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Developmental Cultural Neuroscience: Progress and Prospect

Yang Qu and Eva H. Telzer

Cultural diversity in mind and behavior has received much attention from psychologists, philosophers, anthropologists, and sociologists. With rapid progress in neuroimaging techniques, the past decade has witnessed a number of theoretical and empirical advances in the field of cultural neuroscience (for reviews see, e.g., Chiao & Ambady, 2007; Han & Northoff, 2008; Kim & Sasaki, 2014; Kitayama & Uskul, 2011), which focuses on examining how culture plays a role in neurobiological processes (Chiao & Ambady, 2007). This line of research has documented cultural differences in the neural basis that underlies a variety of psychological processes, such as face perception, language, memory, self-judgment, emotion, and perspective taking (e.g., Freeman, Rule, & Ambady, 2009; Zhu, Zhang, Fan, & Han, 2007). Such compelling evidence suggests that cultural experience can lead to changes in the structure and function of the human brain.

Although cultural neuroscience has revealed the important role of culture in shaping the brain, little is known about *how* such cultural differences in neurobiological processes gradually emerge in the process of children's development. Research on cultural neuroscience has almost exclusively compared adults from different cultures, without taking into consideration how the culturally wired brain develops from childhood into adolescence and adulthood. This is a lacuna, in that the transmission of culture remains unclear without an understanding of the developmental process. For decades, theories and studies in developmental psychology highlight the key role of social inputs in shaping children's cognition, motivation, emotion, and behavior (e.g., Bronfenbrenner, 1979; Collins & Steinberg, 2006). Therefore, the study of culture and biology needs to

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incorporate a developmental perspective, in order to better explain how diverse cultural environments influence the development of children's minds, brains, and behaviors.

What Is Developmental Cultural Neuroscience?

In this chapter, we propose *developmental cultural neuroscience* – the intersection of developmental psychology, cross-cultural psychology, and neuroscience (Figure 19.1). Developmental cultural neuroscience is an emerging interdisciplinary field that investigates cultural similarities and differences in brain, psychological, and behavioral development across the lifespan using a neuroimaging approach along with observation, survey, and experimental approaches. For decades, researchers have extensively investigated each of the intersections of two of these fields: the intersection of cultural psychology and neuroscience (cultural neuroscience), the intersection of developmental psychology and neuroscience (developmental neuroscience), and the intersection of developmental psychology and

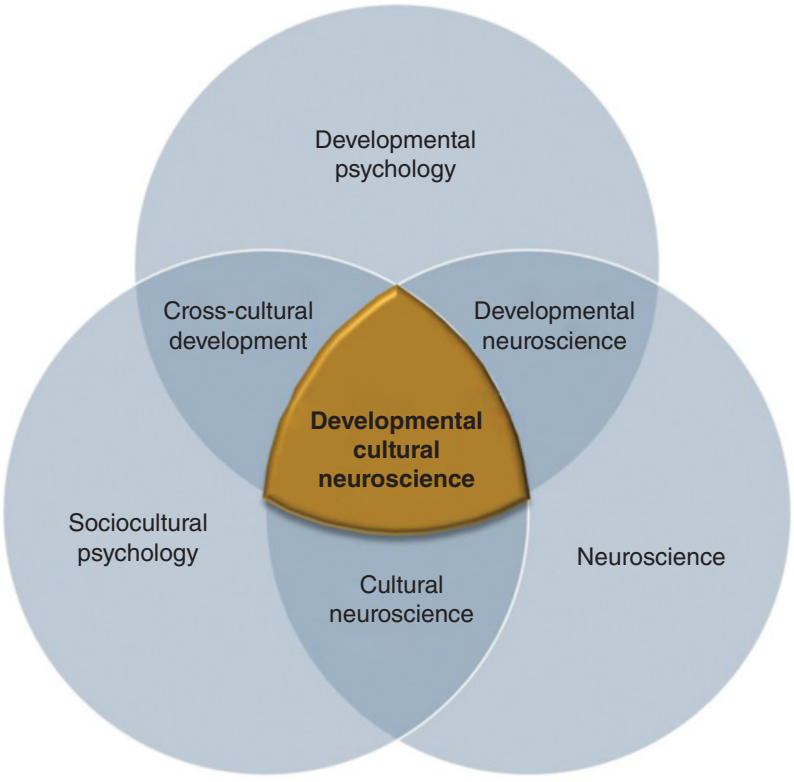

Figure 19.1 Developmental cultural neuroscience as a unique intersection of developmental psychology, cross-cultural psychology, and neuroscience

cultural psychology (developmental cultural psychology). However, the intersection of all three of these fields has received little attention.

