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Neural processes underlying cultural differences in cognitive persistence

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ABSTRACT

Self-improvement motivation, which occurs when individuals seek to improve upon their competence by gaining new knowledge and improving upon their skills, is critical for cognitive, social, and educational adjustment. While many studies have delineated the neural mechanisms supporting extrinsic motivation induced by monetary rewards, less work has examined the neural processes that support intrinsically motivated behaviors, such as self-improvement motivation. Because cultural groups traditionally vary in terms of their self-improvement motivation, we examined cultural differences in the behavioral and neural processes underlying motivated behaviors during cognitive persistence in the absence of extrinsic rewards. In Study 1, 71 American (47 females, M=19.68 years) and 68 Chinese (38 females, M=19.37 years) students completed a behavioral cognitive control task that required cognitive persistence across time. In Study 2, 14 American and 15 Chinese students completed the same cognitive persistence task during an fMRI scan. Across both studies, American students showed significant declines in cognitive performance across time, whereas Chinese participants demonstrated effective cognitive persistence. These behavioral effects were explained by cultural differences in self-improvement motivation and paralleled by increasing activation and functional coupling between the inferior frontal gyrus (IFG) and ventral striatum (VS) across the task among Chinese participants, neural activation and coupling that remained low in American participants. These findings suggest a potential neural mechanism by which the VS and IFG work in concert to promote cognitive persistence in the absence of extrinsic rewards. Thus, frontostriatal circuitry may be a neurobiological signal representing intrinsic motivation for self-improvement that serves an adaptive function, increasing Chinese students' motivation to engage in cognitive persistence.

Introduction

Motivation is perhaps the most important construct in the educational and workforce systems. A distinction has been drawn between internal (or intrinsic) and external (or extrinsic) motivation. Intrinsic motivation refers to doing something because it is inherently interesting or enjoyable irrespective of the outcome. Such motivated behaviors, while no doubt adaptive to the organism, are not done for instrumental reasons, but instead for the positive experience associated with extending oneself (Ryan and Deci, 2000). For instance, individuals may engage in a challenging task for the inherently rewarding nature of improving upon their skills. Self-improvement motivation, which occurs when individuals seek to improve upon their competence by gaining new knowledge and improving upon their skills, is critical for cognitive, social, and educational adjustment. In contrast, extrinsic motivation is driven by the outcome or external factors and has a negative impact on enjoyment and future motivation (Deci et al., 1991). For instance, extrinsic rewards (Deci et al., 1999), threats (Deci and Cascio, 1972), or competitive pressure (Reeve and Deci, 1996) diminish interest, enjoyment, and internal motivation (Ryan and Deci, 2000).

While many studies have delineated the neural mechanisms supporting extrinsically motivated behaviors, such as those induced by monetary rewards (e.g., Delgado et al., 2000, 2003; Elliott et al., 2004; Kirsch et al., 2003; Knutson et al., 2000; Geier et al., 2009, 2012; Geier et al., 2010; Padmanabhan et al., 2011; Murayama et al., 2010), less work has examined the neural processes that support intrinsically motivated behaviors. Developmental work has shown that adolescents show improved cognitive control when they are rewarded for doing so (Geier et al., 2009, 2012; Geier et al., 2010; Padmanabhan et al., 2011) and exhibit increased activation compared to children and adults in the ventral striatum when their efforts are extrinsically rewarded (Padmanabhan et al., 2011). Yet, incentivizing individuals with money or other extrinsic rewards can undermine intrinsic motivation (Deci

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et al., 1999; Murayama et al., 2010) and result in negative long-term effects on future motivation (Gneezy et al., 2011). Thus, our goal was to examine the behavioral and neural correlates of motivated behaviors in the absence of extrinsic rewards. Moreover, because cultural groups traditionally vary in terms of their self-improvement motivation, we examined cultural differences in the behavioral and neural processes underlying motivation and cognitive persistence.

The maintenance and enhancement of self-improvement motivation requires a rearing environment that supports and values motivated behaviors, as motivation can be disrupted by unsupportive conditions (Ryan and Deci, 2000). Thus, the social and cultural context can either promote or undermine the natural tendency to extend and exercise one's capacities (Ryan and Deci, 2000). Cross-cultural research has found that individuals from collectivistic cultures (e.g., East Asians) tend to be more intrinsically motivated in academics than more individualistic individuals (e.g., Americans). Recent meta-analyses have revealed consistently high self-improvement motivation in East Asian populations (Heine and Hamamura, 2007), although research has also shown these patterns in other collectivitistic cultures such as Chileans (Heine and Raineri, 2009). Such heightened self-improvement motivation likely arises due to rearing environments that differentially value motivated behaviors. For instance, persistence is highly valued throughout the educational process in many East Asian countries. In Japanese, the term *gambaru* means to persevere through tough times and to do more than one's best to succeed (Binco, 1992) and in China, Confucian teaching emphasizes the exertion of effort in the learning process, which is seen as a moral endeavor and a lifelong task to improve oneself (Chao and Tseng, 2002; Heine et al., 2001; Li, 2004). Shortcuts are looked down upon as persistence to attain a goal is valued and encouraged (Binco, 1992). Moreover, the Chinese notion of *guan,* which means to govern and to love, is evident in parenting practices, including *chiao shun* (training) of children, which characterizes parents' monitoring and correcting children's behavior to ensure they exert effort to do well in school (Chao, 1994). Indeed, Chinese mothers place greater emphasis on their children achieving and improving themselves than do American mothers (Qu, Pomerantz, and Deng, 2016). Finally, the preschool setting in China encourages and values strong cognitive control skills (Tobin et al., 1989), opportunities that are not necessarily provided by or valued in American schools and families (Sabbagh et al., 2006). Thus, collectivitistic cultures socialize children to inherently value self-improvement and to persist in challenging tasks, whereas in American culture, there is a relative lack of persistence and a greater tendency to give up in the face of challenge (Binco, 1992; Heine and Raineri, 2009).

