Spontaneous default mode network phase-locking moderates performance perceptions under stereotype threat

Chad E. Forbes,[1] Jordan B. Leitner,[1] Kelly Duran-Jordan,[1] Adam B. Magerman,[1] Toni Schmader,[2] and John J. B. Allen[3]

[1]Social Neuroscience Laboratory, Department of Psychological and Brain Sciences, University of Delaware, Newark, DE, USA, [2]Department of Psychology, University of British Columbia, Vancouver, BC, Canada, and [3]Department of Psychology, University of Arizona, Tucson, AZ, USA

This study assessed whether individual differences in self-oriented neural processing were associated with performance perceptions of minority students under stereotype threat. Resting electroencephalographic activity recorded in white and minority participants was used to predict later estimates of task errors and self-doubt on a presumed measure of intelligence. We assessed spontaneous phase-locking between dipole sources in left lateral parietal cortex (LPC), precuneus/posterior cingulate cortex (P/PCC), and medial prefrontal cortex (MPFC); three regions of the default mode network (DMN) that are integral for self-oriented processing. Results revealed that minorities with greater LPC-P/PCC phase-locking in the theta band reported more accurate error estimations. All individuals experienced less self-doubt to the extent they exhibited greater LPC-MPFC phase-locking in the alpha band but this effect was driven by minorities. Minorities also reported more self-doubt to the extent they overestimated errors. Findings reveal novel neural moderators of stereotype threat effects on subjective experience. Spontaneous synchronization between DMN regions may play a role in anticipatory coping mechanisms that buffer individuals from stereotype threat.

Keywords: Stereotype threat; Default-mode network; spontaneous phase locking; performance monitoring; social neuroscience

INTRODUCTION

Situational reminders of negative stereotypes can cue a threat that one might inadvertently confirm that stereotype about one's group. Ironically, these experiences of stereotype threat can impair performance on cognitively challenging tasks and lead to more negative appraisals of one's ability, resulting in confirmatory evidence for the same negative group stereotype one hopes to disconfirm (Steele and Aronson, 1995; Schmader et al., 2008). Past research suggests that stereotype threat induces greater monitoring of the self and one's behavior (Forbes et al., 2008; Schmader, 2010; Forbes and Leitner, 2014), but also that individual differences in one's ability to self-monitor buffer people from threat-induced performance impairments (Inzlicht et al., 2006). This study investigated whether neural correlates of self-oriented processing, measured as baseline neural synchrony within the default mode network (DMN), was associated with stigmatized minorities' performance perceptions in a stereotype threatening context. As the DMN is implicated in self-related cognition broadly defined, individuals who show baseline differences in synchronous activation in the DMN might either be more sensitive to or better able to cope with self-relevant threats. Results provide evidence for a novel biological marker for individual differences in stereotype threat vulnerability.

Negative affect and self-oriented processing in stereotype threatening contexts

Stereotype threat is a psychological and physiological stressor that undermines performance and biases attention towards stereotype confirming evidence (Schmader et al., 2008; Forbes and Leitner, 2014). Results from past studies using social neuroscience methodologies suggest stereotype threat elicits physiological threat responses in the stigmatized. For example, situations of stereotype threat lead to increased activation in the amygdala, orbital gyrus, rostral–ventral

anterior cingulate (VACC), insula and ventrolateral prefrontal cortex (VLPFC) among other regions (Wraga et al., 2007; Krendl et al., 2008; Mangels et al., 2012; Raji et al., 2014).

Each of these regions is thought to play some role in the detection, evaluation and regulation of response to threatening stimuli. For instance, orbital gyrus is found to be active during the evaluation of emotionally evocative or threatening stimuli, including angry or fearful faces (Blair et al., 1999; Armony and Dolan, 2002; Moll et al., 2002; Pichon et al., 2009). Similarly, diminished activation or lesions to the orbital gyrus (and orbitofrontal cortex specifically) has been associated with decreases in both self-monitoring and regulation of socially appropriate emotions and behaviors (Beer et al., 2006; Coccaro et al., 2007). VACC activation has been associated with the detection of social threats and the processing of negative self-referential stimuli (Bush et al., 2000; Yoshimura et al., 2009); decreased VACC activity has been linked to reduction in social pain perception (Onoda et al., 2009). Conversely, extant research implicates lateral PFC, both ventral and dorsolateral aspects (or inferior, middle and superior frontal gyrus, respectively), as integral for emotion regulation, including findings indicating a central role for VLPFC in both the generation and regulation of emotional processes (Wager et al., 2008).

This past literature suggests that the activation of these regions is important in detecting, evaluating, and eliciting an appropriate response to self-relevant and emotionally relevant stimuli. Thus, the activation of these regions under stereotype threat is consistent with the self-threatening nature of the phenomenon. Other physiological research also points to the self-relevant and emotionally threatening nature of stereotype threat. For example, stereotype threat has been shown to elicit increases in sympathetic activation (Osborn, 2006, 2007), blood pressure (Blascovich et al., 2001) and a cardiovascular profile of threat reactivity (Vick et al., 2008). Subjectively, stereotype threat can evoke a more negative evaluation of one's performance including increased levels of explicit anxiety (Spencer et al., 1999), feelings of self-doubt (Steele and Aronson, 1995), dejection (Keller and Dauenheimer, 2003), heightened negative expectations (Stangor et al., 1998) and task-related worries (Cadinu et al., 2005; Beilock et al., 2007).

Correspondence should be addressed to Chad E. Forbes, Department of Psychological and Brain Sciences, University of Delaware, 111 Wolf Hall, Newark, DE 19716, USA. E-mail: cforbes@psych.udel.edu.

In this research, we were particularly interested in these negative subjective appraisals of performance under stereotype threat. If stereotype threat promotes greater vigilance to performance errors and a more negative interpretation of performance as reviewed above, then even in circumstances where performance is not actually impaired, one's subjective appraisal and memory of performance might still be negatively biased. In fact, a meta-analysis of gender differences in math performance suggests a much larger gender gap in self-perceived math ability than in actual standardized math scores (Else-Quest et al., 2010). Yet researchers are only beginning to investigate the processes that might underlie variation in how people process performance information under stereotype threat. Some past research suggests that in stereotype threatening contexts, error feedback (but not correct feedback) receives privileged access to working memory resources and is better encoded (Forbes and Leitner, 2014; Forbes et al., submitted), which could lead stigmatized students to overestimate errors and experience greater feelings of self-doubt. Such evidence suggests that negative performance appraisals under stereotype threat could result from a failure to accurately monitor performance and/or engage efficacious self-enhancement tactics.

Yet, research also reveals a great deal of variation within stigmatized groups in susceptibility to experiencing stereotype threat (Shapiro and Neuberg, 2007). Of relevance here is evidence that variation in self-related processing might play a role in mitigating one's experience of stereotype threat. Specifically, those who are more adept at managing self-presentation or regulating self-critical thoughts and feelings might be better equipped to cope with stereotype threatening situations. Indeed, past research indicates that people high in self-monitoring (i.e. those who are inclined to adjust their behavior to meet others' expectations or social norms) are less susceptible to stereotype threat effects; possibly because self-monitoring affords individuals greater self-regulatory resources and better coping skills in social evaluative situations (Miller et al., 1991; Seeley and Gardner, 2003; Inzlicht et al., 2006). Stigmatized individuals are also less susceptible to stereotype threat effects to the extent they take a promotion (i.e. seeking success) compared to prevention (i.e. avoiding failure) oriented self-regulatory focus (Higgins, 1998; Seibt and Forster, 2004), appraise a performance situation as a challenge (Alter et al., 2010), or have a tendency to reappraise negative, self-oriented emotions when sympathetic arousal levels are high (Schmader et al., 2009).

