CHAPTER

1

Cultural Neuroscience of the Developing Brain in Childhood

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INTRODUCTION

From infancy to adolescence, social contact with parental caregivers, kin, and peers provide the earliest means of cultural transmission. Learning how to perceive, interpret, and respond to people and objects in the environment, infant brains acquire preferences and knowledge of cultural norms, practices, and later beliefs, attitudes, and values from caregivers that independently and interactively shape subsequent neurobiological maturation along with genes. By childhood, the conscious mind develops a continuous subjective experience that is stored as autobiographical memory. This emergence of conscious experience in the form of autobiographical memory represents a pivotal change in the ability to store and transmit cultural information from one's self to another during development.

How does culture shape the mind and brain in childhood? How does learning to acquire and transmit culture occur developmentally? These questions represent some of the most compelling research directions in cultural neuroscience. The goal of this chapter is to provide an overview of research in cultural neuroscience and to introduce a cultural neuroscience framework of the developing brain that provides insight into the promotion of healthy child development.

THEORIES IN CULTURAL NEUROSCIENCE OF THE DEVELOPING BRAIN

Research in cultural neuroscience addresses the origins of human diversity. Where does human diversity come from? Dynamic biocultural constructivism theory posits that culture and biology interact along three primary time scales: phylogeny, ontogeny, and situation (Li, 2003) and a series of interactive processes with developmental plasticity across distinct levels shapes cognitive and behavioral development. Cultural neuroscience is an interdisciplinary field that integrates theory and methods from anthropology, cultural psychology, neuroscience, and genetics to understand diversity in human behavior across multiple time scales (Chiao & Ambady, 2007; Chiao, Cheon, Pornpattanangkul, Mrazek, & Blizinsky, 2013). (See Figure 1.1)

There are at least three mechanisms by which the human brain acquires culture throughout development: experience-dependent neural plasticity, mirror neurons, and culture–gene coevolution. *Behavior* or *experience-dependent neural plasticity* refers to cortical organization that

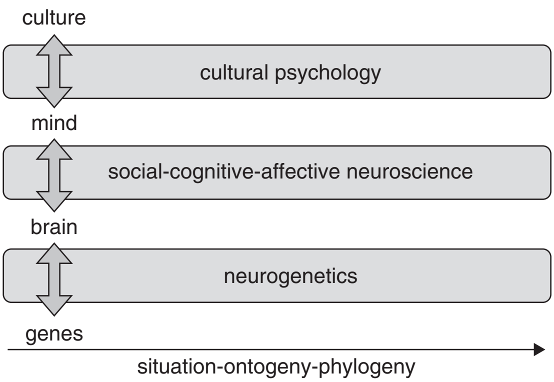

Figure 1.1 The cultural neuroscience framework.
Source: Adapted from Chiao & Ambady, 2007.

is affected by developmental, experiential, and cultural influences. Several structural features of the brain prune and grow as a function of distinct developmental stages. Functional changes in the developing brain also occur in response to neuronal maturation. The term *mirror neurons* refers to brain regions within the premotor and motor cortex that contain neurons that respond when both observing and performing an action (Iacoboni, 2009; Losin, Iacoboni, Martin, & Dapretto, 2012). Activity within mirror neurons is present during infancy during viewing of goal-directed movement (Del Giudice, Manera, & Keyers, 2009; Nyström, 2008). By adulthood, mirror neurons demonstrate a preferential response for reinforced goal-directed movement. For instance, ballet dancers will respond not only when performing a pirourette but also when observing another perform a pirourette; furthermore, mirror neuron response is heightened when experts observe and perform actions within their expertise (e.g., ballet dancers observing ballet) (Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). Mirror neurons form the biological basis of action-based cultural learning and play an important early role in the acquisition of cultural competence.

The term *culture–gene coevolutionary theory* refers to the notion that cultural and genetic selection operate in tandem to shape the human mind, brain, and behavior (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981). Darwinian natural selection asserts that adaptive behavior results from environmental or ecological pressures on genomes. Coevolutionary theory asserts that adaptive behavior is the result of both cultural and genetic selection in response to environmental or ecological pressures. One example of culture–gene coevolution is morality. Recent cultural neuroscience evidence across nations shows that allelic variation of the serotonin transporter gene (5-HTTLPR) predicts moral justification due in part to cultural selection (Mrazek, Chiao, Blizinsky, Lun, & Gelfand, 2013). More specifically, nations with greater frequency of short-allele carriers of the 5-HTTLPR are more likely to demonstrate low tolerance for morally deviant behavior due to increased preference for cultural tightness. Another example of culture–gene coevolution is mental health (Chiao & Blizinsky, 2010; Figure 1.2).

Cross-national evidence shows that allelic variation of the 5-HTTLPR predicts prevalence of anxiety and mood disorders in part due to cultural

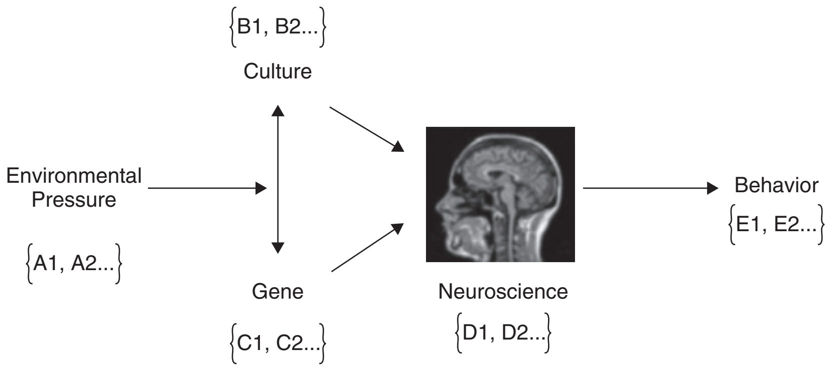

Figure 1.2 Model of cultural neuroscience.
Source: Chiao & Immordino-Yang, 2013.

collectivism. Nations with greater frequency of short-allele carriers of the 5-HTTLPR show lower prevalence of anxiety and mood disorders due partially to increased cultural collectivism. These examples of culture–gene coevolution indicate that both cultural and genetic selection shape cognitive and neural architecture underlying morality and mental health.

METHODS IN CULTURAL NEUROSCIENCE RESEARCH OF THE DEVELOPING BRAIN

While recent evidence suggests distinct putative mechanisms for cultural influences on the mind and brain, less well understood are the specific developmental mechanisms by which culture influences behavior. The development of social and emotional behavior that is adaptive to one's cultural context depends on several biological factors, such as neuronal development and epigenetic expression. Understanding how culture affects social development may involve a number distinct kinds of empirical methods, including behavioral, neural, and genetic measures. Because *social development* refers to changes in social and emotional capacities across the life span, biological changes, such as neuronal growth or epigenetic expression, may provide foundational mechanisms or catalysts for triggering age-appropriate social and emotional maturation. Cultural changes, such as immigration, acculturation, or sociopolitical shifts, may also affect the development of social and emotional capacities. Given the multilevel influences on social development, methods from distinct levels of analysis may provide the necessary tools to identify age-related causal mechanisms of adaptive social and emotional behavior. An overview of methodological approaches to examining cultural influences on the developing brain during childhood is presented next.

