary that evolved to characterize information processing in computers can in fact always be appropriately applied to brains. Back in the 1980s, many researchers hoped that connectionist models might provide an appropriate kind of computational specificity. More recently, computational models from the reinforcement learning and neuroeconomic literatures have been advanced as offering a new level of computational specificity. Although no existing approach has yet offered a computational language that is powerful enough to describe more than thin slices of human information processing, we believe that such a medium will be a key component of the cognitive neuroscience approach in the future.

Translation

In an era in which increasing numbers of researchers are applying for a static or shrinking pool of grant funding, some have come to focus on the question of how to use cognitive neuroscience to solve problems that arise in everyday life (and therefore address the concerns of funding agencies, which often are pragmatic and applied).

Research is often divided into two categories (somewhat artificially): "Foundational" research focuses on understanding phenomena for its own sake, whereas "translational" research focuses on using such understanding to solve a real-world problem. Taking cognitive neuroscience as an example, one could argue that the availability of abilities based on studies of healthy populations and applying them to understand and treat the bases of dysfunction in specific groups is one form of translational research. This will surely be an area of great future growth.

Already, a number of areas of psychiatric and substance abuse research have adopted a two-step translational research sequence (e.g., Bacht et al., 2004; Carret et al., 2009; Oechsler et al., 2008). The first step involves building a model of normal behavior, typically in healthy volunteers, of the cognitive neuroscience approach. The second step involves translating that model to a population of interest, and using its model to explain the underlying basis of the disorder or other deviation from the normal baseline—and this would be a crucial step in eventually developing effective treatments. This population could suffer from some type of clinically dysfunctional behavior, such as the four psychiatric groups described in Part 4 of Volume 2 of the Handbook. It could be an adolescent or older adult population, as described in a handful of chapters scattered across sections of the Handbook. Or—as was not covered in the Handbook, but might be in the future—it could be a vulnerable group for whom training in a specific type of cognitive, affective, or social skill would improve the quality of life.

The possibilities abound—and it would behoove researchers in cognitive neuroscience to capitalize on as many of them as possible. Not just for the pragmatic reason that they may be more likely to be funded but, more importantly, for the principled reason that it matters. It matters that the cognitive neuroscience of real-world, consequential behavior. Yes, we need to start by studying the ability to learn a list of words in the lab, and we need to understand the brain systems responsible for such relatively simple tasks. But then we need to move toward understanding, for example, how these brain systems do or do not function normally in a child raised in an impoverished household compared with a child afforded every advantage (Noble et al., 2007).
This is to be expected, given that it has existed only for a very short period of time. Indeed, the day for cognitive neuroscience is still young.

This is good news. Even though cognitive neuroscience is entering in its mid-30s, compared with other broad disciplines that were established hundreds of years ago, this isn’t even middle age. The hope, then, is that the field can continue to blossom and grow from its adolescence to full maturity—and make good on the promising returns it has produced so far.

References