Decades of research in developmental psychology, cultural psychology, and neuroscience have provided valuable lessons for this interdisciplinary field. For example, developmental psychology highlights the importance of examining developmental populations across the life span. By employing longitudinal assessments, researchers can carefully examine the developmental trajectories of children's and adolescents' functioning over either a short or a long period of time. Moreover, examining individual differences in these developmental trajectories can shed light on the unique or collaborative impact of social environments, such as family, peer groups, and school. Over the past 30 years, cultural psychology has identified key cultural values that guide individuals' motivation, cognition, and emotion in different cultures (e.g., Markus & Kitayama, 1991; Triandis, 1995). For example, the best-known cultural value that differs between the West and East Asia is independence versus interdependence (Markus & Kitayama, 1991), which provides important insights into individual and group behavior in Western and East Asian cultures. Accumulated evidence in cultural psychology emphasizes the necessity of examining psychological and behavioral phenomena in cross-cultural settings to unpack the role of culture. With the advent of sophisticated brain-imaging tools (e.g., functional magnetic resonance imaging (fMRI), electroencephalograms (EEG)), the field of psychology has witnessed a huge influx of neuroscience research in the past two decades. For example, statistical modeling in fMRI allows researchers to examine not only how activation in a specific brain region underlies psychological processes, but also how brain regions interact with other regions during these processes.

Why Study Developmental Cultural Neuroscience?

Developmental cultural neuroscience is a novel empirical approach to the examination of the neural mechanisms that underlie cultural differences and similarities in psychological processes across development. There are three key reasons to study this interdisciplinary field.

First, developmental cultural neuroscience provides *cultural psychology* with information about the process through which culture shapes behavior. Decades of research on cultural psychology has documented cultural differences in how people think, feel, and behave by using a variety of approaches, such as survey, observation, and experimental paradigms

(Kitayama & Cohen, 2007). As evidence of cultural differences accumulates, there have been calls to move from simply documenting cultural differences to unpacking how culture exerts its influence (e.g., Bond, 2002; Bukowski & Sippola, 1998; Heine & Norenzayan, 2006). Echoing these calls, endeavors in developmental cultural neuroscience provide a new approach to identifying the underlying mechanisms. Incorporating perspectives from developmental psychology and neuroscience, researchers can examine how culture shapes children's neurobiological processes over time, and how this contributes to cultural differences in their psychological adjustment.

Second, developmental cultural neuroscience provides *developmental psychology* with information about how social environments lead to cultural diversity in children's functioning. Social environments, such as parent–child interactions, peer socialization, and school structure, shape and are shaped by children's behavioral and psychological adjustment. Past research in developmental psychology has highlighted the role of culturally rooted social practices in the developmental process through which cultural values and norms are transmitted to children. Developmental cultural neuroscience can provide new understanding about the process of cultural socialization. For example, this line of research will elucidate how parenting practices in different cultures affect trajectories of children's brain development, leading to culturally distinct neurobiological processes and behavior over time. Moreover, this field can help us understand how children's neurobiological systems interact with their culturally rooted social environment.

Third, developmental cultural neuroscience provides *neuroscience* with knowledge about brain plasticity and neural function. Advances in developmental cultural neuroscience inspire empirical investigation into how cultural inputs affect brain development, which may support the accumulating evidence of the brain's malleability from childhood to adulthood. Moreover, research on developmental cultural neuroscience may identify the culturally unique or shared neural mechanisms that underlie children's behavior, and explore how neural structure and function are linked to children's psychological processes in different cultures. This line of research will provide a comprehensive understanding of the brain's plasticity.