Cultural Psychology

Cultural psychology examines how culture shapes human behavior. One branch of cultural psychology investigates how environmental and ecological factors, including natural disasters, population density, and food deprivation, shape cultural processes. There are several primary cultural systems that characterize a majority of the world's regions, including individualism-collectivism or independent-interdependence, tightness-looseness, power distance, social dominance orientation, racial identification, long-term–short-term orientation, and masculinity-femininity (Gelfand et al., 2011; Hofstede, 2001; Markus & Kitayama, 1991). Individualism and collectivism, or independence and interdependence, comprises a primary cultural system that shapes the human self. Individualistic or independent cultures emphasize a notion of self that is distinct and unique from others. The ability to express one's self and to define one's self autonomously from social roles and relations comprises a fundamental way that culture shapes the self. By contrast, collectivistic or interdependent cultures highlight the importance of the self as defined in relation to others, including social roles and relationships. The ability to conform one's self to others and to define one's self as dependent or embedded in social roles and relations constitutes another foundational way that culture shapes the self. Cultural psychologists have shown that an environment factor, pathogen prevalence, is associated with individualism and collectivism such that collectivistic cultures may have developed to defend against the presence of infectious diseases (Fincher et al., 2008).

Tightness-looseness refers to a cultural dimension that reflects the degree of tolerance or adherence to social norms. Tight cultures are more likely to exhibit situational constraint, such that appropriate behavior is constrained by daily situations. People living in tight cultures may prefer cautious and dutiful behavior, greater self-regulation, greater self-monitoring, and greater need for structure (Gelfand et al., 2011;

Mrazek et al., 2013); by contrast, people living in loose cultures may prefer unique and autonomous behavior, greater self-expression, greater ingenuity, and greater need for freedom. Cultural psychologists have shown that ecological threats, including population density, food deprivation, disease, and susceptibility to natural disasters and territorial conflicts, account for some of the variation and have led to geographic variation in tight and loose cultural norms. Regions that are affected by ecological threats are more likely to adhere to tight compared to loose cultural norms.

Power distance refers to the extent to which a geographic regions expects societal inequality. Nations that are high in power distance are more likely to accept and expect a hierarchical social order in which everybody occupies an expected social role. Nations with low power distance are more likely to expect an equal distribution of social power and to expect explanations for social inequality. Relatedly, *social dominance orientation* refers to the extent to which a person expects societal inequality among social groups (Pratto, Sidanius, Stallworth, & Malle, 1994). People high in social dominance orientation are more likely to seek hierarchical professional roles, compared to people low in social dominance orientation who are more likely to seek hierarchy-attenuating social roles.

Racial identification is the degree to which a person identifies with members of their social group, and often refers to members of a social minority. *Long-term and short-term orientation*s refer to the extent to which a nation emphasizes the past, present, and future. Nations with low long-term orientation prefer to maintain cultural traditions and norms rather than societal or cultural change; by contrast, nations with short-term orientation are more likely to seek efforts to modernize and change society toward the future. Masculinity is a cultural dimension that emphasizes social preferences typically associated with stereotypical male attributes, including achievement, heroism, assertiveness, and material success. Femininity is a cultural dimension that emphasizes stereotypical female attributes, including cooperation, caring, and quality of life. These cultural dimensions comprise primary systems of societal values that shape how groups and institutions create and maintain social norms of human behavior. The degree of adherence to a given cultural dimension is measurable with behavioral surveys that assess attitudes, values, and beliefs about a given culture. One's cultural identity may affect how a person responds when completing a behavioral survey; nevertheless, response biases within culture tend to be consistent and predictable, allowing for reliable interpretation of behavioral survey data and individual adherence to distinct cultural systems (Johnson, Kulesa, Cho, & Shavitt, 2005). Implicit measures of cultural attitudes may also provide important ways in which individual adherence to distinct cultural systems is observed (Brannon & Walton, 2013).

Understanding age-related changes in cultural values may be limited depending on the type of cultural method. For instance, preverbal infants and young children may not be able to reliably provide accurate responses of their adherence to cultural norms; a number of developmental limitations, from self-awareness and autobiographical memory to motor response, may impede one's ability to understand infant and child cultural values. However, safe and age-appropriate behavioral measures, such as looking time, grasping, tongue protrusion, and crawling, may provide indirect ways to infer the cultural attitudes or normative preferences of infants and children. In older age, elderly persons may have similar difficulty in completing self-report behavioral surveys, due to age-expected cognitive decline. Changes in cognitive ability, such as memory and motor response, may provide a challenge to measurement of cultural values and attitudes of elderly persons. Nevertheless, due to the stability of social and emotional responses in older age, indirect measures, such as implicit attitude tests, may provide additional methods for understanding the culture of elderly persons.

The development of social and emotional behavior occurs within cultural systems and may be influenced by change in one's experience to distinct cultural systems. Processes of cultural change include immigration, acculturation, and sociopolitical shifts. *Immigration* refers to when a person moves from heritage to host culture and the changes in attitudes toward the heritage and host culture as a function of changes in geographic and national boundaries (Berry, 1997). *Acculturation* refers to the processes by which a person negotiates behaviors, attitudes, and beliefs between heritage and host cultures (Berry, 1997; Telzer, 2010). Possessing a multicultural identity may involve "frame switching" between heritage and host culture mind-sets (Hong, Morris, Chiu, & Benet-Martinez, 2000). Cultural priming is an empirical method that allows the researcher to cause a shift in cultural frames within a person with a multicultural identity by changing the person's exposure to cues in the social environment, for brief periods of time ranging from milliseconds to minutes. Both cultural self-report surveys and cultural priming methods have been shown to reliably modulate neural responses associated with social (Chiao et al., 2009; Harada, Li, & Chiao, 2010) and emotional processing in young adults (Cheon et al., 2013; Mathur, Harada, & Chiao, 2012).

Developmental Human Neuroscience

Several neuroscience methods may facilitate the study of culture in the developing brain. *Functional neuroimaging* (*fMRI*) refers to noninvasive means of indirectly measuring neural activity with spatial resolution. One branch of fMRI important to social development is fetal neuroimaging. *Fetal neuroimaging* refers to measurement of fetal brain structure and function, such as the functional connectivity between brain regions that grow in utero (Anderson & Thomason, 2013). Brain regions that have been identified as important in social and emotional development, including the medial prefrontal cortex (MPFC), anterior cingulate, motor cortex, and superior temporal gyrus, are active from as early as 25 to 29 weeks in utero, indicating functional connectivity within social and emotional neural circuitry that begins to develop prebirth (Swartz, Carrasco, Wiggins, Thomason, & Monk, 2014). Developmental neuroimaging aims to examine the neural basis of age-related changes of behavior postbirth (Luna, Velanova, & Geier, 2010). One way to identify the neural basis of age-related changes of behavior is to focus on specific developmental periods where known age-related behavioral changes occur. For instance, infancy is a developmental period characterized by acquisition of fundamental perceptual abilities that contribute to social and emotional cognition, such as social and emotional perception. Infant face and voice perception are one of the first social abilities that newborns acquire, and neural regions associated with visual processing of complex images are recruited to detect social cues (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002; Tzourio-Mazoyer et al., 2002).

By early childhood, social and emotional cognition is sophisticated, as young children learn to detect deception, to feel what others feel, to understand their own social world and emotional states, and to interact with close others and peers. Adolescence is a developmental period of unique biological and social maturation, the gradual transition between childhood and adulthood lasting approximately 5 to 9 years from ages 12 to 19 (Luna et al., 2010). The capacity to regulate emotional and social responses in one's self and to influence others similarly becomes one of the primary ways that adolescence prepares the person for adulthood. By adulthood, the social and emotional brain has matured structurally and functionally to provide the biological basis for adaptive social and emotional behavior, as well as the capacity to ultimately provide parental, familial, and societal care (Adolphs & Anderson, 2013; Heatherton, 2011). During older adulthood, structural and functional changes in the human brain occur, including the gradual decline of neuronal structure and function that accompanies cognitive decline (Gutchess, 2014; Park & Gutchess, 2006). Notably, even with gradual cognitive decline in older adulthood, social and emotional capacities remain intact, indicating an important divergence between cognitive and socioemotional systems during older adulthood (Carstensen, 2006; Samanez-Larkin & Carstensen, 2011). Hence, fMRI provides a potent and viable means of characterizing developmental changes in the human brain and behavior from fetus to old age.

