CHILD DEVELOPMENT PERSPECTIVES

Culture and Neuroscience in Developmental Psychology: Contributions and Challenges

Joan G. Miller and Marcel Kinsbourne

New School for Social Research

ABSTRACT—***Even with the recent exponential growth in neuroscience research, relatively little attention has been given to cultural influences on brain maturation. In the case of psychological processes that are culturally variable, work in cultural developmental neuroscience is vital in determining the degree of generality that can be attributed to neuroscientific findings and in providing unique insight into how developmental neurobiology interacts with sociocultural parameters. The present article highlights contributions of cultural research in developmental neuroscience in identifying both common and culturally variable brain–behavior pathways and in understanding the nature and extent of brain plasticity. It also points to the importance of cultural work in highlighting the constitutive role of collective meanings in psychological phenomena and in preventing the drawing of unwarranted deterministic conclusions from neurological evidence.***

KEYWORDS—*cultural neuroscience; brain plasticity; developmental neuroscience; determinism; cultural psychology*

It is generally agreed that in the course of evolution, the enormous expansion of mental skills, and of their infrastructure in the brain, was largely occasioned by social factors essential for the survival and reproduction of early humans. Extensive regions in the cerebral hemispheres have even been characterized as the "social brain" (Dunbar, 1998), and a major role in the organization of the brain has been attributed to culture (Richardson & Boyd, 2005).

The brain sciences have recently experienced an unprecedented surge in technological advances and an exponential increase in the number of psychological studies incorporating neuroscience approaches (e.g., De Haan & Gunnar, 2009; Nelson, de Haan, & Thomas, 2006; Zelazo, Chandler, & Crone, 2010). Above all, the publication of functional-neuroimaging research has exploded since its origin in the early 1990s (Logothetis, 2008). The appeal of neuroscience is inspired, in part, by a vision of psychology as a natural science and by the "American attraction to material causes and the certainty they promise . . . " (Kagan, 2007, p. 367). Funding agencies increasingly favor neuroscience measures, and the media and policy makers give neuroscience research special respect. Weissberg, Keil, Goodstein, Rawson, and Gray (2008) have reported on the "seductive allure" of neuroscience explanations, which, even if they merely support an existing behavioral finding, greatly raise the profile of the topic in question.

This spectacular surge in cognitive neuroscience production and support offers unique opportunities for cultural work in developmental psychology. The wedding of cultural developmental work with cognitive neuroscience will yield a rich return of fundamental insights, particularly into this key issue: To what extent and how is the genetically programmed maturation of the cerebral hemispheres fine-tuned by their interaction with the human environment, especially caretakers, and how does this modulation of brain development differ depending on differing cultural practices?

Massive psychological evidence attests that intellectual and emotional development is profoundly affected by the quality of the social environment. Nowadays it is generally agreed that cognitive development derives from the interaction of biological and environmental factors. Indeed, "human nature . . . allows and requires environmental input for normal development" (Wexler,

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Correspondence concerning this article should be addressed to Joan G. Miller, Department of Psychology, New School for Social Research, 80 Fifth Avenue, New York, NY 10011; e-mail: millerj@newschool.edu.

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2006, p. 16). It follows that substantial variations in the cultural environment are likely to have a significant impact on how the brain is used and even how it develops. Much less is known, however, about the differences that cultural variations induce in the maturation of the various brain regions concerned with higher mental function, because developmental neuroscience research does not generally address the question of whether its findings are universally applicable or subject to cultural or other environmental variation.

In this article, we examine the role of cultural research in building a developmental psychology that more fully takes into account neurological evidence. We also consider the distinctive contributions made by such research in providing insight into how the maturation of the brain is affected by cultural practices. While the need to give greater attention to cultural considerations extends to all areas of psychology (e.g., Arnett, 2008), we attempt to show that taking the findings of cultural research into account in neuroscience has particular importance in counteracting any temptation either to draw unwarranted deterministic implications from neuroscience findings or to downplay the constitutive role of collective meanings in psychological phenomena.