In sum, past research suggests that individual differences in self-regulation abilities can buffer individuals from stereotype threat, but all of this work focuses on self-report measures of individual differences. Our question was whether there are also individual differences in connectivity between neural networks implicated in self-oriented processes that moderate the effect of stereotype threat on performance perceptions. This question has never been addressed in prior studies. Thus, extending on prior work that has identified neural regions involved in more emotion and cognitive oriented processes (e.g. VACC and VLPFC) that are activated in stereotype threatening contexts, our goal was to identify baseline patterns of spontaneous neural synchronization between regions implicated in self-related processing that might be associated with individuals' susceptibility to stereotype threat.

Self-oriented processing and the default mode network

Regulating self-appraisals with respect to past experiences and anticipation of future outcomes is critical to coping with situational self-oriented threats. The extant literature has now identified a core network of neural regions integral for self-related processes referred to as the DMN. The DMN is a neural network composed of multiple brain regions, including the precuneus/posterior cingulate cortex (P/PCC), the medial prefrontal cortex (MPFC) and medial, lateral and inferior parietal cortex (Raichle et al., 2001; Buckner et al., 2008). Typically, regions in the DMN exhibit collective increases in neural activity when individuals are focusing their attention internally (Buckner et al., 2008), retrieving episodic memories (Greicius and Menon, 2004), adopting a first person perspective (Vogeley et al., 2004) and making distinctions between self and other (Northoff et al., 2006; for a review see Cannon and Baldwin, 2012; Knyazev, 2013). Within the DMN, the precuneus and posterior cingulate have been implicated in many psychological processes but appear to play key roles in episodic memory encoding and retrieval (Cavanna and Trimble, 2006; Huijbers et al., 2012). Similarly, the lateral parietal cortex (LPC) appears integral for both autobiographical and self-semantic processes, and MPFC is largely regarded as a hub for self-oriented processing (Amodio and Frith, 2006).

Of relevance to stereotype threat, research on regions within the DMN clearly points to its role in self-oriented processing, particularly with respect to MPFC. Among other things, the MPFC plays an integral role in the maintenance of self-knowledge, self-perception, autobiographical memory retrieval, attributional processes and self-evaluation (Ochsner et al., 2005; Amodio and Firth, 2006; Forbes and Grafman, 2010). More recent findings suggest the MPFC plays a role in maintaining a general positivity bias in self-evaluations (Kwan et al., 2007; Barrios et al., 2008). Kwan and colleagues found that in a sham transcranial magnetic stimulation (TMS) manipulation, participants exaggerated their self-evaluations of positive traits compared with traits associated with a close friend. However, after applying TMS to the MPFC no such positivity bias existed between the self and close friend ratings. More recently, Leitner et al. (2014) found that people who chronically self-enhanced exhibited decreased MPFC power in response to self-threatening information (social rejection feedback from peers) and, in turn, estimated that they were accepted more by peers than was actually the case. These results suggest that MPFC might play an important role in positively biasing self-evaluations, but whether baseline variations in MPFC activation or synchronization within the DMN are also linked to greater self-enhancing biases in general (much less under stereotype threat) is an important question unaddressed in the literature to our knowledge.

Given its role in autobiographical memory retrieval, the MPFC might facilitate self-monitoring and more accurate self-assessments as well. Theories on DMN function have posited that activation within DMN regions aids in a default mode of self-evaluation that provides broad and accurate updates of the self (Gusnard et al., 2001). Specifically, Gusnard and colleagues (2001) propose that elevated resting activity in the MPFC aids in resting state self-evaluation by analyzing self-related strengths and weaknesses identified through experience to forge more accurate global assessments of the self. Given this, greater activity in DMN regions (and MPFC specifically) at baseline may provide individuals with a means to cope with situational self-threats by either accurately retrieving past experiences associated with success or via self-enhancing and recalling past behavioral outcomes as better than they were in actuality.

While clearly it is important to identify the specific contributions of different DMN regions to self-oriented processes, a true understanding of the role the DMN plays in self-oriented processes likely requires knowledge of how these regions communicate with one another at rest or when cognitively engaged. DMN connectivity can be indexed via functional magnetic resonance imaging (fMRI) or electroencephalographic (EEG) methodologies (Buckner et al., 2008; Knyzaev, 2013). In fMRI studies, DMN integrity is assessed by measuring the extent to which DMN regions' hemodynamic responses (i.e. blood oxygen level-dependent or BOLD responses) covary with one another while individuals sit quietly in the scanner or during performance. In EEG

studies, DMN activity can be assessed via event related potentials (ERPs; during performance) and oscillatory activity (either spontaneous or evoked). As oscillations are critical in the integration of brain functions (Nunez, 2000; Buzsaki, 2006; Knyazev, 2007), examining neural oscillations at rest and during performance can elucidate the role of the DMN in self-oriented processing. Via time–frequency analyses, both the extent to which collections of neurons are active at specific points in time (i.e. power) and fire in synchrony with other regions (i.e. phase-locking and phase coherence; Roach and Mathalon, 2008) can be used to index DMN connectivity.

Regarding oscillatory activity in the DMN, slower frequencies, e.g. theta (4–8 Hz) and alpha (8–12 Hz), appear particularly relevant for DMN integrity. Whereas, theta oscillations have been associated with long distance neural interactions and thus may reflect communication between DMN regions, alpha oscillations have been linked to inter-neuron and thalamic activity and self-oriented processing at rest (Buzsaki, 2006; Knyazev, 2013). For instance, Knyazev et al. (2011) found that enhanced alpha power in DMN-like components predicted spontaneous self-referential thoughts during a social game task. Using sLORETA to identify DMN regions, Cannon and Baldwin (2012) found that spontaneous (i.e. not evoked or induced) DMN current source density levels within frequency bands delta to beta (0.5–30 Hz) were associated with participants' thoughts recorded during a resting period, which were largely self-regulatory (e.g. "I need to focus and sit still"). Similarly, combined fMRI-EEG studies have found evidence for increased phase-locking within the alpha band that coincided with increased activity in DMN regions (Jann et al., 2009; Sadaghiani et al., 2010, 2012).

Thus while a role for alpha and theta oscillatory activity within DMN regions has been established, it remains unclear what role communication between these regions (i.e. phase locking) plays in DMN processing, or how individual differences in phase-locking between DMN regions at slower frequencies are associated with the regulation of self-appraisals, anticipation of future outcomes or buffering the self from self-threatening information. For instance, do individual differences in DMN connectivity suggest a greater sensitivity to potentially threatening self-relevant information or a greater ability to cope with potential threats to the self? On the one hand, greater DMN activity has been linked to an enhanced ability to envision the detail and emotional content of future events (Addis et al., 2007) and depressed individuals are relatively worse at down-regulating their heightened DMN activation in response to negative stimuli (Sheline et al., 2009). Such evidence pertaining to DMN activation (i.e. increased neural activity within DMN regions) might suggest that greater phase-locking in the DMN (i.e. increased communication between DMN regions) during a baseline period would predict more negative self-evaluations among minority students exposed to a manipulation of stereotype threat.

However, as this past research mostly pertains to the activation of regions that are part of the DMN, rather than connectivity between those regions, individual differences in phase-locking between regions might index greater communication within a neural network (Buzsaki, 2006) and thus may provide better insight in to its role in self-relevant coping. For example, consistent with findings on the relationship between the MPFC and self-evaluation, an emerging hypothesis is that greater DMN connectivity corresponds to increased regulation of self-oriented processes, allowing individuals to evaluate their current state with respect to the past, future and the minds of others (Spreng and Grady, 2010). This broader appraisal of self-relevant events might be more akin to reappraisal and self-affirmation processes known to down-regulate stereotype threat (Martens et al., 2006; Johns et al., 2008; Schmader et al., 2009). Given that self-oriented processing and self-regulation are integral for buffering individuals from stereotype threat, and self-oriented processes are largely instantiated by regions in the DMN, individual differences in DMN connectivity could be an important moderator of stereotype threat effects on subjective performance appraisals. How? Possibly via providing a means for stigmatized individuals to self-enhance and/or more accurately monitor their performance in the face of stereotype threat-based self-threats. Thus, we hypothesized that greater DMN phase-locking at rest would predict less negative performance perceptions for minorities under stereotype threat compared with whites, who in similar contexts, theoretically should not experience the context as self-threatening. Such findings would not only inform our understanding of the role of the DMN in stereotype threat, it would also inform our understanding of how spontaneous phase-locking between DMN regions is associated with self-oriented processing in general.