Functional near-infrared spectroscopy (fNIRS) is a neuroimaging method that allows for the indirect measurement of neural activity based on metabolic processes within the brain by optodes or light emitters and detectors (Lloyd-Fox, Blasi, & Elwell, 2010; Vanderwert & Nelson, 2014). fNIRS measurement occurs while participants wear a cap during a given behavioral task. As a developmental neuroimaging method, fNIRS is preferred due to its low cost, ease of use with infants, greater spatial localization compared to fMRI, and portability or ease of use in naturalistic settings (Lloyd-Fox et al., 2010; Vanderwert & Nelson, 2014). A majority of fNIRS studies have measured neural activity in infants during sleep, although more recent studies have also measured functional response in infants while they perform simple behavioral tasks, such as visual perception. For geographic regions where fMRI is prohibitively difficult due to infrastructural issues, fNIRS provides a reasonable and pragmatic method for studying neuronal maturation and behavior throughout development, from infancy to older adulthood.

Finally, the event-related potential (ERP) represents one of the oldest electrophysiological methods that provide a direct, noninvasive means of measuring neural activity throughout development, from infancy to older adulthood. ERP allows for excellent temporal resolution of cortical measurement but relatively worse spatial resolution compared to fMRI. Like fNIRS, ERP allows for neuronal measurement by recording through a cap of electrodes from the scalp. This apparatus allows for more mobility compared to fMRI and may be suitable for studying developmental changes in geographic regions that require naturalistic or remote settings (Chiao, Pornpattananangkul, Stein, & Van Honk, 2015). The earliest studies of infant brain activity used ERP to show that waveforms generated from the ventral visual cortex, for instance, provided the neuronal response associated with social abilities, such as face perception (Courchesne, Ganz, & Norcia, 1981; De Haan & Nelson, 1997) and memory (Nelson & Salapatek, 1986). Age-related developmental changes in neural mechanisms of face processing are detectable into older adulthood with ERP (Wiese, Kachel, & Schweinberger, 2013), providing an important method for understanding social and emotional development across cultural contexts.

Developmental Imaging Genetics

Developmental imaging genetics provides a foundational method for understanding the effect of genotype and genetic expression on the human brain and behavior (Casey, Foliman, Bath, & Glatt, 2010; Viding, Williamson, & Hariri, 2006). Imaging genetics studies combine measures of neural activity and behavior with genotype (Canli et al., 2006; Hariri et al., 2002) and epigenetic expression (Jack, Connelly, & Morris, 2012; Nikolova et al., 2014) to identify the effects of a given gene or functional polymorphism on brain and behavior. The earliest examples of imaging genetics examine the role of the 5-HTTLPR on human brain function. Findings from early imaging genetics studies showed functional differences in the bilateral human amygdala as a function of allelic variation of the 5-HTTLPR (Canli et al., 2006; Hariri et al., 2002). The earliest imaging epigenetic studies show that changes in genetic expression are associated with functional variation within social and emotional brain regions, including the superior temporal gyrus (Jack et al., 2012) and the human amygdala (Nikolova et al., 2014). Together, these results show for the first time genetic effects on functional human brain response in young adults and provide a necessary theoretical link between genetic and neural levels of analysis. These earliest imaging genetics studies are groundbreaking in their demonstration of the empirical ability to measure genetic effects on the human brain and behavior and provide a foundation for understanding how genes affect the human brain across development. More recently, imaging genetic studies have shown effects of multiple functional polymorphisms, including oxytocin, dopamine receptor polymorphism, brain-derived neurotrophic factor (BDNF), and monoamine oxidase A (MAOA), on human brain function (Casey et al., 2010; Padmanabhan & Luna, 2014; Viding et al., 2006).

Distinct empirical approaches have been proposed in developmental imaging genetics. One empirical approach is to conduct longitudinal studies of genetic effects on the human brain and behavior. In longitudinal developmental imaging genetic studies, observations of brain–behavior relations would be measured consistently in genotype groups across distinct developmental periods. For instance, in order to examine whether there exists a developmental shift from infancy to childhood in the 5-HTTLPR effect on the human amygdala, one might examine the degree of amygdala response during a socioemotional task in short- and long-allele carriers of the 5-HTTLPR from infancy to childhood in the same individuals. Another empirical approach is to identify developmental stage-specific genetic effects on brain and behavior. For instance, to study cultural or biological changes associated with a specific developmental stage, such as adolescence, one might compare the genetic effect on brain function pre- and post- a given developmental stage with a cross-sectional design.

Given the known mutual influence of cultural and genetic selection on human behavior, it is important to consider the independent and interactive influence of cultural and genetic effects on the developing brain. The onset of a particular developmental stage in brain and behavior occurs within a given cultural context and mind-set of cultural dimensions of the individual. It is plausible that developmental changes in genetic effects on the human brain are due in part to developmental changes in cultural acquisition or knowledge. Similarly, developmental changes in genetic effects on the human brain may be necessary or catalysts for cultural acquisition or cultural change to occur within a given developmental period. For instance, acculturation to a given host culture may not be necessary unless the cultural change from heritage to host culture occurs after childhood. Similarly, racial identification or identifying with one's social group may not be fully possible within the functional maturation of prefrontal cortex during adolescence, due possibly to changes in genetic expression within a given brain region. Hence, understanding developmental changes in human biology, such as genetic expression and human brain function, is a fundamental goal to fully characterize the acquisition and maintenance of cultural competence across the life span.

Population Genetics

Recent advances in population genetics indicate that allelic variation within functional loci of specific genes may result from both natural and neutral selection mechanisms (Novembre & di Rienzo, 2009). Allelic variation that occurs due to natural selection may be associated with specific functional adaptations that alter the probability of health (Chiao & Blizinsky, 2013; Sasaki, LeClair, West, & Kim, in press; Wang & Sue, 2005). For instance, genes previously shown to be associated with psychological health, including 5-HTTLPR and dopamine receptor polymorphism, show allelic variation across geography, likely due to natural selection mechanisms (Chiao & Blizinsky, 2013). By adulthood, people living in distinct cultural contexts show differential gene–behavior associations, indicating that genes interact with culture in the production of adaptive behavior (Kim et al., 2010; Sasaki, Kim, & Xu, 2011). Variation in allelic frequency of genes associated with psychological health may produce cultural adaptations appropriate for a given ecological or environmental niche, which subsequently trigger an optimized developmental trajectory within the individual. Understanding the allelic variability of a given candidate gene associated with human behavior may provide theoretical insight into how and why cultural differences exist in developmental trajectories of the brain for a given ecological or geographic niche, but not another.