CONTRIBUTIONS FROM ADOPTION OF NEUROSCIENCE METHODS IN CULTURAL RESEARCH

Cultural theorists are increasingly adopting neuroscience methods to examine the impact of culture on brain activity (e.g., Chiao & Ambady, 2007). Future use of structural and functional neuroimaging may prove useful in a number of ways, including revealing (a) structural differences at the population level between diverse cultural groups, if such differences exist; (b) distinct between-culture differences in patterns of utilization of brain circuitry corresponding to known between-culture behavioral differences; (c) unexpected differences in patterns of brain utilization that could point to as-yet-undiscovered behavioral differences; and (d) cultural differences in behavior that result from merely pragmatic adaptations and those in which the cultural differences have actually steered aspects of brain development in different directions. As we will now discuss, the adoption of neuroscience methods is already proving of value in providing (a) more sensitive response indices than can be obtained by cognitive or behavioral measures alone, (b) greater information about common and culturally variable pathways of brain–behavior development, and (c) deeper insights into brain plasticity.

Greater Sensitivity Than Achieved by Cognitive or Behavioral Indices Alone

Under certain circumstances, patterns of brain activity can be used to infer which cognitive process is being engaged (Poldrack, 2006) and even to adjudicate between alternative cognitive mechanisms (Henson, 2006). This methodological strategy can reveal developmental and cultural variation in brain responses even when no behavioral differences are observed. In a study by Noble, Wolmetz, Ochs, Farah, and McCandliss (2006), for example, children of different socioeconomic backgrounds who were matched on phonological awareness and reading accuracy were compared with respect to their patterns of brain activity while completing standardized tests of reading, receptive vocabulary, and phonological processing. Children of higher socioeconomic status (SES), compared to those of lower SES, showed greater increases in neural activity in the left fusiform and perisylvian regions—regions in which activity has been observed to be positively associated with phonological skill. Thus, the impact of differing social experiences on reading achievement, such as the quality of early schooling and the degree of print exposure in the home, may be even more profound than previously believed, in that such experiences may affect the distribution of neural activity even before any differences in reading ability are discernable.

Common and Culturally Variable Brain–Behavior Pathways

Another valuable direction for work in cultural neuroscience is to provide information about the role of contexts when making claims about brain–behavior relations or when using patterns of brain activation as convergent evidence on which to base theoretical assertions.

An effective example of this approach may be seen in research on the neural correlates of theory of mind understandings (Kobayashi, Glover, & Temple, 2006, 2007, 2008). Prior research had shown that Japanese children achieve theory of mind understandings at a later age than do Western children (Naito, 2003), focusing more on behavior and social rules, and less on mental-state information, compared to their Western counterparts (Naito & Koyama, 2006). In a recent study involving false-belief reasoning in U.S. and Japanese children, Kobayashi et al. (2007) found that whereas both groups showed similar activation of the ventromedial prefrontal cortex and precuneus, the U.S. children showed more activity in the right temporo-parietal junction (TPJ) and less activity in the bilateral inferior frontal gyrus (IFG) than did the Japanese children. Similarly, research conducted among U.S. and Japanese adults (Kobayashi et al., 2006) demonstrated that whereas neural correlates of theory of mind—that is, the medial prefrontal cortex and anterior cingulate cortex—were recruited by both cultural samples, the U.S. group showed more brain activity than did the Japanese group in eight different brain regions, including the left IFG and the right TPJ. The right TPJ is known to be involved in mental-state reasoning (Young, Camprodon, Hauser, Pascual-Leone, & Saxe, 2010), and the IFG has been linked to culturally variable ways of understanding emotional aspects of theory of mind (Moriguchi et al., 2005).

Furthermore, in a review of brain-imaging studies related to self-representation, Zhu and Han (2008) found that "Westerners employed the medial prefrontal cortex to represent only the individual self, whereas Chinese utilized the same brain area to rep-

resent both the self and close others" (p. 1799). If the case, such a pattern suggests that not only do the two cultural groups use different parts of the brain to achieve the same goal, they use the same part of the brain in different ways.