METHODS

Participants

Participants were 42 whites and 49 racial minority (38 Latino, 11 African American) male and female undergraduate students who received course credit. This sample included only individuals who were right-handed, permanent US residents, and had no disabilities that would impair task performance. Due to incompatibilities between some EEG data files and the software used for time–frequency analyses, it was necessary to exclude 16 minorities and 17 white participants from EEG analyses. This left a final sample of 33 minorities (22 Female) and 25 white (11 Female) participants.

Procedure and materials

Participants were prepped for EEG recording by a white male experimenter. Before participants learned of study purposes, baseline EEG measurements were obtained. This consisted of participants sitting quietly with their feet resting on the ground and their arms on arm rests. Participants were asked to keep their eyes open, blinking normally, or closed for 60 seconds at a time for 5 min. EEG measures obtained during this initial baseline period were analyzed (described below) to index individual differences in connectivity within the DMN.

After the baseline period, participants were then informed they would complete a task that was ostensibly highly predictive of one's natural intelligence, and that more intelligent people learn the relationships more quickly. To make race salient (and thus further prime stereotype threat for minority participants), participants were asked to mark their race on a demographic questionnaire after hearing this study description (e.g. Steele and Aronson, 1995). Following these instructions, participants completed a probabilistic learning task designed to elicit comparable levels of wrong and correct feedback (Frank et al., 2004). Notably, this task is not actually diagnostic of intelligence, and all participants were debriefed at the end of the session on the true purpose of the study.

Probabilistic learning task

We elected to use a probabilistic learning task as the central task in the study because while it is a meaningful measure of implicit learning, participants are largely unable to develop meta-awareness of their actual performance on the task. Also, as a measure of implicit learning, performance on this task does not rely on working memory resources known to be impaired by stereotype threat (Schmader et al., 2008). Thus, such a task makes it unlikely that minority students would underperform on the task compared with their white peers, while maximizing the degree to which subjective assessments of performance could be biased by the threatening frame of the task.

The probabilistic learning task we used (Frank et al., 2004) consisted of a learning phase and a testing phase. In the learning phase, pairs of
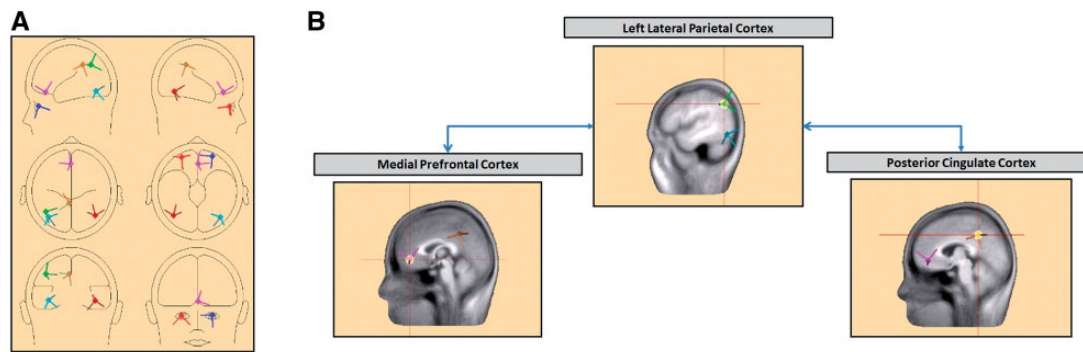
Fig. 1 Source model used for analyses. (A) The seven source model including eye and occipital sources. (B) Sources used to calculate phase-locking estimates within default mode network regions.

Hiragana characters were presented in random order and participants were asked to choose one of the two stimuli. The characters were three different stimulus pairs heretofore referred to as A and B, C and D and E and F. Feedback followed the choice to indicate whether it was correct or incorrect. The valence of the feedback was determined probabilistically. Selecting A provided visual positive feedback in 80% of AB trials, whereas a B choice led to negative feedback in these trials (and vice versa for the remaining 20% of trials). Choosing character C evoked positive feedback in 70% of CD trials, while E was correct in 60% of EF trials. The use of Hiragana characters coupled with the probabilistic feedback associated with each character provides a format that makes it difficult for participants to consciously learn the relationship between multiple characters. Individuals do, however, tend to implicitly learn the relationships via the basal ganglia and variation in dopaminergic output (Frank *et al.*, 2004).

Participants were given six blocks of 60 trials each to learn the relationships between the pairs. Learning was deemed to have occurred if participants learned to choose A more than 65% of the time, C more than 60% of the time, and E more than 50% of the time (Frank *et al.*, 2004). If they reached this criterion for learning before the sixth block, they advanced to a testing phase which was not relevant to the purposes of this study.[1] Instead, our primary outcome variables were participants' subjective reports of their performance included in a final questionnaire.

EEG recording and time–frequency analyses

EEG was recorded from 32 tin electrodes embedded within a stretch-lycra cap. A Cz reference and a ground lead located anterior to Fz on the mid-line of participants' scalps were implemented. All impedances were below $10 \, k\Omega$ prior to recording EEG activity, which was filtered online from 0.05 to 200 Hz, amplified by a factor of 500 with Synamps digital amplifiers, and sampled at 1000 Hz.

Off-line analyses were conducted with brain electromagnetic source analysis (BESA) 5.3 software (MEGIS Software GmbH, Grafelfing, Germany). EEG data was transformed to the average reference for all analyses. EEG signals from eyes open blocks were divided into 365 epochs consisting of 1250 ms. For the learning task, EEG signals were epoched and stimulus locked to correct and wrong feedback from 500 ms pre-feedback to 1000 ms post-feedback. Epochs containing artifacts (amplitude >120 μV, gradients >75 μV, low signal <0.01) were rejected using BESA's artifact scanning tool. Epochs were baseline corrected by subtracting the average value of EEG 100 ms pre-trial onset (or pre-feedback with respect to the learning task) from the entire epoch. All participants had at least 180 epochs from

measurements taken at rest and 20 wrong and correct feedback epochs from the learning task.

Source localization and time–frequency analyses

Source localization and source-based time–frequency analyses were performed in BESA. To avoid distortion of source localization and time–frequency measures, EEG activity for these measures were only high-pass filtered at 0.30 Hz (24 dB/octave). Because connectivity within DMN sources has been shown to increase in eyes open resting conditions (Yan *et al.*, 2009; Chen *et al.*, 2012), source localization analyses were conducted on grand average waveforms for the eyes open condition during rest. Source models were fitted within the 400–800 ms interval of epochs to capture time periods least likely to be distorted by filtering artifacts.

The source model was constructed based on talaraich coordinates of DMN regions outlined in previous research (Fox *et al.*, 2005; Mennes *et al.*, 2010; Figure 1). To account for residual eye movement activities, two additional sources were fitted in the left and right eye and two sources were fitted in the left and right occipital regions. Regional sources (composed of three different orientations to better model current density in a given region) were then placed in brain space and fitted in the left lateral parietal cortex (LLPC; Talairach coordinates: $x = -45$, $y = -64$, $z = 35$), PCC/precuneus (PCC/P: $x = -4$, $y = -46$, $z = 37$) and MPFC ($x = -1$, $y = 42$, $z = -4$). This model accounted for 96.4% of the variance in the EEG signal. To best account for individual variability inherent in participants' brain anatomy, the orientations of the regional sources were uniquely oriented for each participant with respect to their average wave forms.