The developmental cultural neuroscience approach provides a holistic perspective on how culture influences child development, and broadens our understanding of cultural transmission and neural plasticity. Instead of treating cultural influence as static, this approach captures the dynamic process of cultural transmission over time. Children's neural development

serves as a key mechanism through which culturally rooted social practices contribute to divergent developmental trajectories. Thus, children's brain development provides a window on how culture influences children's beliefs, feelings, and behaviors. By examining children's neural functioning, we can elucidate the process through which cultural values are transmitted from social environment to children, across generations. Moreover, the accumulation of empirical evidence can help us understand better when, how, and why there are cultural differences in individuals' adjustment over the course of development. In addition to depicting different trajectories of children's brain development across cultures, development cultural neuroscience can help us identify key social practices that contribute to such differences in children's neural development, providing empirical explanations for cultural differences in child functioning. Finally, developmental cultural neuroscience equips us with valuable tools to examine the underlying neural mechanisms by which social environments and practices shape child development. This knowledge can be used in future interventions that aim to promote children's learning and psychological adjustment.

Framework of Developmental Cultural Neuroscience

To further our understanding of the complex relationships between culture and children's development, we propose an overarching framework of developmental cultural neuroscience that takes into account the reciprocal link between culture, social practices, child biology, and child adjustment, elucidating how cultural and biological factors interact in the process of child development. In particular, this framework highlights the fact that culturally rooted social practices shape children's neural development, which has implications for cultural differences in children's adjustment.

A key aspect of the developmental cultural neuroscience framework is to point out the reciprocal relations between cultural environment, brain, and child development. Theories in cultural psychology argue that culture and individuals' adjustment are mutually constituted (Markus & Kitayama, 2010). On the one hand, sociocultural contexts shape individuals' cognition, emotion, and behavior by providing sociocultural meanings and practices. On the other hand, as highlighted by Markus and Kitayama (2010), individuals' thoughts, feelings, and actions reinforce, and sometimes change, sociocultural meanings and practices. This idea of mutual constitution is echoed in the developmental psychology field, and much

attention has been paid to how children's social environment and behavior influence each other over time. For example, decades of research suggest that parents' practices shape and are shaped by children's psychological adjustment (for reviews, see Belsky, 1984; Sanson & Rothbart, 1995). As a potential mechanism linking the two, children's brain development may also play a role in this reciprocal process.

Culturally Rooted Social Practices Affect Children's Brain Development

As Kitayama and Uskul (2011) have suggested, cultural values and beliefs may be hard to observe. However, they are embedded in a rich array of social practices, such as parent–child interaction, peer communication, and teaching practices. For example, in East Asian and Latino families, emphasis is placed on family obligation, which entails children and adolescents supporting the family, assisting their parents, and making sacrifices for the family (e.g., Chao & Tseng, 2002; Ho, 1996; Suárez-Orozco & Suárez-Orozco, 1995). This distinctive aspect of family relationships deeply shapes East Asian and Latino children's social practices in the family. It is important to note that parent–child interaction is not the only pathway in the process of cultural transmission and that it is likely that multiple forces are involved. Culture can be transmitted from many social agents (peers, teachers, media) via either conscious or unconscious (e.g., modeling) processes. For example, Chen (2012) has elaborated how peer groups can serve as important socialization agents in the process of cultural transmission, guiding children towards cultural beliefs and practices.

These culturally rooted social practices play a key role in shaping children's neural functioning across cultures. A pioneering study conducted by Telzer, Masten, Berkman, Liberman, and Fuligni (2010) examined cultural differences in Latino- and European-American youth's neural activation when making financial decisions in which young people and their families gain or lose money. Latino youth – whose social environments place more importance on helping the family – showed more neural activation in the mesolimbic reward system when making decisions to contribute to their family that involved self-sacrifice. In contrast, European-American youth showed more mesolimbic reward activation when gaining for themselves and not their family. This suggests that cultural differences in family obligation values and behaviors contribute to divergent neural functioning in Latino- and European-American adolescents, leading Latino adolescents to see making sacrifices for the family as personally rewarding. Therefore,

research using a developmental cultural neuroscience approach can elucidate how culturally rooted practices shape children's neural functioning.