Another striking documentation of cross-cultural developmental variation in brain activity is found in work on executive functioning (EF; Lahat, Todd, Mahy, Lau, & Zelazo, 2010). Earlier research had shown that on tests of EF, Asian children tend to perform better than do North American or British children (e.g., Chen et al., 1998; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Lahat et al. (2010) studied evoked potentials during the EF performance of European Canadian and Chinese Canadian 5-year-olds matched in EF performance. In a Go/No-Go reaction-time task, the N2 waveform amplitude was greater over the left hemisphere on go trials and over the right hemisphere on no-go trials. Although the cultural groups did not differ on reaction-time performance, the Chinese Canadian children showed more activation in the dorsomedial, ventromedial, and ventrolateral prefrontal cortex. Also, their differential lateralization for go versus no-go trials was more pronounced, suggesting more effortful approach on the left and inhibition on the right. The authors conclude: "One simply cannot assume that neural function is the same in all samples of healthy children—cultural background and whatever may be correlated with cultural background, needs to be taken into consideration" (p. 8).

Insights Into Brain Plasticity

What can neuroscience contribute to a specifically developmental cultural psychology? By means of longitudinal studies, it could reveal the ontogenesis of cultural differences in cognition by tracking corresponding changes in the brain. It could further determine whether such adaptations by the brain to contrasting cultural environments become fixed or remain malleable in response to subsequent changes in the cultural environment. In short, it would address the fundamental question, Are differences in how the brain approaches various environmental issues simply pragmatic, or do they reflect early learning that involves long-lasting adaptation by the brain as it develops and matures?

It has been empirically documented that in perceiving and assessing information, East Asian cultural groups, compared to North American cultural groups, tend more fully to process contextual information, whereas North American cultural groups tend more fully to process object information (e.g., Nisbett & Masuda, 2003). Consistent with this pattern, Gutchess, Welsh, Boduroglu, and Park (2006) found that U.S. young adults show more engagement of object-processing areas in the ventral visual cortex than do Chinese young adults. With aging, this difference is magnified, with elderly Singaporeans displaying larger deficits in object-processing areas (the lateral occipital complex) than do elderly Americans (Chee et al., 2006). Interpreted as providing neurological support for a "use it or lose it" view of cognitive aging (Park & Gutchess, 2006, p. 107), work in this tradition highlights the potential for distinguishing the relative contributions of biological and experiential processes in human aging (Park & Huang, 2010).

ROLE OF CULTURAL RESEARCH IN ADDRESSING CHALLENGES FACING NEUROSCIENCE

Cross-cultural developmental neuroscience research, as noted, is making valuable contributions to an understanding of brain-behavior relationships. In addition, consideration of cultural variation in psychological functioning is important when drawing implications for psychology from neuroscience findings.

Avoiding Deterministic Interpretations

Deterministic interpretations may arise when investigators conclude that neural processes provide a biological grounding for developmental change without taking into account the extent to which the psychological phenomena under consideration are culturally variable. The need to avoid this type of conclusion can be seen in research on the development of self-understandings.

One of the most well documented cross-cultural findings is that the emphasis on traits in self-understanding is culturally variable. For example, compared with adults from individualistic cultures who tend to emphasize traits in their social attributions (e.g., "she is a friendly person," "he is talkative"), adults from collectivist cultures tend to place greater emphasis on contextual considerations (e.g., "people often come to visit her," "he is a leader in the community"; Bond & Cheung, 1983; Morris & Peng, 1994; Shweder & Bourne, 1984). Moreover, children from these contrasting cultural groups tend to show an age-related increase in their respective emphasis on traits or contextual considerations (e.g., Miller, 1984, 1987; Wang, 2001, 2004). This research adds a new dimension to the understanding of the processes underlying developmental change in social cognition, indicating that such change cannot be fully explained in terms of universal cognitive and experiential processes but, rather, results, in part, from children's adoption of their culture's views of self.

