Negative stereotype activation alters interaction between neural correlates of arousal, inhibition and cognitive control

Chad E. Forbes,[1] Christine L. Cox,[1] Toni Schmader,[2] and Lee Ryan[1]

[1]Department of Psychology, University of Arizona, Tucson, AZ, USA and [2]Department of Psychology, University of British Columbia, Vancouver, B.C., Canada

Priming negative stereotypes of African Americans can bias perceptions toward novel Black targets, but less is known about how these perceptions ultimately arise. Examining how neural regions involved in arousal, inhibition and control covary when negative stereotypes are activated can provide insight into whether individuals attempt to downregulate biases. Using fMRI, White egalitarian-motivated participants were shown Black and White faces at fast (32 ms) or slow (525 ms) presentation speeds. To create a racially negative stereotypic context, participants listened to violent and misogynistic rap (VMR) in the background. No music (NM) and death metal (DM) were used as control conditions in separate blocks. Fast exposure of Black faces elicited amygdala activation in the NM and VMR conditions (but not DM), that also negatively covaried with activation in prefrontal regions. Only in VMR, however, did amygdala activation for Black faces persist during slow exposure and positively covary with activation in dorsolateral prefrontal cortex while negatively covarying with activation in orbitofrontal cortex. Findings suggest that contexts that prime negative racial stereotypes seem to hinder the downregulation of amygdala activation that typically occurs when egalitarian perceivers are exposed to Black faces.

Keywords: stereotypes; stereotype inhibition; implicit and explicit processing; social neuroscience; amygdala; prefrontal cortex

INTRODUCTION

Cultural stereotypes seem as ubiquitous in our society as synapses are in our brains. Although our perceptions of others can often be biased by these stereotypes, their effects can be regulated with time, cognitive resources and motivation (Devine *et al.*, 2002; Payne, 2005). Social neuroscience research suggests that these processes are subserved by neural regions associated with arousal, inhibition and control (Amodio *et al.*, 2003; Cunningham *et al.*, 2004). Prior research, however, has only examined these regulatory processes in neutral contexts—where negative stereotypes are not already activated by other features of the context. But what happens when a White individual encounters a Black male while negative Black stereotypes are cued by the context (e.g. by racially stereotypic music)? Is the individual motivated and able to regulate activated stereotypes despite the context justifying that stereotype, or does this situation provide a 'license to stereotype' (Crandall and Eshleman, 2003)?

Using functional magnetic resonance imaging (fMRI) and functional connectivity analyses, the present study tested the hypothesis that in contexts that prime negative racial stereotypes, exposure to black faces will engender prolonged, rather than reduced, activation in brain regions implicated in arousal that alters the interaction between regions implicated in inhibition and control. Such findings would provide support from a cognitive neuroscience perspective for the parameters under which people control their negative biases toward racial out-groups.

Neural underpinnings of stereotype activation, inhibition and control

Encountering a stereotyped out-group member engenders a fast activation of positive and negative cognitive associations and valenced feelings associated with one's representation of the group (Devine, 1989; Lepore and Brown, 1997). Activation of these attitudes and stereotypes can be countered with a slower, more controlled response reflecting an individual's desire to evaluate the out-group member in a non-biased manner (Wilson and Brekke, 1994; Wegener and Petty, 1997; Payne, 2005). Recent advances in social neuroscience suggest that fast and slow cognitive processes (e.g. stereotype activation and subsequent downregulation of that activation) are neurally, as well as behaviorally, identifiable and may interact at multiple speeds of cognitive processing (Forbes and Grafman, 2010).

In particular, activation in the amygdala differentiates reactions to White and Black faces (Hart *et al.*, 2000; Phelps *et al.*, 2000; Lieberman *et al.*, 2005; Ronquillo *et al.*, 2007). Amygdala activity has also been positively correlated with Whites' implicit associations between 'Black' and 'bad' (Phelps *et al.*, 2000) and habituates more slowly to previously seen Black *vs* White faces (Hart *et al.*, 2000). The amygdala may reflect the immediate and often negative arousal induced by exposure to Black faces that are stereotypically associated with hostility and aggression (Phelps *et al.*, 2000).