Culturally Shaped Brain Processes Underlie Children's Real-Life Functioning

Children's brain development (e.g., neural function and structure), which is shaped by culturally rooted practices, plays a key role in children's behavioral and psychological adjustment. The reason for studying children's brain development in cross-cultural settings is not just to document how culture influences brain development, but also to examine how the brain serves as a mechanism that contributes to differences in children's and adolescents' adjustment. Therefore, the developmental cultural neuroscience framework emphasizes the importance of understanding the link between neural functioning and real-life adjustment. Without an understanding of the *function* and the long-term implications of neural activation in a specific region for each cultural group, the mean difference in neural activation between cultural groups is less meaningful. Therefore, it is important to link culturally shaped neural activation with children's real-life functioning, such as learning, school engagement, risk-taking behavior, and emotional well-being.

Guided by this framework, Telzer, Fuligni, Lieberman, and Gálvan (2013a) examined the impact of family obligation – a distinctive family relationship among Latino families – on Latino adolescents' neural processes, with attention to the implication for their real-life functioning. Adolescents who reported greater family obligation values showed decreased activation in reward regions during risk taking and increased activation in cognitive control regions during behavioral inhibition. Importantly, such culturally shaped neural functioning played a role in Latino adolescents' adjustment. Specifically, the decreased reward activation was associated with less real-life risk-taking behavior, and increased cognitive control activation was associated with better decision-making skills. In another study, Telzer, Fuligni, Lieberman, and Gálvan (2013b) followed adolescents longitudinally and found that Latino youth who showed heightened mesolimbic reward activation when making self-sacrifices for their family showed longitudinal declines in risk-taking behaviors. Taken together, these findings suggest that engaging in social relationships that allow adolescents to put the needs of others before their own may alter activation in neural regions involved in reward sensitivity and cognitive control, and that such culturally shaped neural functioning may facilitate the development of skills and motivations to avoid risk taking.

Identifying cultural differences in children's neural processes can also help us understand why cultural differences in children's adjustment occur. For example, there is much evidence that, compared with their East Asian counterparts, American children and adolescents tend to show poorer performance in a variety of academic subjects (e.g., PISA, 2013; Stevenson, Chen, & Lee, 1993; US Department of Education, 2011). Understanding why East Asian children may do better at school could provide insight into how to promote American children's learning and academic achievement. Given that children's executive function consistently predicts their school engagement and academic achievement (Blair & Razza, 2007; McClelland & Cameron, 2011), executive function may play a key role in creating such differences. Indeed, East Asian children tend to perform better than their age-matched Western peers in a variety of executive function tasks (e.g., Lan, Legare, Ponitz, Li, & Morrison, 2011; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Therefore, a key question is whether children's brain functioning underlies cultural differences in executive function. To address this issue, Lahat, Todd, Mahy, Lau, and Zelazo (2010) examined cultural differences in the neural correlates of executive function by recording high-density EEG data. In the context of a Go/NoGo task, Chinese-Canadian children showed larger N2 amplitudes than European-Canadian children, with larger N2 amplitudes associated with better performance (i.e., faster reaction time). Larger N2 amplitudes among Chinese-Canadian children seem to be driven by their greater activation in dorsomedial, ventromedial, and ventrolateral prefrontal regions than in their European-Canadian counterparts (Lahat et al., 2010). Therefore, children's brain development may serve as a key mechanism underlying differences in their executive function across cultures and ultimately contributing to cultural differences in children's learning and academic achievement.

Progress

In this section, we present emerging findings regarding developmental cultural neuroscience. Although this nascent field includes very few studies that incorporate all three subfields (culture, development, and neuroscience), evidence is emerging and accumulating. We provide a review of the few studies which have incorporated a developmental cultural neuroscience approach, or which have included two of the three subfields but have implications for the third. While the field is extremely new, emerging research has addressed different topics using a developmental cultural

neuroscience framework, including race perception, family relationships and cultural stereotypes of adolescence.