In a creative research program conducted among samples of Caucasian adolescents and adults, Pfeifer, Lieberman, and Dapretto (2007) and Pfeifer et al. (2009) uncovered various neurological correlates associated with age changes in social understandings. During self-knowledge retrieval, the adolescents showed greater activation in the medial prefrontal cortex (MPFC) than did the adults. They also showed different levels of activation in various regions of the medial posterior parietal cortex (MPPC), displaying more activity in the anterior precuneus and posterior cingulate, and less activity in the posterior precuneus, compared to the adults. Pfeifer and her colleagues view this pattern of brain activity among young adolescents as related to their tendencies to be undergoing a transition in self-knowledge in which they come increasingly to define the self in terms of traits that they abstract from instances of behavior. In turn, the researchers consider the relatively lesser activation of the MPFC and MPPC among adults as reflecting that evaluative self-knowledge has become more

automatized and thus involves a different neural system that includes the amygdala and nucleus accumbens. They interpret these findings as indicating that the MPFC and MPPC are relatively more attuned to processing information about the self as perceived by others and thus become less involved as a more decontextualized view of self emerges in adulthood. They see their interpretation as being consistent with processes of cortical maturation, namely, the peaks in gray-matter density for the MPFC, MPPC, the dorsal MPFC, and TPJ that occur between the ages of 9 and 13, followed by a decrease during adolescence and eventual stability during adulthood (Shaw et al., 2008).

Pfeifer and her colleagues (2009) refer to the potential value of cross-cultural studies, and indeed, their neurologically based developmental model (Pfeifer, Dapretto, & Lieberman, 2010) is inconclusive without taking cultural variation into account. To support the model's claim that the degree of maturity of the brain determines aspects of self-knowledge, it is critical to assess whether the model predicts developmental trends among populations in which past research has shown that the trajectory of self-understandings is strikingly different from that of the populations on which the model is based. Extrapolating from the model, it would be predicted that the aforementioned age-related reduction of MPFC and MPPC activation observed among U.S. adults would be less marked in the case of collectivist populations, given that in these populations, the importance of context-specific understandings of self and other attributions continues into adulthood. If the circuitry were found, in fact, to be different, this would illustrate the influence of cultural variation on the pattern of brain activity and thus suggest that the developmental shifts in brain processes identified by Pfeifer and her colleagues are not universal but, rather, are culturally variable. However, if the circuitry were found to operate in the same way across cultures, this would challenge the claims made in the model that particular forms of self-knowledge are determined by brain circuitry.

Universal processes of cortical maturation involving changes in gray-matter density might be recruited in the service of culturally variable forms of social understanding and thus not be associated uniquely with an emphasis on trait understandings. Brain regions such as those nominated above are very broadly defined and unlikely to be dedicated to a single purpose or a single form of processing (e.g., Duncan & Owen, 2000). Importantly, Pfeifer and her colleagues acknowledge that it is unclear whether the reduced activity in the medial fronto-parietal network results from routinization of self-referential processes or from the adoption of a form of decontextualized self-knowledge that may possibly be culturally variable (Pfeifer et al., 2009). Yet they make no reference to this qualification in later forwarding their developmental model (Pfeifer et al., 2010). Rather, they frame their neurologically based developmental model exclusively in terms of assumed universal cognitive and experiential factors and portray the model as capturing developmental pathways that occur among all biologically "typical" or "normal" populations. However, one should avoid arriving at a universal account of culturally variable developmental phenomena on the basis of neurological evidence unless the cultural variability has been taken into account.

Cross-cultural evidence may also moderate claims about biological constraints on environmental influences. For example, findings about the relative immaturity of adolescent brain development (e.g., Blakemore, 2008) have been interpreted as implying that there are limits in the role that environmental factors can play in reducing adolescents' propensities for risk seeking. Taking this view, Steinberg draws implications for social policy:

> The research . . . suggests that heightened risk taking during adolescence is likely to be normative, biologically driven, and *to some extent inevitable*. There is probably very *little that can* or ought to *be done to either attenuate or delay the shift in reward sensitivity that takes place at puberty*. (Steinberg, 2007, p. 58, emphasis added)