EMPIRICAL PROGRESS IN CULTURAL NEUROSCIENCE OF THE DEVELOPING BRAIN IN CHILDHOOD

Much progress has been made in understanding developmental changes in the social and emotional brain, particularly in Western culture. For instance, more than two decades of human neuroimaging studies have been performed to characterize neural systems during development (Casey, Tottenham, Liston, & Durston, 2005). However, a majority of these developmental neuroimaging studies are WEIRD—that is, conducted within Western, educated, industrialized, rich, democracies (Chiao & Cheon, & 2010; Henrich, Heine, & Norenzayan, 2010). This fact suggests that developmental brain scientists may be generalizing from a narrow sample of the species, which is not safe. Such developmental neuroimaging studies may not reveal important neural and behavioral differences across cultures and thus may not be able to fully represent how culture affects the developing social and emotional brain during childhood. This section provides an introduction to specific social and emotional processes that may prove fruitful to study within the cultural neuroscience framework. By studying how developmental changes in social and emotional processing vary across cultures, we gain deeper insight into how people acquire the ability to adaptively interact with one another throughout the life span.

Self and Other Knowledge

One of the primary social capacities that emerge in the developmental transition from infancy to childhood is a sense of self. From birth to approximately 2 years of age, infants and young children experience infantile amnesia such that they lack continuous autobiographical memory of self-experience. As infants become children, they gain the capacity to remember events as autobiographical. Cultural values, practices, and beliefs shape knowledge and awareness of the self (Markus & Kitayama, 1991; Triandis, 1995). *Self-construal style*, or independence and interdependence, refers to how people define themselves and their relation with the world (Markus & Kitayama, 1991). Independent or individualistic selves value freedom and autonomy and think of themselves as distinct from others. By contrast, interdependent or collectivist selves value interconnection and social harmony and think of themselves as connected to others.

Cross-cultural behavioral studies of children in United States and China show cultural differences in the developmental trajectory of self-knowledge (Wang, 2004). Cultural differences in notions of the self have been observed during development as early as 3 and 4 years of age (Han, Leichtman, & Wang, 1998; Wang, 2004). European American children are more likely to recall personal events with elaborate, detailed episodes, compared to Chinese and Korean children (Han et al., 1998). These findings suggest that unique childhood recollections characterize self-knowledge in children raised in an individualistic compared to collectivistic culture. Furthermore, in a study of English-Chinese bilingual children living in Hong Kong, children who were primed with individualism by speaking English were more likely to focus on autonomy and agency in their self-construal, which led to detailed and self-focused autobiographical memories. By contrast, children who were primed with collectivism by speaking Chinese were more likely to focus on relationship networks and social roles in their self-construal and to recall relational or social autobiographical memories (Wang, Shao, & Li, 2010). Hence, cultural differences in self-concept emerge early in childhood and maintain throughout development.

By young adulthood, cultural differences in self-construal are neurally represented within the MPFC (Chiao et al., 2009; see Figure 1.3).

In a cross-cultural neuroimaging study of young adults, native Japanese living in Japan and Caucasian Americans living in the United States completed a self-construal scale and a self-knowledge task during scanning. Native Japanese showed greater MPFC response when processing contextual (e.g., "When talking to my mother, I am dutiful") compared to general self-statements (e.g., "I am dutiful"), whereas Caucasian Americans showed greater MPFC response during general compared to contextual self-statements. Furthermore, irrespective of nationality, people who were more likely to endorse collectivistic cultural values showed increased MPFC response to contextual self-statements. These findings demonstrate that cultural values of individualism and collectivism are predicted by neural response during self-knowledge retrieval, in a culturally appropriate manner.

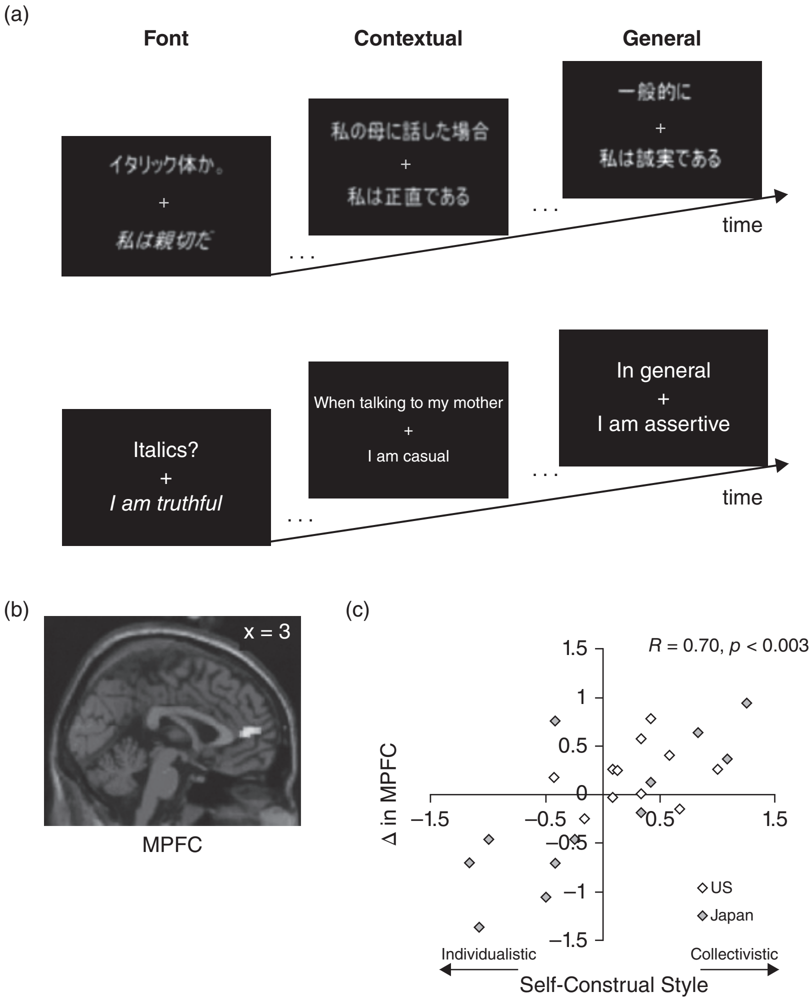

Figure 1.3 Cultural influences on medial prefrontal cortex (MPFC) response during self-judgments. (a) Example of self-judgment task; (b) MPFC response during culturally congruent self-judgments; (c) Degree of cultural collectivism predicts MPFC response to culturally congruent self-judgments.

Source: Adapted from Chiao et al., 2009.

During the developmental transition from childhood to adulthood, the MPFC, along with other brain regions that comprise the default mode network, undergo significant changes in functional and structural connectivity. In particular, connectivity between the MPFC and posterior cingulate cortex is greater in adults compared to children, and maturation of this functional connection may comprise an important biological change in the development of self-knowledge from childhood to adolescence (Supekar et al., 2010). One putative candidate for examining developmental changes in neural representations of the self across cultures is the MPFC and other brain regions of the default mode network. Based on prior behavioral studies, one possibility is that similar to adults, children may recruit MPFC to a greater extent when processing culturally congruent self-knowledge; however, children may differentiate between individualistic and collectivistic self-knowledge to a lesser extent compared to adults. Finally, the degree of connectivity between MPFC and posterior cingulate cortex may predict the degree to which children differentiate between individualistic and collectivistic self-knowledge. Future cross-cultural neuroimaging studies of the self across development are necessary to better understand the neurobiological mechanisms underlying the development of self across cultures.

Emotion

Another important psychological capacity that matures from infancy to childhood is emotion recognition. From infancy, humans respond to emotions expressed by others (Grossmann, Striano, & Friederici, 2006) and are able to distinguish between the emotional signals of own and other group members (Vogel, Monesson, & Scott, 2012). For instance, within the first 5 months of life, young infants distinguish between emotional faces of members of their own race and members of other races; however, by 9 months, infants distinguish the emotional faces of own-race members only (Vogel et al., 2012). Notably, during childhood, the capacity to differentiate between positive and negative emotions, as well as to categorize emotions with verbal labels that imply mental states, emerges gradually (Widen & Russell, 2010), due to increased influence of cognition on emotion processing. However, less well understood is how culture affects the neural bases of emotion recognition during childhood.