The amygdala likely relays this arousing information to ventromedial regions of the brain. Medial regions of prefrontal cortex (PFC), including orbitofrontal cortex (OFC), may be particularly important for regulating perceivers' evaluations of Black targets (Forbes and Grafman, 2010). The OFC is highly interconnected with the amygdala and lateral PFC (according to non-human primate studies and human diffusion tensor imaging studies; Amaral and Price, 1984; Ghashghaei and Barbas, 2002; Ghashghaei *et al.*, 2007; Bracht *et al.*, 2009), and may integrate information pertinent to negative affect received from the amygdala (Banks *et al.*, 2007) with information relevant to current context and past experiences from the lateral PFC (Rolls, 2008). Specific to stereotype inhibition, OFC may play a critical role in modulating amygdala activity elicited by exposure to Black faces if that initial bias conflicts with one's explicit, overarching egalitarian motives represented in lateral PFC (Beer *et al.*, 2003; Blair, 2004; Elliott and Deakin, 2005; Cunningham and Zelazo, 2007).

Downregulation of the amygdala can be achieved by lateral PFC indirectly via the OFC and thalamus, as well as directly via a dorsolateral pathway in the external capsule (Fuster, 1997; Nolte 2002; Bracht *et al.*, 2009). Cunningham *et al.* (2004) demonstrated how lateral PFC regions might downregulate amygdala activation in a social context by manipulating the speed at which Black and White faces were presented to self-reportedly non-biased White participants, controlling whether faster or slower cognitive processing would be involved. When participants were presented with a Black face at faster exposure speeds (30 ms), and thus did not have the time to initiate controlled processes, they exhibited an enhanced amygdala response compared to implicitly presented White faces. When Black faces were presented at slower exposure rates (525 ms), however, this difference in amygdala activity was not evident. Instead, enhanced activity was seen in the dorsolateral prefrontal cortex (DLPFC), among other regions, that was correlated with decreases in amygdala activity in response to slower exposure to Black faces. Thus while exposure to Black faces may elicit an initial, arousing reaction as indexed by increased amygdala activity, with time and motivation, increased DLPFC activity at slower processing speeds suggests individuals are able to downregulate this response. Furthermore, the downregulation of this response is thought to be cognitively taxing and dependent on finite metabolic resources (Richeson *et al.*, 2003).

The goal of the present study was to test the hypothesis that the amygdala activation cued by novel Black faces would not be downregulated when those faces are encountered in a context that primes and reinforces violent or hostile negative racial stereotypes. Past research suggests that individuals' perceptions of out-group members are predicated on the situation (Wittenbrink *et al.*, 2001; Blair, 2002). Even manipulating music played in the background can have robust effects on stereotype activation and overt perceptions of out-group members (Johnson *et al.*, 2000; Rudman and Lee, 2002).

Hypotheses

These findings suggest that contextual cues that sustain negative stereotype activation might either, (i) legitimate the application of a negative stereotype to a target out-group individual (i.e. reduce motivation; Crandall and Eshleman, 2003), or (ii) make it more cognitively demanding to downregulate what is now an enhanced or prolonged negative arousing reaction (i.e. reduce ability). Both routes to the biased response could result in enhanced amygdala activity to Black (*vs* White) faces that persist even when the faces are presented at speeds that normally allow for cognitive control.

This primary hypothesis was addressed using fMRI. Black and White male faces were presented at fast (32 ms) or slow (525 ms) presentation rates to self-reportedly non-biased White participants while (NM), violent and misogynistic rap (VMR) or death metal (DM) played in the background. Past research has demonstrated that rap music is stereotypically associated with Blacks more than Whites, whereas rock music is stereotypically associated with Whites more than Blacks (Rentfrow *et al.*, 2009). We hypothesized that when subjects heard no music in the background findings would replicate Cunningham *et al.* (2004); whereas fast exposure to Black (*vs* White) faces should elicit increased amygdala activity, slow exposure to Black faces should elicit increased DLPFC activity in lieu of amygdala activity.

Since contextual support for negative stereotypes of Blacks should elicit a prolonged arousal response to novel out-group members, we further hypothesized increased amygdala activity in response to both fast and slow exposure to Black faces when subjects are also listening to no music (VMR). If this prolonged amygdala response prompts (rather than reduces) a motivation to downregulate stereotype activation in attempts to perceive out-group members in a non-biased manner, we might expect increases in OFC and DLPFC activity in response to Black faces (*vs* White faces). Functional connectivity analyses will provide a more sensitive, direct assessment of the degree to which amygdala activity modulates OFC and DLPFC activity at both fast and slow presentation speeds.

