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Opinion

A Culture–Behavior–Brain Loop Model of Human Development

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Increasing evidence suggests that cultural influences on brain activity are associated with multiple cognitive and affective processes. These findings prompt an integrative framework to account for dynamic interactions between culture, behavior, and the brain. We put forward a culture–behavior–brain (CBB) loop model of human development that proposes that culture shapes the brain by contextualizing behavior, and the brain fits and modifies culture via behavioral influences. Genes provide a fundamental basis for, and interact with, the CBB loop at both individual and population levels. The CBB loop model advances our understanding of the dynamic relationships between culture, behavior, and the brain, which are crucial for human phylogeny and ontogeny. Future brain changes due to cultural influences are discussed based on the CBB loop model.

Cultural neuroscience research combines cultural psychology, brain imaging, and genetics to investigate whether and how cultural contexts/experiences interact with genes to shape the functional organization of human brain and behavior.

Cultural neuroscience findings suggest indirect culture–brain interactions, through practice of behaviors, and direct culture–brain interactions, which constitute an interacting loop that provides a basis of human development.

The CBB loop model of human development considers different timescales along which genes and culture interact with the brain and behavior, and highlights genetic interactions with the CBB loop.

The CBB loop model can be used to predict future brain changes.

Neuroscience Enters the Culture Arena

Why do people in culturally-distinct societies behave differently? This fascinating question has been studied extensively in psychology by examining human cognitive and affective processes across **cultures** [1,2]. For example, one line of research that compares individuals from East Asian and Western cultures has revealed that East Asians tend to attend to contexts and relationships between objects [3,4], categorize objects in terms of their relationships [5], emphasize contextual effects during causal attribution of physical and social events [6,7], view the self as being interdependent with significant others and social contexts [8,9], and prefer low-arousal positive affective states [10]. By contrast, individuals from Western cultures are inclined to attend to a focal object, categorize objects by their internal attributes, emphasize individuals' internal dispositions during causal judgments, view the self as being independent of others and social contexts, and favor high-arousal positive affective states. These findings support a conceptual framework that **collectivistic** East Asian cultures foster a holistic thinking style whereas **individualistic** Western cultures cultivate an analytic thinking style [11].

Because mental activity is underpinned by the neurobiology of the brain that is shaped by experience [12], increasing interest has emerged in the discovery of brain activities that underlie cultural differences in mental processes and behaviors. Viewing culture as beliefs and behavioral scripts that are shared by a group of individuals

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visual perception [20–22], attention [23,24], causal attribution [25], processing semantic relationships [26], processing music [27,28], mental calculation [29], self-face recognition [30,31], self-reflection [32–36], perception of body gesture [37], mental state reasoning [38,39], empathy [40,41], and trait inference [42] (Box 1). Researchers have also investigated the role of a specific cultural trait in mediating individual differences [33,35] and cultural group differences in brain activities [24,36,42]. Studies of **cultural priming** (Box 1) have shown that reminding participants in laboratory studies of specific East Asian/Western cultural values, such as independence versus interdependence, modulates brain activity during tasks that engage pain perception [43], visual perception [44], self-face recognition [45], self-reflection [46–48], motor processing [49], and brain activity during a resting state [50].

The increasing number of cultural neuroscience findings propels a conceptual framework that integrates dynamic interactions between culture and th5669234.7082525.4865Tm()Tj/7.708.9663395.0928621.1274Tm(brain)Tj-37Tm()Tj/F5Tfe

The CBB Loop Model of Human Development

The CBB Loop Model

The CBB loop model, as illustrated in Figure 1, posits that novel ideas are created by individuals and are diffuse in a population through social interactions in a specific ecological environment to become dominant shared beliefs and behavioral scripts that influence and contextualize human behavior. The functional and/or structural organization of the brain, owing to its inherent plasticity, changes as a consequence of absorbing cultural values and performing culturally patterned behaviors. The modified brain then guides individual behavior to fit into specific cultural contexts, and also modifies concurrent sociocultural environments. The CBB loop model proposes two types of behaviors. Culturally contextualized behavior (CC-behavior) refers to overt actions that are mainly governed by a specific cultural context, such as when a Chinese student who is accustomed to accepting a professor's opinion in China arrives in the USA and imitates American students to argue with a professor. CC-behavior may not occur when leaving a specific cultural environment. Culturally voluntary behavior (CV-behavior) denotes overt actions that are guided by specific cultural beliefs/values and behavioral scripts that are encouraged by a specific cultural environment and are embedded in the brain. For example, after the Chinese student has studied in the USA for a long time, and has internalized Western cultural values such as independence, he may default to arguing with a professor, regardless of the actions of his peers. CV-behaviors can occur independently of a specific cultural context if the cultural system in the brain remains stable to some degree.