Frontostriatal circuitry is involved in motivated behaviors and effective cognitive control (Casey et al., 2011). The ability to persevere through difficult challenges relies on the lateral prefrontal cortex (PFC). The PFC supports the ability to select and motivate thoughts and actions in relation to internal goals (Kouneiher, Charron, and Koechlin, 2009). In both humans and primates, the inferior frontal gyrus (IFG) is involved in regulation, inhibitory control, and cognitive flexibility (Aron, Robbins, and Poldrack, 2004; Levy and Wagner, 2011; Brass et al., 2005; Neubert et al., 2014; Egner, 2011), and is the center for preparatory responses to engage in effective cognitive control to achieve goals (Matsumoto et al., 2003; Bunge, 2004). Individuals who are not motivated to engage in challenging tasks show decreases in IFG activation over time (Murayama et al., 2010), and adults with poor delay of gratification measured prospectively in childhood show lower IFG activation during cognitive control (Casey et al., 2011), underscoring the important role of the IFG in promoting motivated behaviors.

In addition to the IFG, the mesolimbic reward system supports motivated behaviors. The positive experience associated with extending oneself promotes enjoyment and spontaneous self-satisfaction (Ryan and Deci, 2000). Thus, the ventral striatum (VS), which responds to rewards and is tightly tied to motivated behavior in both humans and animals (Knutson and Cooper, 2005; Spear, 2011; Pessiglione et al., 2006; Ikemoto and Panskepp, 1999; Delgado, 2007) is likely linked to the rewarding nature of self-improvement. Indeed, ventral striatum activation during challenging tasks promotes more effective working memory, (Satterthwaite et al., 2012), and is associated with intrinsic motivation (Murayama et al., 2010), suggesting that ventral striatal responses during challenging cognitive control tasks may reflect intrinsic reinforcement signals.

In the current study, we recruited two samples of students, Chinese and Americans, who traditionally vary in terms of their self-improvement motivation. In Study 1, we examined cultural differences in self-improvement motivation and cognitive persistence. Participants completed a cognitive control task that required effort and persistence with no reinforcements or rewards. Cognitive persistence was measured by examining change in performance across the task. East Asian culture socializes children to engage in self-improvement and persist in challenging tasks, whereas in American culture, there is a relative lack of persistence and a greater tendency to give up when performing difficult tasks (Binco, 1992). Indeed, prior work has shown that East Asian students are more likely to persist following failure compared to their American counterparts (Heine et al., 2001). We therefore hypothesized that Chinese students would show greater cognitive persistence, and this would be explained by their increased motivation for self-improvement.

In Study 2, we examined the neural processes that explain cultural differences in cognitive persistence. Because individuals who are not motivated to engage in challenging tasks show decreases in IFG activation over time (Murayama et al., 2010), we hypothesized that Chinese students' increased motivation to engage in self-improvement would rely on increasing engagement of the IFG, suggesting increasing effort and persistence. In addition, because persistence and self-improvement are highly valued in East Asian culture, and effort is seen as a moral endeavor (Chao and Tseng, 2002; Heine et al., 2001; Li, 2004), we hypothesized that Chinese students would evidence increasing ventral striatum activation over time, ventral striatum activation that would remain low in American students across the task. Finally, the ventral striatum may be functionally connected to the IFG through bottom-up processing that facilitates cognitive engagement. Thus, in addition to examining neural reactivity in the IFG and ventral striatum, we examined functional coupling between these regions in order to test whether reward processes facilitate effective cognitive engagement. We hypothesized that Chinese students' increased self-improvement motivation may be subserved through reward processes that shape their motivation to engage in cognitive control. Thus, Chinese students would show increasing functional coupling between the striatum and IFG across the task, functional coupling that would promote more effective cognitive persistence.

Study 1 methods

Participants

Participants included 71 American (47 females, M=19.68 years) and 68 Chinese (38 females, M=19.37 years) students. All American participants were born and raised in the United States and were of European decent. All Chinese participants were born and raised in China, had lived in China for at least 18 years, and came to United States for college. Participants were matched in terms of age and level of education. Participants provided written consent in accordance with the University of Illinois' Institutional Review Board.

Cognitive persistence task

Participants completed several rounds of a Go-NoGo (GNG) Task to target cognitive persistence. Participants were presented with a series of rapid trials (500 ms), each displaying a single letter, and were

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