Time–frequency analyses

The source waveforms were transformed into time–frequency space to calculate the instantaneous envelope amplitude and phase of each source as a function of frequency and latency. This was achieved via complex demodulation (Papp and Ktonas, 1976) as implemented in BESA 5.3. Frequencies of interest were sampled between 4 and 50 Hz in steps of 2 Hz and in sampling steps of 25 ms latencies within the 1500 ms time frames. Consistent with Sauseng and Klimesch (2008), we operationalized frequency bands as followed: theta = 4–8 Hz, alpha = 8–12 Hz.

Phase-locking values were extracted by calculating a correlation of two normalized spectral density functions (i.e. amplitudes of two signals at a certain frequency and interval in relation to an event). Phase-locking values were calculated for the same frequencies described above (4–50 Hz), with a baseline correction window of 100 ms pre-trial onset (or pre-feedback with respect to the learning task) presentation. All phase-locking analyses used the LPPC source as

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[1]Analyses revealed no significant effects of ethnicity, DMN phase-locking, or the interaction of the two variables on number of wrong categorizations during the learning phase, *Ps* > .10.

Table 1 Descriptive statistics and intercorrelations of study variables

	Whites								Minorities							
	Mean (s.d.)	1	2	3	4	5	6	7	Mean (s.d.)	1	2	3	4	5	6	7
1. LLPC–MPFC phase-locking (theta)	0.17 (0.08)	—							0.18 (0.09)	—						
2. LLPC–P/PCC phase-locking (theta)	0.17 (0.08)	0.13	—						0.18 (0.09)	0.04	—					
3. LLPC–MPFC phase-locking (alpha)	0.25 (0.11)	0.53**	−0.12	—					0.25 (0.14)	0.74***	0.20	—				
4. LLPC–P/PCC phase-locking (alpha)	0.15 (0.08)	0.27	0.17	0.01	—				0.17 (0.08)	0.17	0.28	0.29	—			
5. Error estimates	18.18 (40.39)	−0.01	0.24	0.16	0.22	—			20.72 (45.14)	−0.01	−0.39*	−0.13	−0.04	—		
6. Doubt	3.67 (1.37)	−0.19	−0.29	−0.04	−0.25	0.01	—		4.04 (.96)	−0.43*	−0.11	−0.54**	−0.30†	0.35*	—	
7. Total wrong	247 (132)	−0.22	−0.30	−0.07	−0.03	0.39†	0.07	—	185 (134)	−0.05	−0.12	−0.15	0.12	0.24	0.20	—

Whites and minorities did not significantly differ on any of these variables.
*$P < 0.05$ **$P < 0.01$ ***$P < 0.001$ †$P < .10$.

the source reference given this region's integral role in DMN processes (Fox and Raichle, 2007; Buckner *et al.*, 2008). Thus, higher phase-locking values indicate that a given source exhibited greater phase-locking with activity in the LPPC source.

Post-task error estimation

In a post-task questionnaire, participants were asked to estimate the percentage of errors they made on the supposed intelligence test. These percentage estimates were then converted to a number based on their actual performance in the learning phase (given that the number of trials participants completed in total could vary). For example, if participants estimated they got 50% of the trials wrong, then they were given a predicted error value equal to half of the total trials they completed. To derive error estimations, we then subtracted the number of actual errors they made on the task from their predicted error estimates so that positive numbers indicated that participants overestimated the number of errors they committed. Negative numbers denote an underestimation of errors committed, and numbers closer to zero reflect more accurate performance assessments.

Post-task doubt and manipulation check

To assess the degree of self-doubt individuals experienced post-performance, participants used a scale of 1 (strongly disagree)–7 (strongly agree) to rate the extent to which they were currently feeling doubtful, foolish, inferior, insecure and unsure. Mean composites were generated such that higher numbers equaled greater self-doubt ($\alpha = 0.79$). To assess the effectiveness of our stereotype threat manipulation, participants were also asked to answer the question 'How do you think the researcher expects different racial/ethnic groups to do on the pattern recognition task relative to each other?' using a scale of 1 (White students will score higher than minority students)–7 (Minority students will score higher than white students).

RESULTS
Behavioral analyses

An independent samples *t*-test was conducted on participants' learning performance (total number of wrong trials), error estimations, doubt and the stereotype threat manipulation check. These analyses revealed that minorities and whites exhibited comparable learning rates, degree of error overestimation and ratings of self-doubt, all $Ps > 0.05$, see Table 1. Compared with whites ($M = 3.60$, s.d. $= 0.77$), however, minorities ($M = 3.08$, s.d. $= 1.11$) were more likely to assume the researcher expected minorities to do worse on the supposed intelligence test than whites, $t(86) = -2.48$, $P < 0.02$. These findings suggest that while there were no overall differences between minorities and whites

on learning task performance or performance perceptions, the variability found on stereotype threat perceptions affords the possibility to examine how individual differences in subjective perceptions of performance related to DMN phase-locking.

Error estimates and self-doubt

Consistent with past findings suggesting negative performance perceptions are internalized by stigmatized individuals under stereotype threat (e.g. Cadinu *et al.*, 2005), error estimates were related to self-doubt among minorities, but not whites (Table 1): Minorities reported greater self-doubt to the extent they overestimated the number of errors made on the supposed intelligence task. These correlations were not, however, significantly different from one another ($P = 0.20$).

Time–frequency analyses

DMN synchrony was indexed by calculating mean phase-locking values between LLPC–P/PCC and LLPC–MPFC over 400 ms epochs in theta and alpha frequency bands at rest and during the learning task.

Phase-locking during the learning task

Given the probabilistic nature of the learning task, the learning criterion that was established and the lack of any differences in learning performance, we can assume that participants received equivalent amounts of correct and incorrect feedback regardless of ethnicity. Although we did not anticipate that DMN phase locking during the learning task itself would play a role in the evaluation of this feedback during the task, we conducted analyses to establish this. Specifically, separate regression models were conducted to test whether error estimations, self-doubt, or learning (i.e. total trials necessary to learn probabilistic relationships) were predicted by DMN phase-locking to wrong and correct feedback received during the learning task. Ethnicity, the difference scores between each DMN variable in response to wrong and correct feedback (in the alpha or theta bands), and the interaction between ethnicity and phase-locking was also entered in to each model. No effects were significant, $Ps > 0.50$, indicating that DMN phase-locking to wrong or correct feedback during the main task was unrelated to outcome variables. These findings are not surprising given that extant literature provides a clear distinction between performance monitoring (i.e. the task-positive network) and self-oriented processes/networks (i.e. the DMN). Thus, we next examined whether DMN phase locking measured pre-test at rest had stronger relationships with post-task self-perceptual and appraisal processes as opposed to actual performance monitoring.
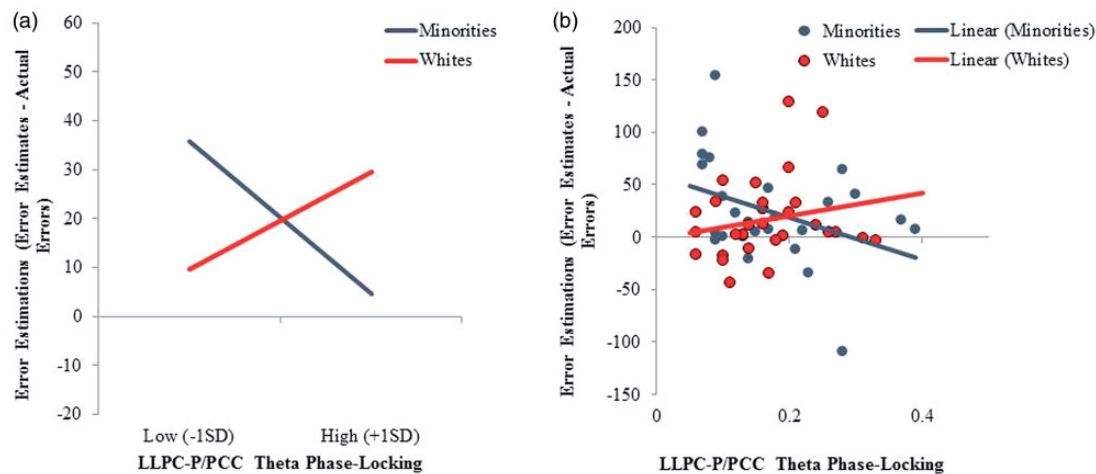
Fig. 2 Theta phase-locking between LLPC and P/PCC. (A) Standard plotting of moderated regression analyses. B) Scatter plot for minorities and whites' error estimations as a function of LLPC–P/PCC phase locking in the theta frequency band. The mean of error estimations was 21.278, and the s.d. was 42.276. Thus, 1 s.d. below the mean is −21, while 1 s.d. above the mean is 63.