Cultural differences in emotion emerge as a function of systems of values, practices, and beliefs (Elfenbein & Ambady, 2002; Kitayama & Markus, 1999; Mesquita & Frijda, 1992; Russell, 1991). Self-construal style is a fundamental cultural dimension that affects how people perceive emotions (Elfenbein & Ambady, 2002), express and experience emotions (Kitayama & Markus, 1999), regulate their emotions (Ford & Mauss, 2015; Mauss & Butler, 2010), and conceptualize their ideal affect (Tsai, 2007). Cultural familiarity affects the degree to which people accurately perceive and recognize emotional expressions (Elfenbein & Ambady, 2002). People from the same cultural group demonstrate an in-group advantage in emotion recognition such that they recognize emotions better when expressed by members of their group. People from interdependent cultures attend to the emotions of surrounding others to a greater extent relative to people from independent cultures (Masuda et al., 2008). Regulating emotions in social situations is more highly valued in interdependent relative to independent cultures (Kitayama & Markus, 1999; Mauss & Butler, 2010), and how people regulate their emotions, either by cognitive appraisal or emotion suppression, varies as a function of culture (Ford & Mauss, 2015). People living in interdependent cultures are more likely to utilize emotional suppression strategies for regulation, whereas people living in independent cultures are more likely to rethink their feelings or engage in cognitive reappraisal. Even the emotional states that people consider their "ideal affect" or emotional experience differs depends on cultural heritage (Tsai, 2007). Independent cultures emphasize positive emotions with high arousal, such as feelings of joy or elation; by contrast, interdependent cultures prize positive emotions of low arousal, such as feelings of calm.

By young adulthood, culture shapes different facets of emotion not only in behavior but also in neurobiology. Culture has been shown to affect bilateral amygdala response to fear faces (Chiao et al., 2008). In a cross-cultural neuroimaging study, native Japanese living in Japan and Caucasian Americans living in the United States viewed emotional expressions of their own and other cultural group during scanning. Both native Japanese and Caucasian Americans showed greater bilateral amygdala response to fear faces expressed by own group members compared to other group members (Chiao et al., 2008). These findings indicate that amygdala response is heightened when processing the fear of a cultural group member, possibly due to the expectation that a member of one's own cultural group will be more likely to respond to one's fear or that the fear of a cultural group member may be more salient or relevant to one's self.

One possible mechanism underlying a cultural influence on amygdala response during emotion recognition is developmental changes in functional connectivity between the amygdala and cortical regions, such as the

MPFC (Gee et al., 2013). During early childhood, functional connectivity between the amygdala and MPFC is strong such that heightened amygdala reactivity is coupled with high prefrontal cortex activity; however, by young adulthood, functional connectivity is significantly weaker. In young adults, high amygdala reactivity is associated with low prefrontal activity. A plausible developmental mechanism for cultural differences in emotional brain response is that during early childhood, amygdala response to fear faces of own and another cultural group may be undifferentiated but, by young adulthood, the amygdala shows preferentially response to fear expressed by cultural group members due in part to developmental changes in functional connectivity between the amygdala and MPFC. Future developmental neuroimaging studies of emotion recognition across cultures may provide important insights into the role of maturation in neuronal connectivity on cultural specificity.

Empathy

Understanding the emotions of others is an essential social skill that allows people to care for and respond to the suffering of others. The ability to understand and respond to the suffering of others is present from infancy; during childhood, the capacity to empathize with others becomes essential to the formation of friendships and peer relations that are constructive and promote adaptive social behaviors. Cultural differences in empathy result from a number of distinct emotional and cognitive processes (Chiao & Mathur, 2010, in press). Individualism-collectivism, or independence and interdependence, and power distance represent fundamental cultural dimensions affecting emotional and cognitive aspects of empathy (Chiao & Mathur, 2010; Hofstede, 2001). Members of collectivistic or interdependent cultures show greater attention to the emotions of others (Masuda et al., 2008) and perspective-taking (Wu & Keysar, 2007; Wu, Barr, Gann, & Keysar, 2013) or cognitive empathy relative to those of individualistic or independent cultures. Sociopolitical attitudes such as social dominance orientation, or equality preference, have also previously been associated with empathy (Pratto et al., 1994). People who prefer social equality across groups are more likely to express empathy to those in need. Racial or ethnic identification also affects how people empathize with members of their own and other social groups (Mathur et al., 2012).

Minority group members who exhibit stronger racial or ethnic identification may rely on affective empathy to a greater extent with group members, whereas majority group members with little to no racial or ethnic identification may utilize cognitive empathy with group members.

In young adulthood, culture shapes neurobiological responses during empathy. In a cross-cultural neuroimaging study of native Koreans living in South Korea and Caucasian Americans living in the United States, participants viewed scenes of native Koreans and Caucasian Americans in the midst of a natural disaster during scanning and rated how much empathy they felt toward the victims (Cheon et al., 2011). Afterward, participants completed a behavioral survey of social dominance orientation. One notable finding is that Koreans showed greater social dominance orientation compared to Caucasian Americans; furthermore, this cultural difference in social dominance orientation predicted intergroup empathy due to cultural differences in intergroup empathic neural response within the left temporopariental junction. These findings indicate that cultural values of hierarchy preference modulate empathic neural response and predict subsequent behavioral differences in empathy.

In another cross-cultural neuroimaging study of native Koreans and Caucasian Americans, participants simply viewed scenes of native Koreans and Caucasian Americans in the midst of a natural disaster and completed a behavioral survey of other-focusedness (Cheon et al., 2013). Neural response within the anterior cingulate cortex and right anterior insula were more strongly correlated with degree of other-focusedness in Korean relative Caucasian American participants (see Figure 1.4). These findings demonstrate for the first time cultural differences in empathic neural response as a function of other-focusedness.

Racial identification has been shown to modulate default mode network response to empathic processing in African American and Caucasian American young adults (Mathur et al., 2012). African American and Caucasian American young adults were scanned while viewing scenes of victims of a natural disaster and rating how much empathy they felt for the victims. Results from this study showed that both African American and Caucasian American young adults expressed empathy for same- and other-race victims. Additionally, African Americans showed increased neural response within default mode network regions, including