However, Steinberg's (2007) pessimistic conclusion about the limits of environmental influences on adolescents' risk proneness is based primarily on studies that have been conducted in modern Western settings, yet it is phrased in an unqualified way as applying to adolescents in general. Yet cross-cultural evidence indicates that the incidence of adolescent risk taking tends to be less in certain cultural settings in which normative expectations related to adolescence differ from those characteristic of modern Western cultures (e.g., Cheung & Cheung, 2006; Schmid et al., 2003). Thus, while the brain may be programmed to mature slowly over the period from the onset of puberty through early adulthood and to be associated with some increase in risk proneness, the conclusion that brain immaturity sets a limit on environmental influences on adolescents' psychological propensities for risk taking must be considered premature in that it does not account for the marked cultural variation in adolescent outcomes (Brown, Larson, & Saraswathi, 2002). How the brain is structured may limit the individual's potential, but how that potential is realized in varying cultural contexts is another matter altogether.

Downplaying of Meaning

An additional concern raised in regard to interpretations made of certain neurological research is a tendency to downplay the social construction of meaning and treat psychological concepts as observer independent. In this regard, critics have charged that recent neuroscience research on morality (e.g., Casebeer, 2003; Greene & Haidt, 2002) neglects the role of normativity, interpretation, and social context in constituting morality (Carpendale, Sokol, & Muller, 2009).

Highlighting the importance of attending to cultural meanings, Barrett (2009) observes that the role of collective processes, such as modes of discourse and institutional practices, in the creation and sustaining of meaning applies not only to prescriptive psychological phenomena, such as morality, but more generally to all higher order psychological processes. As Barrett argues:

> The complex psychological categories we refer to as *thoughts*, *memories*, *emotions*, and *beliefs*, or *automatic processing*, *controlled processing*, or the *self*, and so on, are observer dependent. . . . If emotion, cognition, memory, the self, and so on, exist—they are real by virtue of the fact that everyone within a culture experiences them, talks about them, uses them as reasons for actions—then they cannot be discarded or ontologically reduced to (or merely redefined as nothing but) neurons firing. (Barrett, 2009, pp. 328–330)

Regardless of the comment about reduction to "neurons firing," which misses the point that all of human thought and endeavor is, indeed, "neurons firing," this observation implies that explaining psychological phenomena requires consideration of cultural meaning and practices, and that the scope of cultural variability transcends obvious conceptual differences between cultures to encompass all the main categories of mental activity that are of interest to psychologists and cognitive neuroscientists. This observation resonates with the core theoretical insight of cultural psychology that "accords culture a central role in the constitution of mind" (Cole, 1990, p. 283)—that is, the idea that culture, as both "constraint and tool of human action," is essential in the emergence of all higher order psychological phenomena (p. 282; see also Cole, 1996; Geertz, 1973; Shweder, 1990). As Wertsch (1995) observes, with the exception of certain involuntary responses or of certain responses at early stages of ontogenesis, "it is virtually impossible for us to act in a way that is not socioculturally situated" (p. 90). This insight also points to a central role for cultural research in conceptually broadening the constructs and theories developed to understand psychological phenomena (Miller, 1999, 2004).

Future Directions

Neuroscience research has developed to the point that its conceptual and methodological agendas are undergoing constructive reappraisal, even as their potential value and promise are more fully appreciated. While crediting neuroimaging for its contributions to the understanding of functional localization, the physical properties of different brain structures, and neuropsychology, Logothetis (2008) also comments on its inherent limitations. Taking issue with the claim that "with MRI we can read minds better than with direct tests of behavior itself," he points out categorically that "FMRI is not and never will be a mind reader" (p. 869). Yet mind reading is precisely a focus of work in cultural psychology—determining how different cultures favor different ways of thinking and strategies for viewing information under objectively identical circumstances. These distinctions offer neuroscience attractive cases for study regarding the underlying brain processes, even though they may not add theoretical weight to what has already been discovered at the behavioral level of analysis.