Error estimation

To determine whether phase locking between DMN regions at rest predicted error estimations for whites and minorities, we conducted a moderated regression analysis in which error estimations were regressed on dummy coded ethnicity (minority = 0, white = 1), mean-centered phase-locking within the DMN, and the interaction terms between ethnicity and the phase-locking variables. We conducted separate regression analyses to independently examine alpha and theta phase-locking between LLPC–MPFC and LLPC–P/PCC (the two phase locking variables were not correlated, see Table 1). Initial analyses included gender and the requisite interaction terms in the model and yielded no significant main effects or interactions, $Ps > 0.16$. Thus gender was excluded as a predictor in all analyses reported below.

For both whites and minorities, error estimations were unrelated to LLPC–P/PCC phase-locking in the alpha band and LLPC–MPFC phase-locking in the alpha or theta bands, $Ps > 0.30$. A different pattern emerged, however, when examining the relationship between LLPC-P/PCC phase locking in the theta band and error estimation. Whereas ethnicity was unrelated to the tendency to overestimate errors ($P = 0.957$), a main effect emerged for LLPC–P/PCC theta phase-locking, $b = −195.29$, $\beta = −0.37$, SE $= 81.13$, $P = 0.021$, which was qualified by a significant interaction, $b = 350.13$, $\beta = 0.37$, SE $= 147.26$, $P = 0.021$ (Figure 2).[2] Simple slopes analyses (Preacher et al., 2006) revealed that among minorities, greater LLPC-P/PCC theta phase-locking predicted less of a tendency to overestimate errors, $b = −195.29$, SE $= 82.13$, $P = 0.021$, whereas LLPC–P/PCC phase-locking was not related to error estimation for whites ($b = 0.15$, SE $= 122.24$, $P = 0.210$). Furthermore, among participants lower in LLPC–P/PCC theta phase-locking, minorities reported marginally greater overestimates of their errors than did whites, $b = −27.39$, SE $= 15.80$, $P = 0.088$. Among those higher in LLPC–P/PCC theta phase-locking, minorities reported marginally smaller, more accurate error estimates than did whites (i.e. at 1 s.d. above the mean on theta phase locking, the point estimate of 5.95 for minorities was close to zero), $b = 28.63$, SE $= 16.85$, $P = 0.095$.

Post-task self-doubt

We repeated the analyses described above predicting self-doubt to determine whether ethnicity moderated the relationship between

[2] One white participant was excluded from this analysis for having a theta LLPC-P/PCC phase locking value that was greater than four standard deviations from the mean.

spontaneous DMN phase-locking and self-doubt. No effects emerged when examining phase-locking between LLPC–P/PCC in the alpha or theta bands, $Ps > 0.40$. However, phase-locking between LLPC–MPFC predicted decreased doubt, regardless of ethnicity. The relationship between LLPC–MPFC phase-locking and doubt emerged in both the theta band, $b = −4.41$, $\beta = −0.09$, SE $= 1.95$, $P = 0.028$, and alpha band, $b = −3.79$, $\beta = −0.12$, SE $= 1.28$, $P = 0.005$ (Figure 3). Though the interactions between ethnicity and LLPC–MPFC phase-locking were not significant $Ps > 0.20$, LLPC–MPFC theta phase-locking and self-doubt was significantly correlated among minorities ($r = −0.54$, $P < 0.01$) but not whites ($r = −0.04$; see Table 1), and a Fisher r-to-z transformation test on these correlation coefficients indicated that the relationship between these variables was significantly greater among minorities compared with whites, $z = −2.0$, $P < 0.05$ (two-tailed). No other effects were significant. Overall, the pattern of correlations and findings converge to suggest that DMN phase-locking was associated with performance perceptions and self-doubt for stereotype threatened minorities but not whites.

DISCUSSION

Findings from this study suggest that individual differences in spontaneous phase-locking between DMN regions at rest were associated with stereotype threatened minorities' self and performance perceptions. Although we observed no overall differences between minority and whites' self-perceptions (or implicit learning) on the task, minorities with lower levels of spontaneous phase-locking in DMN regions during the initial rest phase tended to overestimate the number of errors they made on the supposed intelligence test (LPC–P/PCC phase-locking in the theta band) and reported greater self-doubt (LPC–MPFC phase-locking in both the alpha and theta bands) compared with whites (the latter pattern was less robust, however). Conversely, minorities exhibiting increased phase-locking between these DMN regions at rest reported somewhat more accurate error estimations on the supposed intelligence test and somewhat less self-doubt compared with whites. Whites, who presumably did not experience stereotype threat-based self-doubt, did not exhibit any relationships between error estimations, self-doubt and DMN phase-locking. Finally, the effect of phase-locking between DMN regions was unique to post-performance self-perceptions, as no relationships were found between spontaneous resting state DMN phase-locking and implicit learning performance among minorities or whites. This suggests that DMN connectivity might be more relevant to self-evaluation
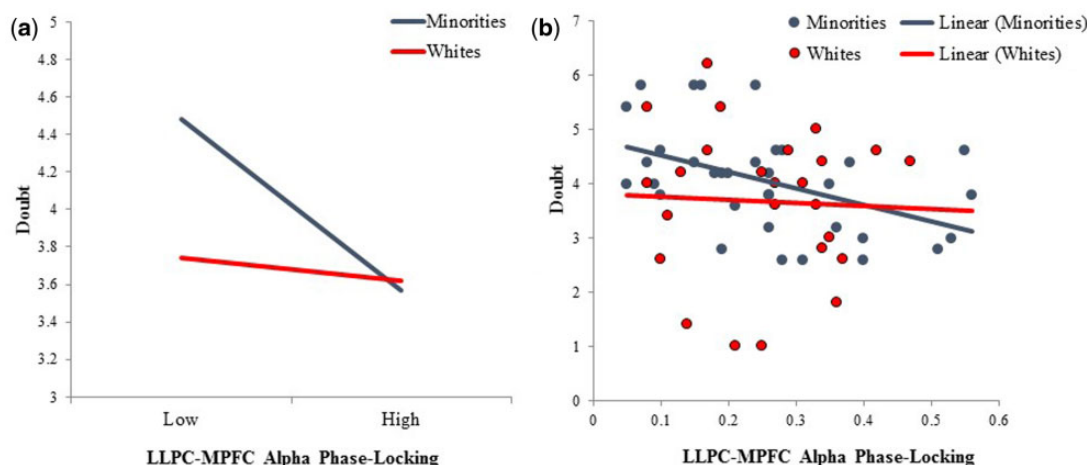
Fig. 3 Alpha phase-locking between LLPC LPC and medial prefrontal cortex (MPFC). (A) Standard plotting of moderated regression analyses. (B) Scatter plot for minorities and whites' reported self-doubt as a function of LLPC–MPFC phase locking in the alpha frequency band. Note that effects are largely driven by minorities with less LPC–MPFC phase locking reporting greater self-doubt (these correlations are significantly different from one another).

or appraisals of implicit learning processes than to learning the probabilistic relationships themselves.

