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Neural mechanisms of proactive and reactive cognitive control in social anxiety

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ABSTRACT

Social anxiety—the fear of social embarrassment and negative evaluation by others—ranks among people's worst fears, and it is often thought to impair task performance. We investigated the neurocognitive processes through which trait social anxiety relates to task performance, proposing a model of the joint contributions of reactive control, theoretically associated with conflict monitoring and activity of the dorsal anterior cingulate cortex (dACC), and proactive control, theoretically associated with top-down regulation and activity of the dorsolateral prefrontal cortex (dlPFC). Participants varying in their degree of trait social anxiety completed the Eriksen flanker task while electroencephalography (EEG) was recorded. Task-related left dlPFC activity was indexed by relative left prefrontal EEG (inverse alpha), and conflict-related dACC activity was indexed by the N2r component of the event-related potential. Stronger activity in both regions predicted better response control, and greater social anxiety was associated with worse response control. Furthermore, for all participants, greater left prefrontal EEG activity predicted better behavioral control, but for high social anxiety participants only, greater N2r responses also predicted behavioral control. This pattern suggests that high social anxiety individuals relied more strongly on a reactive control pattern, driven by conflict-related dACC activity, whereas low social anxiety individuals engaged a proactive control pattern, driven primarily by dlPFC activity. These findings support a model of control that involves different patterns of interplay between proactive and reactive strategies and may help to explain self-regulatory impairments in social anxiety.

1. Introduction

When people are asked to rank their greatest fears, the fear of public embarrassment often tops the list. According to some popular surveys, fear of public speaking even outranks fear of one's own death (Croston, 2012). Considering the importance of community support and social standing for human survival, the desire to avoid embarrassment, criticism and social rejection should not be surprising (Williams, 2007). What is ironic, perhaps, is that social anxiety, born out of the need to perform well in front of others, is often thought to undermine

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performance, especially on relatively difficult tasks that require a high degree of cognitive control.

Although the notion of "choking under pressure" has received empirical support (e.g., Baumeister, 1984; Beilock & Gray, 2007; Wittchen, Fuetsch, Sonntag, Mueller, & Liebowitz, 2000), the extent to which individuals' degree of dispositional social anxiety affects performance on tasks that require cognitive control has received less attention. This is an important question, as cognitive control—the process that governs one's ability to adapt to changing environments while maintaining goal directed behavior—is required in many situations in daily life. In the present research, we asked whether social anxiety is associated with impaired cognitive control and, to the extent that it is, whether different mechanisms of control are recruited depending on individuals' level of social anxiety when performing a task that requires cognitive control. To this end, we examined the relationship between trait social anxiety and cognitive control performance, and compared the roles of two major neural substrates of cognitive control—the left dorsolateral prefrontal cortex (dlPFC) and the anterior cingulate cortex (ACC), assessed using electroencephalography (EEG)—in individuals reporting relative high and low degrees of social anxiety.

1.1. *Cognitive control: psychological mechanisms and neural substrates*

People often encounter situations where they must override a dominant response in order to behave in an intended manner. Whether this involves sticking to one's diet despite a tasty dessert offering or treating someone fairly without the bias of implicit stereotypes, cognitive control is often critical to the pursuit of personal goals (Amodio et al., 2004; Devine, 1989; Heatherton, 2011). In the laboratory, cognitive control is typically investigated using response conflict paradigms such as the Stroop (Stroop, 1935) or flanker (Eriksen & Eriksen, 1974) tasks. These tasks manipulate the need for cognitive control by creating situations in which the attainment of a task goal is either disrupted (or not) by task irrelevant distractors. For example, in the flanker task, participants are required to quickly and accurately identify a target letter placed in the middle of a letter string. The target stimulus is surrounded by non-target stimuli, which correspond either to the same response as the target (congruent trials; e.g., HHHHH) or to the alternative response (incongruent trials; e.g., SSHSS). Incongruent trials (but not congruent trials) elicit response conflict, and enhanced control is required to override the countervailing tendency in order to deliver an intended (i.e., correct) response.

A dominant neurocognitive model proposes that control involves two main components: conflict monitoring and response implementation (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick & Cohen, 2014). *Conflict monitoring* is the process by which conflict between higher-level goals and lower-level response tendencies is detected, and both fMRI and ERP studies have linked this process with activity in the dorsal ACC (dACC; e.g., Kerns et al., 2004). As conflict levels rise, the dACC is believed to increase its signaling to regions of the dorsolateral prefrontal cortex (dlPFC). The dlPFC supports goal representation and response selection, and aids in exerting top-down *regulative control* on behavior. This process describes a *reactive control* process, such that control is engaged in reaction to the detection of conflict (Botvinick et al., 2001; Braver, 2012).

Alternatively, control may be driven by a top-down goal-directed strategy, associated with expectancy, preplanning, and vigilance, that may operate independently of the conflict monitoring process. This *proactive control* process is associated with activity in the dlPFC but not the dACC (Amodio, 2010; Braver, 2012). The proactive/reactive framework described above builds on models that distinguish between the early selection of an intended response strategy and a late correction process that is triggered only when a response conflict is experienced (e.g., Botvinick et al., 2001; Gratton, Coles, & Donchin, 1992; Jacoby, 1991). A consideration of these two forms of control, and their neural substrates, has been useful for explaining why some individuals tend to succeed or fail in self-regulation on tasks requiring cognitive control (e.g., Amodio, 2010; Amodio, Devine, & Harmon-Jones, 2007; Amodio, Master, Yee, & Taylor, 2008).

1.2. *Social anxiety and cognitive control*

The existing links between social anxiety and impaired task performance, reviewed above, suggests that trait social anxiety may be associated with impairment in aspects of cognitive control. To date, research addressing this hypothesis has focused on the degree to which socially-threatening stimuli interfere with task performance, as compared with non-threatening stimuli. The general finding of this work is that socially anxious people perform worse in the presence of socially-threatening distractors compared with healthy controls (Amir, Freshman, & Foa, 2002; Becker, Rinck, Margarf, & Roth, 2001; Grant & Beck, 2006; Lundh & Öst, 1996; Maidenberg, Chen, Craske, Bohn, & Bystritsky, 1996). Although these studies revealed that highly socially anxious individuals are particularly sensitive to socially threatening distractors, they did not address our more general question of whether social anxiety is associated with worse cognitive control, and whether individuals with high versus low social anxiety tend to rely on different forms of control when performing tasks that entail response conflict.

Insights related to these questions come from research in cognitive neuroscience that has begun to examine the roles of ACC and dlPFC activity in control processing among anxious individuals. In particular, conflict-related ACC activity has been associated with some forms of anxiety. For example, patients with obsessive-compulsive disorder exhibited larger amplitudes of the error-related negativity (ERN) component of the ERP (which is primarily generated in the dACC) than non-anxious controls while responding to incongruent trials of the Stroop task (Gehring, Himle, & Nisenson, 2000; Hajcak & Simons, 2002; Soenke et al., 2001). This pattern has also been observed among individuals high in general anxiety (Hajcak, McDonald, & Simons, 2003; Moser, Moran, Schroder, Donellan, & Yeung, 2013). In the same vein, trait and state anxiety have been related to stronger conflict-related ACC activity, as assessed by the N2 ERP component during completion of the Go/No-Go task (Righi, Mecacci, & Viggiano,