How informative is inference in the opposite direction—that is, from cultural variation in brain processes to cultural variation in behavior? Can the neuroimaging of cultural differences in brain function lead to novel insights into the manner in which thought processes differ, using paradigms that start with the neuroimage, and then predict the co-occurring behavior, as outlined by Henson (2006) and Poldrack (2006)? Ambady and Bharucha (2009) would begin with "cultural mapping" of differences in activation maps and then search for the behavioral sources of the differences that they discover in their participants' brains ("source analysis"). However, generating a viable theory of cultural differences by looking at activation maps is forbidding, unless one has a general theory of what to look for, the difficulty in replicating outcomes aside (e.g., Vul, Harris, Winkelman, & Pashler, 2009). For example, Chiao et al. (2009) aspire "to predict how individualistic or collectivist a person is across cultures" (p. 2813) by scrutinizing the pattern of activation in the MPFC, yet to try to achieve this they have to draw on past findings of robust cross-cultural differences in attribution that have been linked to patterns of brain activation and found in past research to be related to self-construal. This approach is circular and, while it may represent an impressive feat of neuroscience, does not further enrich understanding of cultural variation.

It makes little sense to pit neuroscience research against research that utilizes only conventional psychological methodologies. They are complementary, not alternative, domains of research. For a start, their range of potential discovery overlaps but is not the same. There are many effects, such as everyday social interaction or the impact of real-life experiences on developmental outcomes (e.g., Bronfenbrenner, 1977), that cannot be readily studied using currently available neuroscience approaches. More central to cultural neuroscience is the benefit and great potential for discovery of informing neuroscience research with culturally sensitive variables.

Efforts in this direction would lead to a conceptual broadening of research agendas. As noted, much of the agenda of contemporary cultural work in developmental neuroscience has been directed toward identifying the neural correlates of known psychological effects. However, beyond documenting correspondence of effects across psychological and brain levels of analysis to provide confirmatory evidence for existing theoretical claims, it is important to pursue agendas that identify previously unrecognized psychological phenomena—creative research agendas that depend crucially on conventional psychological methodologies.

In terms of promising directions, neuroscience methods in studies involving forward inference may provide more sensitive response measures than can be obtained using conventional psychological approaches (e.g., Nelson, Moulson, & Richmond, 2006). As a strategy that involves assessing whether performance on related behavioral tasks is associated with contrasting brain activation patterns, forward inference provides a means of tapping mental processes that are not expressed in overt behavior (Marshall, 2009).[1] Caccioppo, Berntson, and Nusbaum (2008,

[1] "Forward inference" contrasts with "reverse inference," a strategy that involves inferring the localization of mental activity in particular brain regions on the basis of associations observed between patterns of brain activation and specific mental outcomes (Henson, 2006; Marshall, 2009).

p. 66) foresee "a new era of psychological theory in which what constitute elemental functional processes (functional elements) are tied to specific neural mechanisms (structural elements) and in which the properties of interrelated networks of areas may indeed be more than the sum of the parts." Berman, Jonides, and Nee (2006, p. 160) assert that "the true value of neuroimaging data comes in concert with sophisticated behavioral data collected from normal and brain-injured participants." We would include participants from different cultures in that listing, where there is evidence of cultural differences.

These are, after all, early days in neuroimaging, with many efforts being substantially methodological, aimed at showing that one can, in fact, generate cortical maps that have somewhat reliable relations to the mental state of the individual. Overenthusiastic extrapolations apart, the real challenge is yet to come: How does culture take root in the developing brain, and once it has, how can it be dislodged, if at all? As noted by Wexler (2006, p. 13), "Our biology is social in such a fundamental and thorough manner that to speak of a relation between the two suggests an unwarranted distinction." The genetic instructions to the developing brain express potential, and influences from the environment determine which of the potentials will be realized. But which dimensions of the cultural environment exert this influence, and by what means? Also, as plasticity wanes in the matured brain, how much culturally specific thinking, attending, and acting can be reversed and supplanted, and again how? In his essay on culture and the brain, Wexler foreshadows the cultural developmental neuroscience of the future. A neuroscience that is sensitive to both culture and context and that retains a view of the person as actively contributing meanings to experience (e.g., Bruner, 1973, 1990) will convey great benefit to developmental psychology.

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