These findings suggest a possible biological marker for individual differences in stereotype threat vulnerability: spontaneous fluctuations in phase-locking or neural synchrony, between regions integral for the DMN. With regard to current conceptions of DMN function, this suggests that stigmatized individuals' performance perceptions under stereotype threat might vary to the extent they can cope with and/or anticipate emotionally stressful situations. Nevertheless, it is difficult to determine whether coping takes the form of being buffered against the emotional consequences of taking a diagnostic intelligence test as a stigmatized minority (which would facilitate more accurate performance and self-monitoring) or reactive self-enhancement whereby people react to a threat by thinking they performed better than they actually did. Based on the DMN literature and our findings suggesting greater accuracy but not underestimation of errors (i.e. self-enhancement) among minorities high in theta phase-locking, the former possibility seems more plausible. To our knowledge, the DMN has not been implicated in self-enhancing processes per se but rather in autobiographical memory retrieval, judgments of self-relevance and accurate self-evaluations. Thus, individuals with greater phase-locking in the DMN might acquire a more accurate, objectively appraised and less negatively biased impression of the self during a threatening performance situation. If this conjecture is accurate, however, then why don't whites exhibit the same relationship? Based on the stereotype threat literature it's likely because for whites, the situation of taking a diagnostic intelligence test should not arouse the same self-reflective metacognitive processing of performance among those who are not stigmatized (Schmader et al., 2009).

Findings from this study also have important implications for the DMN and the role of phase-locking between regions in the DMN specifically. Past research on DMN connectivity has relied almost exclusively on fMRI and functional connectivity analyses, which measure covariation in the BOLD signal between DMN regions. To date, the neural mechanisms that engender the BOLD effect are still unclear, suggesting DMN connectivity is largely misunderstood as well. Given that phase-locking provides a more direct index of neural function and may represent how different regions communicate with one another on the order of milliseconds (Buzsaki, 2006), findings from this study suggest that phase-locking analyses may provide a more veridical index of the dynamic interaction between regions implicated in the DMN

and the role these interactions play in the modulation of psychological processes implicated in the DMN literature. To that point, consistent with conjectures that neural regions that are more distal from one another (like DMN regions are) utilize slower oscillations to communicate with one another, our findings indicate that associations between DMN synchrony and self-oriented processing likewise manifest at slower oscillations, i.e. theta and alpha (4–12 Hz).

At the same time our findings suggest that phase-locking in the theta and alpha bands were similar, but not redundant. Specifically, LLPC–P/PCC phase-locking in the alpha and theta bands were only marginally correlated ($r = 0.25$, $P = 0.06$), although LLPC–MPFC phase-locking in the alpha and theta bands were highly correlated ($r = 0.67$, $P < 0.001$). This pattern of findings is consistent with past research that has found that theta and alpha interact in space and time to enable the necessary operations of working memory and selective attentional processes (Dipoppa and Gutkin, 2013; Lee et al., 2013; Leitner et al., 2013). However, the current findings also suggest that alpha and theta phase-locking within the DMN might have distinct cognitive consequences.

These findings also provide further insight into the role of LPC–P/PCC and LPC–MPFC phase-locking at slower oscillations in DMN processes. Buckner et al. (2008) argues that the DMN consists of subsystems, including a subsystem for autobiographical memories and learned associations and a more flexible subsystem that can utilize this information for construction of self-relevant processes (e.g. mental simulations). Whereas the three regions of interest in this study have been identified as integral to both subsystems (as well as other psychological processes), results from the present study suggest that LPC–P/PCC phase-locking might play a role in performance/self-monitoring and autobiographical memory processes. Specifically, phase-locking in the theta band between these two regions was related to more accurate performance assessments among minority students. In contrast, LPC–MPFC phase-locking might play a role in processes involving the self-concept, given our evidence that phase-locking in the alpha band was related to individuals' ratings of self-doubt. These findings are not entirely surprising given that extant literature has identified key roles for the precuneus and posterior cingulate in episodic memory encoding and retrieval (Cavanna and Trimble, 2006; Huijbers et al., 2012), and MPFC in self-oriented processing and the self-concept (Amodio and Frith, 2006). Consistent with Buckner et al. (2008), our findings further add to the literature by implicating

the LPC as particularly important for both autobiographical and self-semantic processes as they relate to the DMN. Nevertheless, these conjectures are speculative in nature given the correlational nature of the present research. Thus future research would be necessary to more fully elucidate the role of these regions in distinct psychological processes as well as the role of DMN phase-locking in other psychological processes that might play a role in self-doubt and biased appraisal processes.

Consistent with this sentiment, findings should be tempered with respect to the fact that source localization analyses were conducted on 32 channels, which is less than ideal given issues of volume conduction. As such, findings can only be interpreted as representative of activity in or around the LPC, PCC/P and MPFC. However, there is precedent for using 32 channels for source localization analyses (Hanslmayr *et al.,* 2008), including studies examining DMN regions (Knyazev *et al.,* 2011; Canon and Baldwin, 2012) and to our knowledge the extent to which additional channels enhance the precision and veracity of source localization analyses remain unclear.

Further, it must be stated that standard electrode placement was assumed and not directly verified via either digitization or MRI scans. Practical reasons precluded an MRI scan of each participant or the measurement of exact 3D electrode placement via a digitizer. Given that these circumstances are more commonplace, prior research has examined the effect of electrode misplacement on dipole placement and revealed that localization error is quite small and may be considered inconsequential compared to noise induced error (Khosla *et al.,* 1999; Van Hoey *et al.,* 2000; Michel *et al.,* 2004). Additionally, the usage of pre-fabricated caps with standardized electrode spacing and the measurement of landmarks (i.e. inion, nasion, auricular points) on each individual have previously been deemed sufficient to determine the position of all electrodes (De Munck *et al.,* 1991; Khosla *et al.,* 1999), which is consistent with the methodologies used in current research. Therefore, we are confident that the electrode positioning is as accurate as possible without digitization or structural MRI models.

Nevertheless, future studies using combined EEG and fMRI procedures would be necessary to corroborate results found in this study. It would also be necessary to determine whether these effects were specific to stereotype threatening contexts as opposed to minorities in general (i.e. assess whether DMN phase-locking moderates minorities' self-perceptions after they complete a task in a stereotype neutral context).

In sum, findings from this study indicate that phase-locking between DMN regions is associated with stigmatized individuals' ability to buffer themselves from the deleterious consequences of stereotype threat, perhaps by enabling more accurate performance appraisals. This provides evidence for novel biological and psychological individual difference buffers of stereotype threat effects. How these inherent differences moderate performance and self-perceptions in stigmatized domains over time will be intriguing questions for future research; but these findings provide insight into the means through which stigmatized individuals can persist in the face of salient negative group stereotypes and leave stereotype threatening contexts with more positive self-perceptions intact.

REFERENCES

Addis, D.R., Wong, A.T., Schacter, D.L. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia*, 45, 1363–77.

Alter, A., Aronson, J., Darley, J., Rodriguez, C., Ruble, D.N. (2010). Rising to the threat: Reducing stereotype threat by reframing the threat as a challenge. *Journal of Experimental Social Psychology*, 46, 166–71.

Amodio, D.M., Frith, C.D. (2006). Meeting of minds: The medial frontal cortex and social cognition. *Nature Reviews Neuroscience*, 7, 268–77.

Armony, J.L., Dolan, R.J. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia*, 40(7), 817–26.

Barrios, V., Kwan, V.S., Ganis, G., Gorman, J., Romanowski, J., Keenan, J.P. (2008). Elucidating the neural correlates of egoistic and moralistic self-enhancement. *Consciousness and Cognition*, 17(2), 451–56.

Beer, J.S., John, O.P., Scabini, D., Knight, R.T. (2006). Orbitofrontal cortex and social behavior: Integrating self-monitoring and emotion-cognition interactions. *Journal of cognitive neuroscience*, 18, 871–9.

