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Culture and education: new frontiers in brain plasticity

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Cognitive neuroscience has started to probe cross-cultural differences in the neuronal mechanisms underlying cognitive, perceptual and social domains. Moreover, brain imaging has revealed how education changes the brain. Such research opens up a new frontier in brain plasticity research, breaking down the boundaries between neuroscience and other traditionally non-biological disciplines, resulting in many conceptual and practical implications.

Towards an interdisciplinary science of uniquely human brain plasticity

Investigations into neuronal plasticity – how the brain changes with experience – represents a major trend in the neurosciences. Research in this vibrant field has demonstrated that the brain is not a static organ, but is changeable (within constraints) in response to experience. Historically, most work on neuronal plasticity has focused on experience-dependent changes in sensorimotor brain functions in animals, such as dynamic changes in the motor cortex following the amputation of limbs, or reorganization in the auditory and visual cortices as a result of sensory deprivation or enrichment [1]. These studies have provided unprecedented insights into the experience-dependent changes in brain function at molecular, cellular and systems levels of description with clear clinical implications. Moreover, following the advent of non-invasive neuroimaging methods, it has become possible to study the consequences of sensorimotor deprivation and enrichment as well as learning on the human brain, such as changes that are associated with acquiring new, complex motor skills [2]. Although these studies have enhanced our understanding of the 'changeable brain', neither animal models nor studies of basic sensorimotor plasticity in the human brain can provide insights into the plasticity associated with uniquely human learning and experiences.

Research in cross-cultural psychology and anthropology has demonstrated that human cognitive functions differ markedly across cultures. Furthermore, both formal and informal education leads to changes in cognitive and social functions, and these differ across contexts and cultures. Behavioral studies have demonstrated that cultural changes affect not only high-level functioning, such as social cognition, but also basic perceptual processing [3]. Therefore, a comprehensive human cognitive neuroscience requires an exploration of the mechanisms by which cross-cultural variability creates differences in brain function and structure.

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Until recently, brain research was not commonly thought to be capable of providing much insight into cross-cultural variability and the effects of education. Thus, brain research and the study of the transformative effects of culture and education operated in isolation of one another. Contemporary research, however, demonstrates that this state of affairs is rapidly changing. Against the backdrop of advances in the understanding of human neuronal plasticity, as well as the availability of functional neuroimaging methods to tap into the neural mechanisms underlying complex human functions, researchers have begun to use neuroscience to constrain our understanding of the way in which culture and education shape human neurocognitive functions.

The emerging body of studies on the effects of culture and education on human brain function and structure is challenging the dichotomy between, on the one hand, neuroscience as describing biologically determined variations between people and, on the other hand, social sciences as accounting for sociocultural and educational differences. Specifically, the available evidence is revealing striking cross-cultural differences in the brain mechanisms underlying a wide range of cognitive functions including, for example, arithmetic [4], reading [5] and self-representation [6]. Even comparatively lower-level perceptual brain processes related to object processing [7] and attentional control [8] have been found to be modulated by culture. Such findings draw attention to two important issues. First, these data show just how powerful is the influence of culture on brain function, and second, they question the generalizability of neuroimaging findings from participants in one culture to human brain function across cultures. Can we advocate a universal cognitive neuroscience of human brain function without running systematic cross-cultural studies to investigate the cultural effects on basic perceptual as well as complex neurocognitive functions?

In addition to the study of cultural effects on brain function, a complementary body of recent empirical endeavors has mapped plastic neuronal changes that occur in response to educational intervention to increase reading [9] and numeracy [10] skills. Furthermore, recent structural and functional neuroimaging studies comparing literate and illiterate participants have provided new insights into the plastic changes in brain function that result from the acquisition of reading skills [11,12]. Surprisingly, these studies are revealing that learning how to read not only brings about the specialization of brain mechanisms typically associated with fluent reading, but also has effects on the functioning of other brain regions, such the neural correlates of speech perception and categorical visual processing in the ventral stream [12]. In other words, the acquisition of cultural skills such as

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reading results in functional plasticity across a wide range of brain networks. Such data raise the possibility that small educational or cultural differences can lead to broad (and not exclusively domain-specific) neuronal plasticity. One clear implication from these findings is that cognitive neuroscientists should use a variety of tasks to probe the potential for plasticity in brain functions other than those that are the focus of the educational experience; that is, what are the transfer effects of educational experiences at the level of brain function and structure?