Race Perception

A well-documented phenomenon in the field of race perception is the differentiation between faces of own versus other ethnic groups. Because they have greater exposure to faces from their own culture, people are better at perceiving and recognizing the facial expressions of individuals from their own races than those of other races, a phenomenon called the other-race effect or in-group advantage (Elfenbein & Ambady, 2002; Kelly et al., 2007; Scott & Monesson, 2009; Vogel, Monesson, & Scott, 2012). Neuroimaging research examines the neural processes that underlie in-group versus out-group perception. A key neural region involved in this process is the amygdala, which is consistently involved in face perception and emotion processing (e.g., Anderson & Phelps, 2001; Hamann, Ely, Hoffman, & Kilts, 2002). Specifically, the amygdala shows greater activation to racial out-groups and unfamiliar faces than to racial in-groups and familiar faces (DuBois et al., 1999; Hart et al., 2000; Rule et al., 2010). For example, both American and Japanese individuals show a stronger amygdala response to cultural out-group faces than to cultural in-group faces (Rule et al., 2010).

The developmental process underlying this in-group/out-group bias has remained elusive. There is scarce evidence of when and how culture exerts its influences on children's neurodevelopment of race perception. Developmental research suggests that infants less than 1 year old can categorize faces by race and are sensitive to in-group versus out-group faces in their environment (for a review, see Shutts, 2015). The exclusive exposure to in-group faces in early postnatal development may modulate children's neurodevelopment and influence their neural response to in-group/out-group faces later in life. To investigate how culture exerts its influence on children's neural development of race perception, Telzer, Flannery, and colleagues (2013) examined this issue, using an international adoption design. In this study, children were raised in orphanage care in either East Asia or Eastern Europe as infants and later adopted by families in the United States. This experience limits children's exposure to faces of other cultures in early life (e.g., they have exclusive exposure to Asian faces or European faces), which is considered a form a deprivation, and also provides a natural way of quantifying the length of deprivation (that is, the age of adoption and initial exposure to other-race faces is known). Findings suggest that deprivation of other-race faces in infancy disrupts recognition of

emotion and results in heightened amygdala response to other-race faces during adolescence. More importantly, greater length of deprivation (that is, a later age of adoption) is associated with greater neural activation to other-race faces. This research not only elucidates how changes in cultural environments (e.g., deprivation of other-race faces) influence children's neural function over time, but also informs developmental theories on early postnatal development, suggesting that this period of development may be a sensitive period for neural development of race perception.

In addition to resulting in differentiation between own- and other-race faces, culture shapes children's neurodevelopment of race perception in other ways. Notably, culture conveys knowledge and biases about specific races (e.g., stereotypes of these races). For example, implicit negative stereotypes about African Americans are still evident in American society. Such stereotypes and biases may be reflected in neural activation during perception of that racial group. Indeed, neuroimaging research in American adults has consistently found that perception of African-American (versus European-American) faces is associated with increased amygdala activity (e.g., Cunningham et al., 2004; Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005), suggesting that African American faces hold significant saliency in adulthood, probably because of a lifetime of learned associations about black versus white. Importantly, both European-American and African-American adults show greater amygdala response while viewing African-American than European-American faces (Lieberman et al., 2005), suggesting that learned associations are shared across racial groups. Given that the internalization of stereotypes is a process of cultural learning, it is important to examine when this cultural bias is reflected in differential neural reactivity over development and whether the social environment can attenuate such differentiation. To address these issues, Telzer, Humphreys, Shapiro, and Tottenham (2013) examined age-related differences in amygdala sensitivity to race by recruiting children aged from four to sixteen years. Interestingly, differential amygdala sensitivity to African-American (versus European-American) faces was not present in childhood, but emerged over adolescence, a time when children begin to explore the meaning of race and are aware of racial stereotypes (Apfelbaum, Pauker, Ambady, Sommers, & Norton, 2008; Roberts et al., 1999). Moreover, children from European-American and African-American backgrounds showed similar developmental trajectories in amygdala response to African-American faces, suggesting that they are exposed to similar messages about race in society. Children's social environment also modulates the amygdala response to race: greater

peer diversity is associated with attenuated amygdala response to African-American faces, suggesting that greater contact with individuals from diverse backgrounds can reduce the neural salience of race.