Beilock, S.L., Rydell, R.J., McConnell, A.R. (2007). Stereotype threat and working memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology: General*, 136(2), 256.

Blair, R.J., Morris, J.S., Frith, C.D., Perrett, D.I., Dolan, R.J. (1999). Dissociable neural responses to facial expressions of sadness and anger. *Brain: A Journal of Neurology*, 122((Pt 5), 883–93.

Blascovich, J., Spencer, S.J., Quinn, D., Steele, C. (2001). African americans and high blood pressure: The role of stereotype threat. *Psychological Science*, 12(3), 225–9.

Buckner, R.L., Andrews-Hanna, J.R., Schacter, D.L. (2008). The brain's default network. *Annals of the New York Academy of Sciences*, 1124, 1–38.

Bush, G., Luu, P., Posner, M.I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, 4(6), 215–22.

Buzsaki, G. (2006). *Rhythms of the Brain*. New York: Oxford University Press.

Cadinu, M., Maass, A., Rosabianca, A., Kiesner, J. (2005). Why do women underperform under stereotype threat? evidence for the role of negative thinking. *Psychological Science*, 16, 572–8.

Cannon, R.L., Baldwin, D.R. (2012). EEG current source density and the phenomenology of the default network. *Clinical EEG and Neuroscience*, 43, 257–67.

Cavanna, A.E., Trimble, M.R. (2006). The precuneus: A review of its functional anatomy and behavioural correlates. *Brain*, 129, 564–83.

Chen, J.L., Ros, T., Gruzelier, J.H. (2013). Dynamic changes of ICA-derived EEG functional connectivity in the resting state. *Human Brain Mapping*, 34(4), 852–68.

Coccaro, E.F., McCloskey, M.S., Fitzgerald, D.A., Phan, K.L. (2007). Amygdala and orbitofrontal reactivity to social threat in individuals with impulsive aggression. *Biological Psychiatry*, 62(2), 168–78.

De Munck, J., Vijn, P., Spekreijse, H. (1991). A practical method for determining electrode positions on the head. *Electroencephalography and Clinical Neurophysiology*, 78(1), 85–7.

Dipoppa, M., Gutkin, B.S. (2013). Flexible frequency control of cortical oscillations enables computations required for working memory. *Proceedings of the National Academy of Sciences of the United States of America*, 110(31), 12828–33.

Else-Quest, N.M., Hyde, J.S., Linn, M.C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, 136(1), 103.

Forbes, C.E., Schmader, T., Allen, J.J. (2008). The role of devaluing and discounting in performance monitoring: A neurophysiological study of minorities under threat. *Social Cognitive and Affective Neuroscience*, 3, 253–61.

Forbes, C.E., Leitner, J.B. (2014). Stereotype threat engenders neural attentional bias toward negative feedback to undermine performance. *Biological psychology*, 102, 98–107.

Fox, M.D., Raichle, M.E. (2007). Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nature Reviews Neuroscience*, 8, 700–11.

Fox, M.D., Snyder, A.Z., Vincent, J.L., Corbetta, M., Van Essen, D.C., Raichle, M.E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences of the United States of America*, 102, 9673–8.

Frank, M.J., Seeberger, L.C., O'Reilly, R.C. (2004). By carrot or by stick: Cognitive reinforcement learning in parkinsonism. *Science*, 306, 1940–3.

Frank, R.H., Gilovich, T., Regan, D.T. (1993). The evolution of one-shot cooperation: An experiment. *Ethology and Sociobiology*, 14, 247–56.

Greicius, M.D., Menon, V. (2004). Default-mode activity during a passive sensory task: Uncoupled from deactivation but impacting activation. *Journal of Cognitive Neuroscience*, 16, 1484–92.

Gusnard, D.A., Raichle, M.E. (2001). Searching for a baseline: Functional imaging and the resting human brain. *Nature Reviews Neuroscience*, 2(10), 685–94.

Hanslmayr, S., Pastötter, B., Bäuml, K., Gruber, S., Wimber, M., Klimesch, W. (2008). The electrophysiological dynamics of interference during the stroop task. *Journal of Cognitive Neuroscience*, 20, 215–25.

Higgins, E.T. (1998). Promotion and prevention: Regulatory focus as a motivational principle. *Advances in Experimental Social Psychology*, 30, 1–46.

Huijbers, W., Schultz, A.P., Vannini, P., et al. (2013). The encoding/retrieval flip: interactions between memory performance and memory stage and relationship to intrinsic cortical networks. *Journal of Cognitive Neuroscience*, 25(7), 1163–79.

Huijbers, W., Vannini, P., Sperling, R.A., Cabeza, R., Daselaar, S.M. (2012). Explaining the encoding/retrieval flip: memory-related deactivations and activations in the posteromedial cortex. *Neuropsychologia*, 50(14), 3764–74.

Inzlicht, M., Aronson, J., Good, C., McKay, L. (2006). A particular resiliency to threatening environments. *Journal of Experimental Social Psychology*, 42, 323–36.

Jann, K., Dierks, T., Boesch, C., Kottlow, M., Strik, W., Koenig, T. (2009). BOLD correlates of EEG alpha phase-locking and the fMRI default mode network. *Neuroimage*, 45, 903–16.

Johns, M., Inzlicht, M., Schmader, T. (2008). Stereotype threat and executive resource depletion: Examining the influence of emotion regulation. *Journal of Experimental Psychology: General*, 137(4), 691.

Keller, J., Dauenheimer, D. (2003). Stereotype threat in the classroom: Dejection mediates the disrupting threat effect on women's math performance. *Personality and Social Psychology Bulletin*, 29, 371–81.

Khosla, D., Don, M., Kwong, B. (1999). Spatial mislocalization of EEG electrodes–effects on accuracy of dipole estimation. *Clinical Neurophysiology*, 110(2), 261–71.

Knyazev, G.G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neuroscience & Biobehavioral Reviews*, 31, 377–95.

Knyazev, G.G., Slobodskoj-Plusnin, J.Y., Bocharov, A.V., Pylkova, L.V. (2011). The default mode network and EEG alpha oscillations: An independent component analysis. *Brain Research*, 1402, 67–79.

Knyazev, G.G. (2013). EEG correlates of self-referential processing. *Frontiers in Human Neuroscience*, 7.

Krendl, A.C., Richeson, J.A., Kelley, W.M., Heatherton, T.F. (2008). The negative consequences of threat a functional magnetic resonance imaging investigation of the neural mechanisms underlying women's underperformance in math. *Psychological Science*, 19, 168–75.

Kwan, V.S., Barrios, V., Ganis, G., et al. (2007). Assessing the neural correlates of self-enhancement bias: A transcranial magnetic stimulation study. *Experimental Brain Research*, 182(3), 379–85.

Lee, D.J., Gurkoff, G.G., Izadi, A., et al. (2013). Medial septal nucleus theta frequency deep brain stimulation improves spatial working memory after traumatic brain injury. *Journal of Neurotrauma*, 30(2), 131–9.

Leitner, J.B., Jones, J.M., Hehman, E. (2013). Succeeding in the face of stereotype threat the adaptive role of engagement regulation. *Personality and Social Psychology Bulletin*, 39, 17–27.

Leitner, J.B., Hehman, E., Jones, J.M., Forbes, C.E. (2014). Self-enhancement influences medial frontal cortex alpha power to social rejection feedback. *Journal of Cognitive Neuroscience*, 26(10), 2330–41.

Mangels, J.A., Good, C., Whiteman, R.C., Maniscalco, B., Dweck, C.S. (2012). Emotion blocks the path to learning under stereotype threat. *Social Cognitive and Affective Neuroscience*, 7(2), 230–41.

Martens, A., Johns, M., Greenberg, J., Schimel, J. (2006). Combating stereotype threat: The effect of self-affirmation on women's intellectual performance. *Journal of Experimental Social Psychology*, 42(2), 236–43.