The CBB loop model also distinguishes between two types of culture–brain interactions. Behavior-mediated culture–brain interaction refers to the interplay between culture and brain via overt behavioral practice. For instance, Western cultural values such as independence in the USA encourage the Chinese student to argue with his professors, and practicing such behaviors influences his brain. Direct culture–brain interaction refers to the interplay between culture and brain that does not involve overt actions. For example, reminding individuals of specific cultural values such as independence or interdependence in a laboratory setting can directly modulate brain activity. Thus, in the CBB loop model, behavior is not simply considered as a consequence of culture–brain interaction. Instead, behavior is considered as a part of the mechanisms of human development. The three key nodes, culture, behavior, and the brain, dynamically interact through their mutual connections and constitute a loop. Each node, and the connection

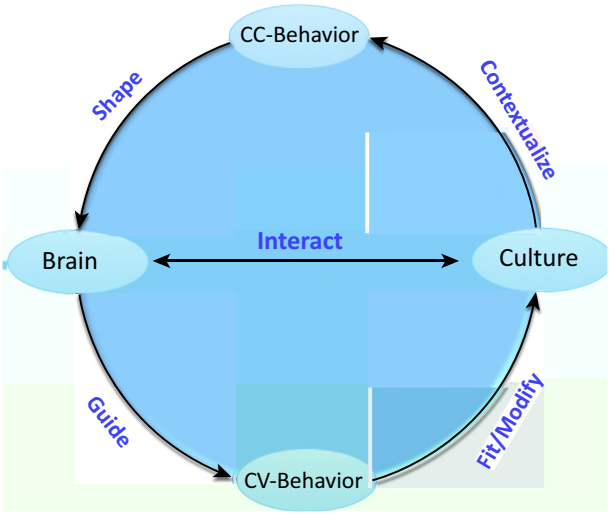
Individualism: a basic cultural element that emphasizes the importance of independence, one's own goals/preferences, needs/desires, and rights in thought and behavior. People in an individualistic culture give priority to personal rather than to group goals.

Independent self-construal: the cultural trait of viewing the self as autonomous and bounded entity, emphasizing independence and uniqueness of the self.

Interdependent self-construal: the cultural trait of viewing the self as interconnected and overlapping with close others, emphasizing harmony with close others.

Medial prefrontal cortex (mPFC): the medial region of the prefrontal cortex that is involved in social cognition, with the dorsal part being engaged in mental state reasoning and the ventral part engaged in self-reflection.

Temporoparietal junction (TPJ): a brain region at the border of the posterior parts of the temporal lobe and the inferior parts of the parietal lobe. This brain region is engaged in taking the perspective of others and inferring their mental states.



Trends in Cognitive Sciences

Figure 1. Illustration of the CBB Loop Model of Human Development. Cultural environments contextualize human behaviors. Learning novel cultural beliefs and the practice of different behavioral scripts in turn modify the functional organization of the brain. The modified brain then guides individual behavior to voluntarily fit into a cultural context and meanwhile to modify current cultural environments. Direct interactions also occur between culture and brain without overt behavior. Abbreviations: CBB, culture–behavior–brain, CC-Behavior, culturally contextualized behavior; CV-Behavior, culturally voluntary behavior.

between two nodes of the CBB loop, vary continuously across time and influence human phylogeny and ontogeny.