Taken together, studies that use a developmental cultural neuroscience approach to examine race perception inform us about how culture exerts its influences on children's race perception. First, culture may play a role in children's neural development to race perception during early postnatal development. The international adoption study conducted by Telzer, Flannery, and colleagues (2013) suggests that even later exposure to other-race faces (e.g., adoption into a new culture) cannot attenuate heightened neural activation to other-race faces. Second, cultural knowledge and biases about races may have an impact on children's neurodevelopment. For example, developmental changes in children's neural reactivity to African-American faces suggest that the neural biases observed among adults do not reflect innate processes (Telzer, Humphreys et al., 2013). Rather, such neural biases emerge during adolescence, reflecting children's increasing internalization of cultural norms and biases. Third, greater exposure to diverse peers attenuates the amygdala response to race, highlighting the importance of diversity in youths' lives and underscoring how plastic the amygdala response is. In each of these studies, findings indicate that culture may influence children's neural functioning of race perception during a critical developmental period.

Family Relationships

As children's most proximal social environment, the family serves as a core mechanism through which cultural values and beliefs are transmitted to children. The emphasis placed on family relationships varies across different cultures. As discussed above, Latin American cultures place a significant emphasis on fulfilling family obligation (Suárez-Orozco & Suárez-Orozco, 1995). Specifically, children and adolescents are expected to support, assist, and take into account the needs and wishes of the family, for example by caring for siblings, doing household chores, and providing financial assistance (Fuligni & Pedersen, 2002; Telzer & Fuligni, 2009). Family obligation has consistently been identified as the most distinctive aspect of relationships within families from Mexican backgrounds in the United States, and it conveys unique cultural meanings and values. Indeed, compared with youth from European backgrounds, youth from Mexican backgrounds spend almost twice as much time helping their family each day, and assist their family 5–6 days per week on average, suggesting

that family assistance is a meaningful daily routine for these adolescents (Telzer & Fuligni, 2009). Further, young adults from Mexican backgrounds make greater financial contributions to their families than their peers from European backgrounds (Fuligni & Pedersen, 2002), and those from second and third generations continue to maintain a strong sense of family obligation (Fuligni, Tseng, & Lam, 1999).

The culturally rooted family practices that children and adolescents are engaged in may modulate their neural functioning across cultures. Specifically, the practices that fulfill family obligation often require Latino youth to sacrifice their time and money to help their family. Although these practices can be demanding, Latino youth may begin to internalize the heightened cultural value of family obligation and perceive such behavior as personally and socially rewarding. As described above, Telzer and colleagues (2010) examined Latino-American and European-American youth's neural activation when they made sacrifices for their family at a cost to themselves, a behavior that closely approximates family obligation behaviors. Compared with their European-American counterparts, Latino-American youth showed greater activation in the mesolimbic reward system (i.e., the ventral striatum) when making a donation to the family that involved self-sacrifice, suggesting that Latino youth see such behaviors as personally rewarding. Importantly, the extent of reward activity when contributing to their family varied, depending on the young person's family obligation values: youth who reported greater family obligation values showed the highest reward activation when contributing to their family (Telzer, Fuligni, & Gálvan, 2016), which suggests that family relationships that are culturally meaningful can modulate youth's neural functioning.

Family obligation values may be a cultural resource, protecting youth from maladaptive outcomes such as risk taking and depression. Indeed, Mexican-origin youth with higher family obligation values show lower rates of substance use and association with deviant peers (Telzer, Gonzales, & Fuligni, 2014), as well as longitudinal declines in depression and greater self-reported meaning in life (Telzer, Tsai, Gonzales, & Fuligni, 2015). To test whether the rewarding nature of family obligation explains this protective effect, Telzer, Fuligni, Lieberman, and Gálvan (2013b, 2014) scanned a sample of Mexican youth as they completed a family obligation task during which they made financial sacrifices for their family. Results indicated that Mexican youth who showed greater ventral striatum activation (i.e., greater reward-related activation) when providing assistance to their family showed longitudinal declines in risk-taking behaviors and depressive symptoms across the high-school years. These data suggest that

the meaningful and rewarding nature of family obligation is protective for Mexican-origin youth. Taken together, these findings suggest that culturally rooted family practices, such as practices that fulfill family obligation, affect adolescents' neural functioning, which plays a role in their real-life functioning.