Mennes, M., Kelly, C., Zuo, X., et al. (2010). Inter-individual differences in resting-state functional connectivity predict task-induced BOLD activity. *Neuroimage*, 50, 1690–701.

Michel, C.M., Murray, M.M., Lantz, G., Gonzalez, S., Spinelli, L., Grave de Peralta, R. (2004). EEG source imaging. *Clinical Neurophysiology*, 115(10), 2195–222.

Miller, M.L., Omens, R.S., Delvadia, R. (1991). Dimensions of social competence: Personality and coping style correlates. *Personality and Individual Differences*, 12, 955–64.

Moll, J., de Oliveira-Souza, R., Bramati, I.E., Grafman, J. (2002). Functional networks in emotional moral and nonmoral social judgments. *Neuroimage*, 16(3), 696–703.

Moll, J., de Oliveira-Souza, R., Eslinger, P.J., et al. (2002). The neural correlates of moral sensitivity: A functional magnetic resonance imaging investigation of basic and moral emotions. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, 22(7), 2730–36.

Moll, J., Schulkin, J. (2009). Social attachment and aversion in human moral cognition. *Neuroscience & Biobehavioral Reviews*, 33(3), 456–65.

Murphy, M.C., Steele, C.M., Gross, J.J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science*, 18, 879–85.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., Panksepp, J. (2006). Self-referential processing in our brain–a meta-analysis of imaging studies on the self. *Neuroimage*, 31, 440–57.

Nunez, P.L. (2000). Toward a quantitative description of large-scale neocortical dynamic function and EEG. *Behavioral and Brain Sciences*, 23, 371–98.

Ochsner, K.N., Beer, J.S., Robertson, E.R., et al. (2005). The neural correlates of direct and reflected self-knowledge. *Neuroimage*, 28(4), 797–814.

Onoda, K., Okamoto, Y., Nakashima, K., Nittono, H., Ura, M., Yamawaki, S. (2009). Decreased ventral anterior cingulate cortex activity is associated with reduced social pain during emotional support. *Social Neuroscience*, 4(5), 443–54.

Osborne, J.W. (2006). Gender, stereotype threat, and anxiety: Psychophysiological and cognitive evidence. *Electronic Journal of Research in Educational Psychology*, 4(1), 109–38.

Osborne, J.W. (2007). Linking stereotype threat and anxiety. *Educational Psychology*, 27(1), 135–54.

Papp, N., Ktonas, P. (1976). Critical evaluation of complex demodulation techniques for the quantification of bioelectrical activity. *Biomedical Sciences Instrumentation*, 13, 135–45.

Preacher, K.J., Curran, P.J., Bauer, D.J. (2006). Computational tools for probing interactions in multiple linear regression, multilevel modeling, and latent curve analysis. *Journal of Educational and Behavioral Statistics*, 31(4), 437–48.

Raichle, M.E., MacLeod, A.M., Snyder, A.Z., Powers, W.J., Gusnard, D.A., Shulman, G.L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences*, 98, 676–82.

Raji, T.T., Korkeila, J., Joutsenniemi, K., Saarni, S.I., Riekki, T.J. (2014). Association of stigma resistance with emotion regulation—Functional magnetic resonance imaging and neuropsychological findings. *Comprehensive Psychiatry*, 55(3), 727–35.

Roach, B.J., Mathalon, D.H. (2008). Event-related EEG time–frequency analysis: An overview of measures and an analysis of early gamma band phase-locking in schizophrenia. *Schizophrenia Bulletin*, 34, 907–26.

Sadaghiani, S., Scheeringa, R., Lehongre, K., et al. (2012). Alpha-band phase synchrony is related to activity in the fronto-parietal adaptive control network. *The Journal of Neuroscience*, 32, 14305–10.

Sadaghiani, S., Scheeringa, R., Lehongre, K., Morillon, B., Giraud, A., Kleinschmidt, A. (2010). Intrinsic connectivity networks, alpha oscillations, and tonic alertness: A simultaneous electroencephalography/functional magnetic resonance imaging study. *The Journal of Neuroscience*, 30(30), 10243–50.

Sauseng, P., Klimesch, W. (2008). What does phase information of oscillatory brain activity tell us about cognitive processes? *Neuroscience & Biobehavioral Reviews*, 32, 1001–13.

Schmader, T. (2010). Stereotype threat deconstructed. *Current Directions in Psychological Science*, 19, 14–8.

Schmader, T., Forbes, C.E., Zhang, S., Mendes, W.B. (2009). A metacognitive perspective on the cognitive deficits experienced in intellectually threatening environments. *Personality and Social Psychology Bulletin*, 35, 584–96.

Schmader, T., Johns, M., Forbes, C. (2008). An integrated process model of stereotype threat effects on performance. *Psychological Review*, 115, 336.

Seeley, E.A., Gardner, W.L. (2003). The "selfless" and self-regulation: The role of chronic other-orientation in averting self-regulatory depletion. *Self and Identity*, 2, 103–17.

Seibt, B., Förster, J. (2004). Stereotype threat and performance: How self-stereotypes influence processing by inducing regulatory foci. *Journal of Personality and Social Psychology*, 87, 38.

Shapiro, J.R., Neuberg, S.L. (2007). From stereotype threat to stereotype threats: Implications of a multi-threat framework for causes, moderators, mediators, consequences, and interventions. *Personality and Social Psychology Review: An Official Journal of the Society for Personality and Social Psychology, Inc*, 11(2), 107–30.

Sheline, Y.I., Barch, D.M., Price, J.L., et al. (2009). The default mode network and self-referential processes in depression. *Proceedings of the National Academy of Sciences of the United States of America*, 106(6), 1942–47.

Spencer, S.J., Steele, C.M., Quinn, D.M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, 35, 4–28.

Spreng, R.N., Grady, C.L. (2010). Patterns of brain activity supporting autobiographical memory, prospection, and theory of mind, and their relationship to the default mode network. *Journal of Cognitive Neuroscience*, 22, 1112–23.

Steele, C.M., Aronson, J. (1995). Stereotype threat and the intellectual test performance of african americans. *Journal of Personality and Social Psychology*, 69, 797.

Van Hoey, G., Vanrumste, B., D'Havé, M., Van de Walle, R., Lemahieu, I., Boon, P. (2000). Influence of measurement noise and electrode mislocalisation on EEG dipole-source localisation. *Medical and Biological Engineering and Computing*, 38(3), 287–96.

Van Hoey, G., De Clercq, J., Vanrumste, B., et al. (2000). EEG dipole source localization using artificial neural networks. *Physics in Medicine and Biology*, 45(4), 997.

Vick, S.B., Seery, M.D., Blascovich, J., Weisbuch, M. (2008). The effect of gender stereotype activation on challenge and threat motivational states. *Journal of Experimental Social Psychology*, 44, 624–30.

Vogeley, K., May, M., Ritzl, A., Falkai, P., Zilles, K., Fink, G.R. (2004). Neural correlates of first-person perspective as one constituent of human self-consciousness. *Journal of Cognitive Neuroscience*, 16, 817–27.

Wager, T.D., Davidson, M.L., Hughes, B.L., Lindquist, M.A., Ochsner, K.N. (2008). Prefrontal-subcortical pathways mediating successful emotion regulation. *Neuron*, 59, 1037–050.

Wraga, M., Helt, M., Jacobs, E., Sullivan, K. (2007). Neural basis of stereotype-induced shifts in women's mental rotation performance. *Social cognitive and affective neuroscience*, 2, 12–19.

Yan, W.X., Mullinger, K.J., Brookes, M.J., Bowtell, R. (2009). Understanding gradient artefacts in simultaneous EEG/fMRI. *Neuroimage*, 46, 459–71.

Yoshimura, S., Ueda, K., Suzuki, S., Onoda, K., Okamoto, Y., Yamawaki, S. (2009). Self-referential processing of negative stimuli within the ventral anterior cingulate gyrus and right amygdala. *Brain and Cognition*, 69(1), 218–25.