To illustrate human development in the CBB loop framework, let us consider a key cultural trait (i.e., interdependence/independence) that differentiates between East Asian and Western societies (Western culture encourages **independent self-construal** that views the self as an autonomous and bounded entity, whereas East Asian culture promotes **interdependent self-construal** that views the self as interconnected and overlapping with close others [8]). Previous research suggests that the idea of interdependence/independence emerged during dynamic changes of ecological environments (e.g., adaptation to rural environments prioritizes social obligation/duty and social belonging to promote a strong connection between the self and others, whereas adaptation to urban environments prioritizes choice and personal possessions to foster the unique self [56]) and during specific social practice (e.g., farming and fishing communities emphasize harmonious social interdependence, whereas herding communities emphasize individual decision-making and foster social independence [57]). Individuals dominated by interdependence or independence behave differently, such as categorizing objects in terms of their relationships or attributes, respectively [5,8]. Moreover, priming interdependence or independence in laboratories induces behavioral changes. For instance, priming interdependence speeds responses to a friend's face, whereas priming independence speeds responses to one's own face [45]). Cultural neuroscience research has further revealed that interdependence/independence correspond to distinct patterns of brain activity in different cultures, such as increased activity in the **temporoparietal junction** (TPJ) in East Asians compared to Westerns [36] (Box 1). Moreover, priming interdependence/independence can lead to changes of brain activity. Specifically, priming independence increases right frontal activity during perception of one's own face [45–50]. Culturally patterned brain activity, such as the increased TPJ activity in East Asians [36], may be associated with the ability to take others' perspectives voluntarily [58] such that one can easily fit into a collectivistic cultural context. Therefore, interdependence/independence, behavior, and related brain function constitute a circular interaction during which culture, behavior, and the brain vary dynamically.

At the group level, behaviors guided by shared beliefs may lead to similar changes of brain functional organization in a population, and this facilitates group behavioral adaptation to sociocultural contexts. In support of this notion, cultural neuroscience studies have shown evidence for cultural group differences in brain activity and behavior (e.g., Westerners vs East Asians [20–32], atheists vs Christians/Buddhists [33,34]). However, the group difference does not necessarily indicate homogeneity of brain activity and behavior across all individuals in a society. At the individual level, practice of culture-specific behavioral scripts results in unique functional organization of the brain and associations between a cultural trait and brain activity {e.g., correlations between interdependence and activity in the **medial prefrontal cortex** (mPFC) across individuals [35,36]} that can provide a neural basis of CV-behavior and help an individual to adapt to a cultural context. This occurs during both child development in a specific sociocultural environment and adult acculturation during emigration. Human development is influenced by how easily each node of the CBB loop can be modified and changed, how strongly two connective nodes influence each other, and how quickly a circular interaction in the CBB loop occurs. The CBB loop model characterizes dynamic interactions between culture, behavior, and the brain by assuming culture-induced brain changes in a population during human phylogeny, and in an individual during human ontogeny. Next we will discuss evidence for connections between each pairing of nodes in the CBB loop.