Cultural Stereotypes of Adolescence

As anthropologists have long noted, culture shapes how youth navigate the teen years (e.g., Mead, 1928; Schlegel & Barry, 1991). Compared with their counterparts in Western countries, youth in non-Western countries appear to be less prone to the "storm and stress" of adolescence (for a review, see Arnett, 1999). For example, American youth often view school as less valuable as they enter adolescence, becoming less engaged in academics over time (e.g., Eccles et al., 1993). In contrast, research in China does not reveal such a trend: Chinese youth maintain their engagement in school over early adolescence (e.g., Wang & Pomerantz, 2009). Moreover, American youth engage in more risk taking than their Chinese counterparts (e.g., Greenberger, Chen, Beam, Whang, & Dong, 2000).

Research suggests that cultural stereotypes about adolescence differ in the United States and China, creating differences in the pathways youth take over this phase of development. For example, American youth view the teenage years in a more negative light – as fighting with their parents, being rebellious, and disengaging from school (e.g., Buchanan & Hughes, 2009; Qu, Pomerantz, Wang, Cheung, & Cimpian, 2016). In contrast, because of the key role of filial piety in Chinese culture, which involves children repaying parents and bringing honor to their family, adolescence in China is viewed as a time of fulfilling responsibilities to the family and working hard at school (Qu et al., 2016). Importantly, differences in how youth view adolescence contribute to their adjustment. For example, the more youth see the teenage years (as compared with younger children) as a time of disregarding family responsibilities, the less they are engaged with school and the more they take part in risky activities (e.g., cheating or fighting; Qu et al., 2016; Qu, Pomerantz, Wang, & Ng, in preparation). Therefore, these findings not only identify differences in how adolescence is viewed in different cultures, but also highlight how such differences contribute to divergent trajectories as youth navigate the early adolescent years.

Guided by the developmental cultural neuroscience framework, Qu, Pomerantz, McCormick, and Telzer (in preparation) further examined

how cultural stereotypes about teens – seeing adolescence in a negative way – contribute to changes in American youth's neural processes that accompany their adjustment during adolescence. Using a three-wave longitudinal neuroimaging design, they found that youth with more negative conceptions about the teen years showed greater increases in risk taking over the transition from middle to high school (8th to 9th grade, which occurs around age 14 to 15). Moreover, youth who viewed the teen years more negatively also showed longitudinal increases in activation of the bilateral ventrolateral prefrontal cortex (VLPFC), a brain region involved in cognitive control. This suggests that youth who see the teen years in a negative light may engage in more effortful control in order to regulate their impulsive behavior effectively over time, as they need to recruit more neural resources to do so. Notably, such neural increases were related to longitudinal increases in young people's risk taking over the transition from middle to high school. Taken together, these findings highlight neural plasticity during adolescence and underscore the detrimental role of cultural stereotypes of teens in shaping youth's neural and psychological development at this stage.

Conclusions and Future Directions

Most of the studies in developmental cultural neuroscience to date have exclusively used cross-sectional designs, which compare children in different cultural groups at a single time point or examine how individual differences in cultural experiences correlate with neural processing. Although some studies have examined how the neural processing of cultural values relates to longitudinal changes in adolescents' internalizing and externalizing symptoms (e.g., Telzer, Fuligni, Lieberman, & Gálvan, 2013b, 2014), to the best of our knowledge no study so far has utilized longitudinal neuroimaging scans to examine how culture and brain correlations change over development.