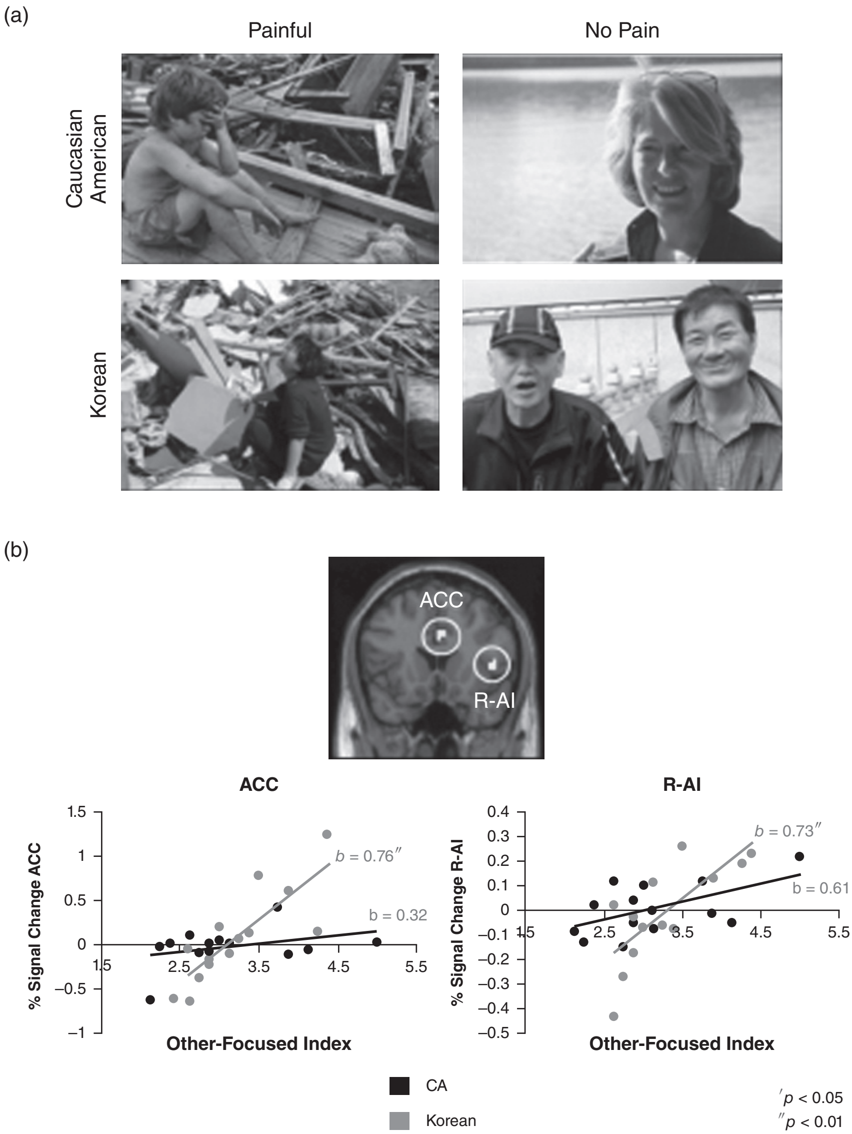

Figure 1.4 Cultural influences on empathic neural response. (a) Example of painful and nonpainful emotional scenes; (b) Other-focusedness predicts anterior cingulate cortex (ACC) and right anterior insula (right AI) empathic response to group members in Koreans to a greater extent relative to Caucasian Americans.

Source: Adapted from Cheon et al., 2013.

the MPFC, anterior cingulate cortex, and posterior cingulate cortex during empathy toward African Americans compared to Caucasian Americans; by contrast, Caucasian Americans showed greater neural response within bilateral medial temporal lobes during empathy toward Caucasian Americans compared to African Americans. Finally, degree of racial identification predicted neural variation in empathic neural response within the default mode network (see Figure 1.5). Greater racial identification positively predicts activity within cortical midline regions within the default network when viewing same-race victims.

Cultural influences on empathic neural response may result from developmental neural changes during childhood. In particular, the functional connectivity changes within the default mode network that occur during the transition from childhood to adulthood may provide a developmental mechanism by which culture affects empathic neural response. Future neuroimaging studies of empathy in majority and minority members across development are needed in order to better determine the causal mechanism underlying cultural differences in empathic neural response during childhood.

Theory of Mind

One of the earliest social cognitive capacities that children develop is the ability to detect the mental states of others. Theory of mind, or the ability to understand the mental state inference of others, allows people the ability to recognize the beliefs and feeling states of other people. Classic behavioral paradigms, such as geometric animation (Heider & Simmel, 1944) and "Reading the Mind in the Eyes" tasks (Baron-Cohen, Wheelwright, & Jolliffe, 1997), provide nonverbal methodological paradigms for examining the ability to understand mental states. Nonverbal paradigms may be especially well suited for developmental examinations of mental state understanding in children (Callaghan et al., 2005). Numerous behavioral studies with children suggest that they readily understand false beliefs by childhood, irrespective of culture, despite observable cultural differences in executive function (Callaghan et al., 2005; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Notably, cultural differences in neurobiological mechanisms of theory of mind may be present, even in the absence of behavioral differences, due to the influence of culture on

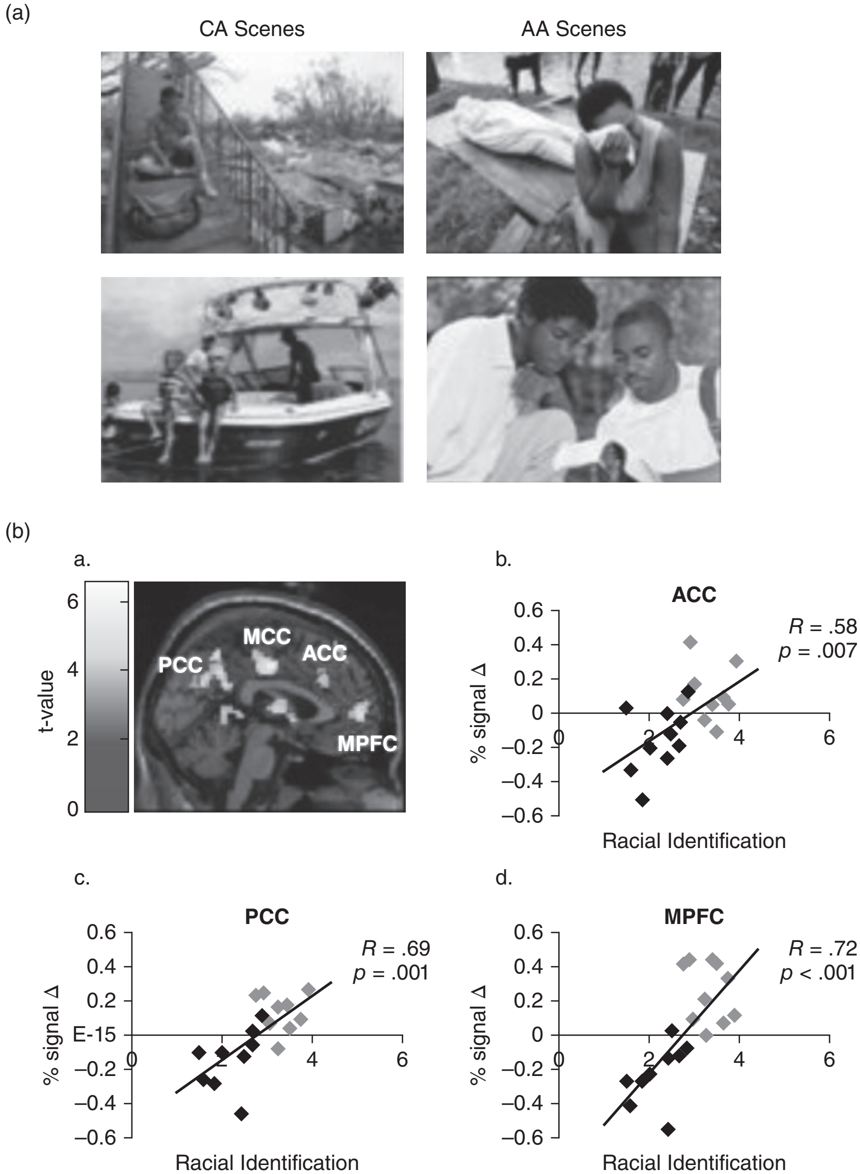

Figure 1.5 Racial identification predicts default mode network response during empathy in African American (AA) and Caucasian American (CA) young adults (a) Example of painful and nonpainful emotional scenes; (b) Racial identification predicts empathic neural response within the default mode network.