Culture Influences Behavior

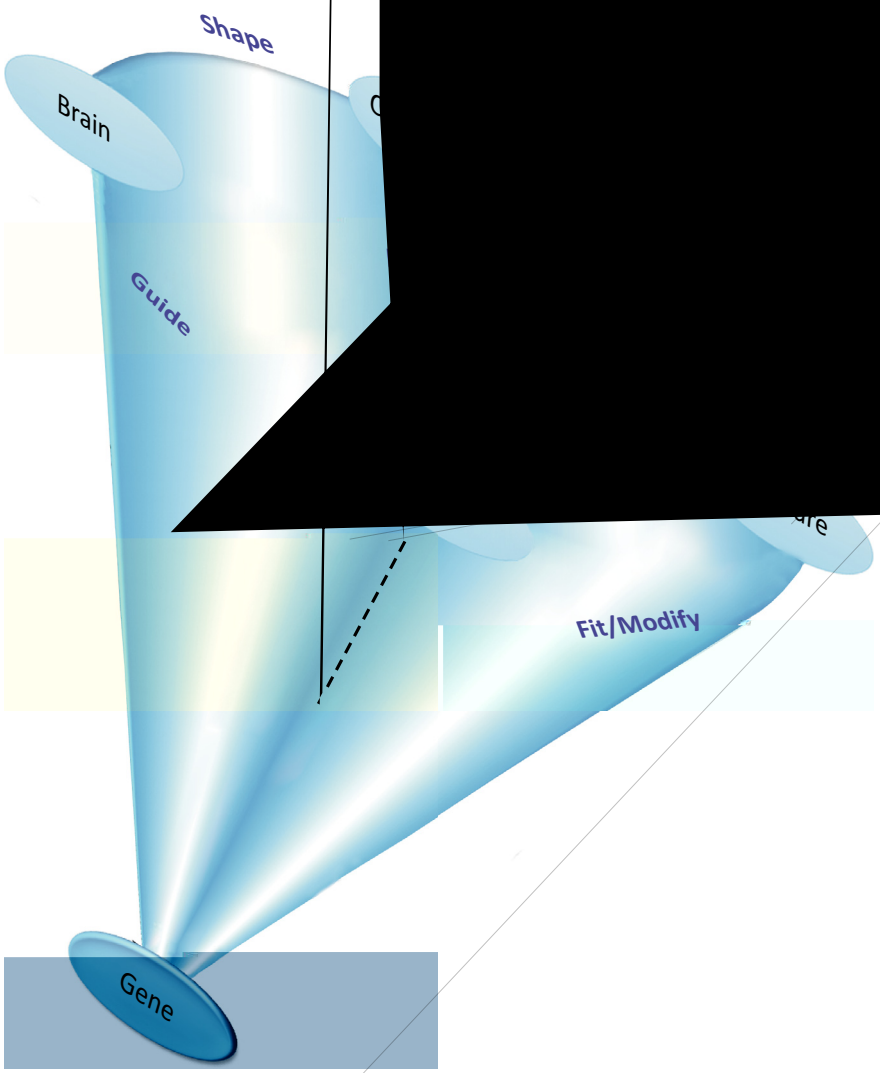
The impact of culture on behavior is evident in both the history of humankind and in extant societies. Shared cultural beliefs can induce huge behavioral changes. For instance, shared

beliefs that farming would supply more food produced one motivation for transition from gathering/hunting to farming during the Agricultural Revolution [59]. There are many behavioral differences in contemporary individualism/collectivism societies that developed as adaptations to the environment [60]. As an example, at the individual level, parents who believe/value independence in an individualistic society may put their children to sleep in separate bedrooms after birth, whereas parents who believe/value interdependence in a collectivistic society may share a bedroom with their children until early adulthood [61]. There are ample evidence that people acquire different beliefs and behavioral scripts that

reward-related activity in the bilateral ventral striatum in response to winning money for a friend during a gambling game [74]. Priming interdependence versus independence decreased early sensory responses to painful electric shocks [43], increased motor-evoked potentials induced by transcranial magnetic stimulation during an action observation task [49], and increased local synchronization of spontaneous activity in the dorsal region of the mPFC – but

Key Figure

Illustration of the Relationship B



cultural and behavioral influences on the brain occur much faster (e.g., lifespan) [62]. Cultural priming on the timescale of minutes in a laboratory setting can even induce functional changes of brain activity during a variety of tasks [43–50]. Given that the brain changes associated with genetic and cultural factors operate at different speeds, we suggest that genes interact with the CBB loop by providing a fundamental basis for the CBB loop in several ways, as illustrated in Figure 2

take a recent example, the rapid growth of internet commerce and communication has created 'an internet culture' [77] that has changed human behaviors substantially and may lead to modification of brain function. For instance, the internet search engines allow students to

how to access these literatures rather than to remember their contents [99]. Thus, the neural structures that are currently used to store and retrieve semantic knowledge (e.g., the inferior

cingulate – areas related to the inference of others' mental states and empathy

and smartphone also keep people continuously digitally

[78,103] lead to a high level of disc

tasks that may br

changes of brain functions, which should be test

search, may help the next generation to easily fit into the internet

Meanwhile, the brain shaped by the internet culture may produce new

online shopping and social networking) that may modify

environment

Concluding Remarks

Although cultural neuroscience findings related to the CBB loop model of human development are mainly derived from studies of individuals from East Asian/Western cultures, this model can advance our understanding of the relationships between culture, behavior, and the brain in general. The CBB loop model gives prominence to the dynamic features of CBB interactions that allow continuous changes of culture, behavior, and the brain. The CBB loop model proposes cultural and genetic modifications of the functional organization of the brain along different timescales, and this has important implications

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