Conceptually, cross-sectional designs treat childhood and adolescence as a snapshot in time (Kraemer, Yesavage, Taylor, & Kupfer, 2000). This static perspective cannot capture both the dynamic nature of brain development and longitudinal relationships between brain and behavior. Statistically, although cross-sectional studies aim to provide information on mean-level differences in terms of neural activation across different cultural groups, it is impossible to know, from only a single time point, if

children's neural systems develop in the same direction or at the same rate in different cultures. For example, although children in two cultures may show the same neural activation at the mean level, children in one culture may be in the upward trajectories and children in the other culture may be in the downward trajectories. Such differences would not be observable in children's mean-level activation at a single time point. Therefore, many scholars highlight the importance of applying longitudinal approaches to research in developmental neuroscience (e.g., Dahl, 2011).

Longitudinal studies on adolescent brain development have revealed striking neural changes as children navigate the teen years (Braams, van Duijvenvoorde, Peper, & Crone, 2015; Pfeifer et al., 2011; Qu, Galván, Fuligni, Lieberman, & Telzer, 2015). While all these studies have been conducted with Western samples, the results provide initial evidence for how the brain is changing across development, underscoring significant neural changes that occur during the adolescent years. In fact, neural processing may be more variable and sensitive to the social and cultural environment during adolescence than during childhood or adulthood, as evidenced by greater variability and less stability in neural processing across 3-month intervals (van den Bulk et al., 2013), as well as by greater sensitivity to the social context in adolescence (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011). This line of research suggests that culture may exert greater influence on children's brain development during this period of development. Therefore, future studies should employ a longitudinal neuroimaging approach to investigate how culture contributes to divergent trajectories of children's brain development and how such different neural trajectories lead to different changes in children's adjustment over time. This can inform our understanding of how culture is internalized at the neural level and how that changes across time. Moreover, longitudinal neuroimaging enables us to examine the reciprocal relationships between culture, brain, and child functioning.

A second important future direction is to design culturally relevant tasks that capture culture-specific values and practices. These tasks need to meet two criteria. First, they need to reflect specific cultural values or knowledge. By capturing key cultural values in the tasks, investigators can measure the neural processes that are shaped by such cultural values. However, this does not mean that the task design needs to be complicated. Differences in cultural values can be reflected in a variety of areas, ranging from low-level sensory/perceptual processing to high-level social cognitive processing and decision making. Therefore, the usefulness of tasks

depends on whether cultural values play a role in the design paradigm. Second, tasks need to be developmentally appropriate. The latter may be particularly important when researchers plan to examine neural functioning longitudinally or across different developmental groups. This requires that participants of different ages are able to understand and perform the task, so that the comparison is meaningful.

A good example of culturally relevant tasks is the family donation task developed by Telzer and colleagues (2010). The key purpose of this task was to capture family obligation in Latino-American families. In this task, youth can earn money for themselves and contribute money to their family. In particular, they can contribute money to their family at a cost to themselves, a behavior that closely approximates family obligation behaviors. Although it embodies a relatively complex psychological construct, the task is ecologically valid for several reasons. First, meaningful cultural group differences emerged, so that Latino and European youth showed distinct neural signals during the task (Telzer et al., 2010). Second, activation during the task was correlated with meaningful behaviors and values, including how fulfilled they felt in their daily lives when helping their family (Telzer et al., 2010) and how much they valued family obligation (Telzer et al., 2016). Third, neural activation during the task had significant predictive validity across time, predicting trajectories of psychological functioning (Telzer, Fuligni, Lieberman, & Gálvan, 2013b, 2014). Finally, the task is widely used across samples and age groups (Telzer et al., 2010, 2016).

In conclusion, numerous empirical studies in adults have demonstrated that individuals in different cultures show different neurobiological processes underlying a variety of psychological functioning, such as face perception, language, memory, self-judgment, emotion, and perspective taking (e.g., Chiao & Ambady, 2007; Freeman et al., 2009; Kim & Sasaki, 2014; Zhu et al., 2007). However, without systematic examination of the developmental process, little is known about how culture influences the brain as individuals develop from childhood to adulthood, and how such brain development underlies cultural differences in psychological adjustment across time. Developmental cultural neuroscience provides researchers with a unique approach to investigating *when*, *how*, and *why* children in different cultures show divergent neural, psychological, and behavioral trajectories in the course of development. Advances in this promising field may provide valuable insights into cultural transmission and neuroplasticity, with implications for promoting children's learning and mental health in diverse cultures.

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