Source: Adapted from Mathur et al., 2012.

neurodevelopmental pathways of social cognition (Kobayashi Frank & Temple, 2009).

By young adulthood, culture affects neurobiological responses during theory of mind tasks. In a neuroimaging study of native Japanese and Caucasian participants living in Japan, participants completed an adaptation of the Heider-Simmel theory of mind task of geometrical shapes moving in a social manner. Caucasians living in Japan showed greater MPFC response during theory of mind perception compared to native Japanese. These findings indicate cultural differences in MPFC response during theory of mind perception (Koelkebeck et al., 2011). In a cross-cultural neuroimaging study of native Japanese living in Japan and Caucasian Americans living in the United States, participants completed the “Reading the eyes in the mind” theory of mind task. Results showed greater superior temporal sulcus response when mentalizing own-culture compared to other-culture social cues (Adams et al., 2010). These results show cultural specificity in superior temporal sulcus response during theory of mind.

Developmental differences in neural bases of theory of mind have been previously observed in the left superior temporal gyrus, right MPFC, right middle frontal gyrus, and right ventral inferior frontal gyrus, such that children show greater response within these regions compared to adults (Kobayashi, Glover, & Temple, 2007). One possible developmental mechanism to explain cultural differences in the neural basis of theory of mind in young adults is neuronal maturation of the MPFC from childhood to adulthood. Age-dependent plasticity within the superior temporal sulcus may also play an important role in explaining cultural sensitivity within this brain region to theory of mind social cues by adulthood. Further investigations of how culture affects neural pathways of social cognition during development may illuminate with specific neurobiological mechanisms by social competence within a given cultural context is acquired.

Cognition

One of the most fundamental ways that cultures differ is in systems of thought or how people think of themselves and their relation to the world (Nisbett, Peng, Choi, & Norenzayan, 2001). Collectivistic cultures are thought to value “holistic” systems of thinking, or attention to the entire field and dialectical reasoning, whereas individualistic cultures emphasize "analytic" systems of thinking, or attention primarily to the object and reliance on logical thinking. Cultures also vary in the extent to which they emphasize cognitive or inhibitory control (Markus & Kitayama, 1991; Suh, 2002). Behavioral inhibition is a temperament style whereby a person responds to novel and unfamiliar situations with withdrawal (Kagan, Reznick, Clarke, Snidman, & Garcia-Coll, 1984). Behavioral inhibition, or inhibitory control, represents an important cognitive skill that develops with maturation of executive function (Zelazo, Carlson, & Kesek, 2008). Collectivistic cultures value flexibility and the self as defined by social relations and contexts, whereas individualistic cultures value behavioral consistency and a self that is reliable or predictable across situations (Markus & Kitayama, 1991; Suh, 2002).

In early childhood, culture affects the extent to which toddlers show behavioral inhibition, such as whether they approach toys and people in a novel environment (Chen et al., 1998). Chinese toddlers are significantly more inhibited to approach a stranger and a robot in a novel play environment compared to Canadian toddlers. Rather than approach an unfamiliar person or toy, Chinese toddlers are more likely to stay close to their mother, although children from both cultures are equally likely to play with an unfamiliar toy when in close contact with their mother. Behavioral inhibition in Chinese and Canadian toddlers was associated with parenting style, such that Chinese mothers' acceptance and encouragement of achievement was positively associated with Chinese toddlers' behavioral inhibition; by contrast, Canadian mothers' punishment orientation was positively associated with behavioral inhibition. These behavioral findings indicate that behavioral inhibition as a temperament style is differentially affected by cultural transmission between parent and child in Chinese and Canadian culture. Given the notable role of cultural transmission of parenting style on behavioral inhibition, it is plausible that genetic transmission may similarly influence inhibitory control in children.

Supporting this hypothesis, a recent behavioral genetics study of behavioral inhibition in Chinese toddlers showed that the short allele of 5-HTTLPR was associated with reduced levels of behavioral inhibition (Chen et al., 2014), a pattern distinct from developmental research of 5-HTTLPR and behavioral inhibition among American children in the United States, suggesting a gene-by-environment interaction

(Fox et al., 2005). These findings provide initial evidence of cultural variation in genetic basis of inhibitory control during childhood; however, future studies are needed to directly assess cultural mechanisms underlying variation in gene–behavior associations of behavioral inhibition throughout development. For instance, one possible explanation of the earlier results may be the role that multiple gene systems play during inhibitory control. A recent behavioral genetics study showed that children with at least one 7-repeat allele of the dopamine D4 receptor gene polymorphism showed lower inhibitory control compared to children without this allele, when positive parenting was reduced (Smith, Kryski, Sheikh, Singh, & Hayden, 2013). By adulthood, individuals with the 7-repeat allele have higher novelty-seeking scores (Ebstein et al., 1996) and are more likely to take financial risks (Kuhnen & Chiao, 2009), suggesting that genetic influences on behavioral inhibition are present early in development.

The possibility of cultural variation in the genetic basis of inhibitory control also suggests that cultural variation in inhibitory control may be observed in the developing brain. In a cross-cultural electrophysiological study of executive function in children, Lahat and colleagues (2009) measured neurophysiological response in young European Canadian and Chinese Canadian children while they completed a Go/No-Go task. Cultural differences were observed in N2 response during conscious inhibition, such that Chinese Canadian children showed larger N2 amplitude waveforms compared to European Canadian children on the right side of the scalp. (see Figure 1.6).

The N2 is an important psychophysiological component typically observed at medial-frontal sites approximately 250 and 500 ms after stimulus presentation. The N2 amplitude has previously been associated with behavioral inhibition and cognitive control. Neural response related to N2 has been localized within dorsal and anterior cingulate cortex as well as ventral prefrontal cortex. These findings demonstrate for the first time cultural differences in inhibitory neural response in children. Results suggest that cultural variation may be more readily observed at the neural level of analysis during early development, as has been previously observed with young adults (Chiao, 2009).

Cultures differ in the extent to which they value cognitive regulation or control. A recent cross-cultural neuroimaging study of Japanese adults