Challenges and future directions

The study of how culture and education shape brain function is a growing direction within cognitive neuroscience. For this emerging field of inquiry to reach maturity, a number of challenges need to be overcome. First, it is important that cognitive neuroscientists work in collaboration with experts in the long-standing, empirical study of cross-cultural variability, such as anthropologists and cross-cultural psychologists as well as educational researchers. Only through interdisciplinary interactions and the establishment of a common language will true progress be made. In this vein, it is important carefully to consider definitions of culture that go beyond broad categorizations such as 'East Asia' versus 'The West'. Cultures are complex and such simple dichotomies will, in the long run, not suffice to fully characterize the interaction between cultural variability and brain function. The same issues apply to studies of brain plasticity that result from educational experiences, where more refined operational definitions are needed, including differentiations between formal and informal education.

Important questions arise when considering the effects of culture and education across the life span. Are there sensitive periods for education and culture-dependent brain plasticity? Answers to questions such as this could have important implications for the timing, content and cultural context within which educational interventions occur. Even in adulthood, individuals change their cultural environment through migration. Could cognitive neuroscience provide new insights into the effects of migration and the constraints on cultural integration?

From the perspective of studying brain plasticity, it is important to acknowledge that, although non-invasive brain imaging methodologies can be used to study experience-dependent changes in brain function and structure, the precise mechanisms often remain opaque given the limitations of currently available methods for human brain imaging. In this context, it is important to develop mechanistic models for the way in which culture affects brain function that draw on evidence from brain evolution and establish how mechanisms subserving sensorimotor plasticity provide the basis for the plasticity that is induced by educational and cultural experiences [13,14] (connecting the 'traditional approaches' and 'new frontiers' displayed in Figure 1). Furthermore, such theoretical frameworks should not only consider how culture influences brain plasticity, but also endeavor to provide explanatory frameworks for how brain plasticity came to enable cultural variability as well as the transmission of culture across generations through education (see bidirectional arrows in Figure 1).

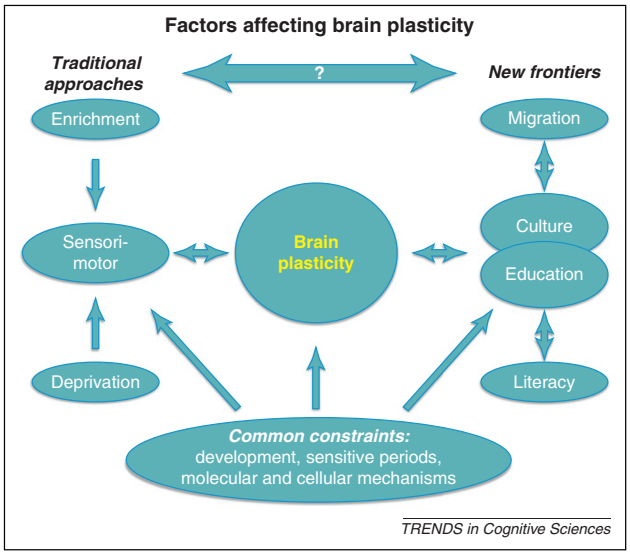

Figure 1. Variables influencing brain plasticity. The left-hand side of the figure depicts factors traditionally studied in research on neuronal plasticity; the right-hand side displays more recently studied variables in brain plasticity.

Often, the emergent fields of 'cultural neuroscience' and 'educational neuroscience' are discussed separately from one another. Yet there is clearly potential in discussing the effects of culture and education on brain function as interactive factors. Culture shapes pedagogy and educational infrastructure and, in turn, education is a major vehicle by which children become enculturated. The study of human brain plasticity should therefore consider these interactive factors together rather than in isolation. In this way, cognitive neuroscience may provide a bridge between traditionally separate disciplines of study and connect traditional 'biological' and 'sociocultural' research fields. In other words, cognitive neuroscience may provide an important hub for connecting previously, arguably artificially, disconnected domains of inquiry and thus lead to new interdisciplinary conceptualizations as well as societal discourse about the role of neuroscience in understanding complex human behavior. Cognitive neuroscience can, for example, serve to further inform questions such as how cross-cultural differences lead to variability in educational achievement.

Although culture and education were previously not commonly considered candidates for the study of neuronal plasticity, recent efforts demonstrate that cognitive neuroscience can enhance our understanding of culture and education. It is now possible to characterize how uniquely human experiences shape brain function and, in turn, consider how neuronal mechanisms give rise to culture, thereby opening new horizons in the study of uniquely human brain functions. This new research is opening pathways between traditional 'social' and 'biological' approaches. Results from this research will change societal discourse and have important implications for a better understanding of educational and social problems.

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