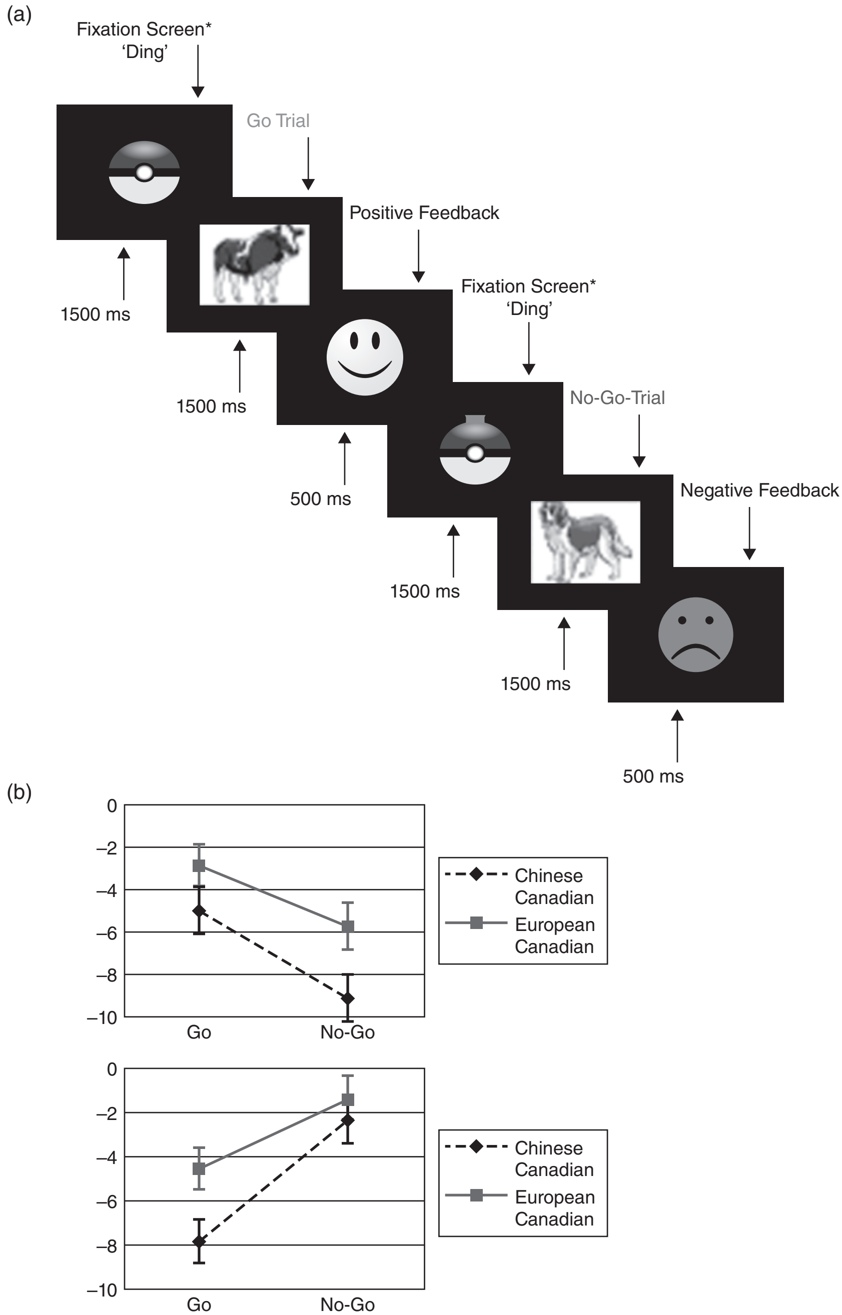

Figure 1.6 Cultural differences in N2 response during behavioral inhibition in Chinese Canadian and European Canadian children (adapted from Lahat, et al., 2009). (a) Go/No-Go task performed by children; (b) Mean amplitude response of the N2 waveform in the right (top) and left (bottom) hemisphere during Go and No-Go trials in Chinese Canadian and European Canadian children.

Source: Adapted from Lahat et al., 2009.

living in Japan and Caucasian American adults living in the United States investigated cultural influences on the neural basis of inhibitory control (Pornpattananangkul et al., 2016). Across cultures, participants completed a cognitive inhibition, or Go/No-Go, task whereby they pressed a button each time they saw a letter on the screen but inhibited their motor response only when they saw the letter "V" on the screen while their brain responses were recorded. After scanning, participants completed a self-report scale of self-construal style. Results showed that neural response within the rostral anterior cingulate cortex predicts cultural values of behavioral consistency. These findings identify for the first time a neural correlate of culture values of behavioral consistency and suggest that neural representations of culture during inhibitory control are reflected within activity of the rostral anterior cingulate cortex. Given the importance of the cultivation of inhibitory control as a developmental skill during childhood and acquisition of culture as a means of gaining cognitive control, future studies may examine the developmental trajectory of neurobiological mechanisms underlying cultural differences in inhibitory control.

FUTURE DIRECTIONS IN CULTURAL NEUROSCIENCE OF THE DEVELOPING BRAIN IN CHILDHOOD

Future directions in cultural neuroscience include implementation of research programs that investigate the developing brain in childhood across cultures (Chiao, Li, Seligman, Turner, 2016). One important research gap to close is the need for developmental neuroimaging studies within developing countries and geographical regions with remote cultures (Chiao & Blizinsky, 2013). Numerous countries facing a high degree of environmental and ecological threats may be amenable to developmental neuroimaging research involving portable technologies, such as fNIRS, which may allow for the noninvasive measurement of brain function across age groups (Lloyd-Fox et al., 2014). Investing in neuroscience research and education infrastructure within developing countries may enhance the ability of those nations to anticipate and respond to the needs of their youngest citizens.

Another research direction is characterizing the structural and functional changes in the developing brain across cultures as a methodological goal. Cross-cultural neuroimaging studies have identified cultural variation in structural volume and cortical thickness between Western and Eastern young adults (Chee, Zheng, Goh, Park, & Sutton, 2011); however, little is known about the developmental origins of neuronal connectivity variation across cultures. Future studies that examine cultural influences on the development of brain structure may provide important insight into how to identify and interpret functional differences observed with similar methods. Additionally, several studies show that socioeconomic status during childhood affects cognitive performance and, more recently, neurocognitive development (Hackman & Farah, 2009). Future developmental neuroimaging investigations into the effects of socioeconomic status on neuronal development are necessary to better identify ways of buffering children from negative effects of childhood socioeconomic status. Future developmental imaging genetic studies across cultures that examine cultural and genetic influences on the developing brain will allow for novel insights into the origins of adaptive behavior. Complex human behavior, from morality to mental health, is characterized as a by-product of an interaction of environmental, cultural, and biological factors. Understanding the developmental trajectory of the brain in distinct cultural contexts may provide novel insights into how genetic and cultural factors independently and interactively contribute to development of the healthy adult brain.

A final major research direction for future research is developmental neuroimaging studies of cultural change in childhood. Immigration, acculturation, and sociopolitical shifts represent societal mechanisms of cultural change that can affect how the brain develops during childhood. For instance, young children who immigrate may have a less difficult time acculturating to the host culture, compared to older counterparts who must consciously integrate heritage and host cultures (Berry, 1997). What contributes to this cultural resilience to cultural change during early childhood? Understanding the cultural advantage of immigration during childhood may illuminate a similar biological advantage of immigration during this developmental period. Once a biological advantage of immigration during childhood is identified, one may be able to devise a cultural strategy or intervention for older youth so that they may be able to similarly experience adaptive immigration and acculturation.

IMPLICATIONS OF CULTURAL NEUROSCIENCE OF THE DEVELOPING BRAIN

A consistent theme in developmental neuroscience is to identify causal mechanisms for the prevention of and intervention in maladaptive behaviors in order to promote habits leading to healthy adult brains. As recent as 2012, 6.6 million children perished prematurely and 58 million children of primary school age were out of school around the globe (UNICEF, 2013). When considering how to protect children from environmental influences that put them at risk, culture becomes the crucial means by which child mortality can be reduced and childhood education can be achieved (Bornstein & Putnick, 2012). Technologies that provide nutrition and vaccines to children in need are an example of how culture provides basic routes to survival; similarly, educational infrastructure that provides children literacy, peer relations, and leadership opportunities provide another example of how culture fosters human growth and potential.

A comprehensive cultural neuroscience of the developing brain may allow for the characterization of ways that culture, including values, practices, and beliefs, contributes to the development of healthy brains in both industrialized and nonindustrialized nations. Given the importance of personal choice in participation of cultural practices particularly within Western industrialized cultures, understanding what kinds of cultural norms enhance cortical performance, in families, schools, and communities with our youngest children, will also heighten our ability to make sound decisions regarding what kinds of cultural practices lead to healthy development. During development, children do not necessarily have personal choice or insight into the consequences of cultural practices that they engage in; hence, it is essential that a deeper sophistication of scientific knowledge guide informed decisions regarding when and why culture matters for a child's future.

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