We included a DM condition to prime negative affect but not negative Black stereotypes. Thus, in this context, we did not expect differences in amygdala, OFC or DLPFC activation when participants were exposed to Black *vs* White faces (regardless of presentation speed).[1]

MATERIALS AND METHODS

Participants

Twenty-three White undergraduates (10 males, 13 females; aged 18–21 years) participated for course credit. Participants were screened to exclude drug and/or alcohol abuse, neurological disorder, head injury with sequelae, psychiatric illness and contraindications to MRI. The data from two participants were excluded due to aberrant artifacts incurred during data acquisition.

Materials

In an initial pilot study, White participants ($n = 20$) listened to five songs from the VMR and DM genres and rated each song on its valenced feeling, stereotypicality of Black or White Americans, tempo and association to violence. Out of this analysis, 'Straight Outta Compton' by N.W.A. (VMR) and 'Only One' by Slipknot (DM) were selected because they were equivalent in negative affect, perceived violence and tempo, but the VMR song was rated more stereotypic of Black Americans than the DM song.

Task and procedure

As part of a larger study, the experiment was a within-subjects design that used a task similar to that of Cunningham *et al.* (2004). Participants believed they were serving as a control group for a study investigating neural relationships between music and spatial processing in prosopagnosic patients.[2] Participants were exposed to either fast (32 ms) or slow (525 ms) presentations of emotionally neutral Black and White male faces. Three fMRI scans were completed while either NM, VMR or DM played in the background over headphones.

During the task, participants were instructed to focus on a crosshair in the middle of the screen (ISI jittered 1945–2445 ms) presented through goggles in the scanner,

and to press a mouse button (left or right) corresponding to which side of the crosshair an image appeared. Stimuli were randomized and counterbalanced according to stimulus type and left/right presentation. Each face was presented once and masked with its corresponding scrambled, Fourier-transformed image. For the fast presentation condition, each trial began with the presentation of a cross hair in the middle of the screen, followed by the presentation of a Black or White face for 32 ms, and then the presentation of its Fourier-transform for 525 ms (Morris *et al.*, 1998; Whalen *et al.*, 1998). For the slow presentation condition, a Black face or White face was presented for 525 ms, followed by its Fourier-transform for 32 ms. Trial lengths were held constant at 557 ms. Each block consisted of 96 total trials that contained 12 each of Black and White faces presented at both presentation speeds, and 24 fast and slow square trials. All sessions began with the NM block so that baseline reactions to fast and slow Black faces could be obtained. The two remaining music blocks were counterbalanced.

Once participants completed the task, they were asked to complete a series of questionnaires outside the scanner, including questions specific to what they thought the purpose of the study was and whether they saw fast face primes. Participants were then extensively probed for knowledge or suspicion specific to both impressions of true study purposes and awareness of fast faces, before being debriefed. No participants reported any connections between the music and race of the faces, nor did anyone report seeing any fast duration faces.

Image acquisition and analysis

Functional images were acquired on a 3.0T scanner with an eight-channel phased-array coil (HD Signa Excite, General Electric, Milwaukee, WI, USA). Using a 2D single shot spiral in/spiral out sequence (Glover and Law, 2001; TR = 2300 ms, TE = 30 ms, FOV = 240 mm, matrix = 64×64), 35 sections were collected (3 mm, 0.5 mm skip) aligned obliquely in the coronal plane, tilted $30°$ anterior of the anterior commissure/posterior commissure axis. Audiovisual stimuli were projected through VisuaStim digital goggles and headphones (Resonance Technologies, Inc.). High-resolution anatomical 3D SPGR as well as T1-weighted anatomical images were obtained for localization of functional activity and for registration of fMRI data sets to stereotactic space according to the Montreal Neurological Institute (MNI) template. Images were reconstructed offline and preprocessed using Statistical Parametric Mapping software (SPM2; Wellcome Department of Cognitive Neurology, London, UK). All volumes were realigned to the third volume to correct for movement. The data in each section were interpolated in time to match the acquisition timing of the middle section. In order to minimize normalization errors due to partial brain coverage, spatial normalization parameters were estimated by first co-registering each participant's mean functional image to their T1 anatomical image, warping the T1

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[1]Although rock music is stereotypically associated with Whites, our participants were White and there is no empirical precedent for expecting amygdala activation in response to in-group faces. Thus, we did not hypothesize (nor did we find) a symmetrical effect indicating activation of biases to white faces in this condition.

[2]Participants were specifically told that we were interested in facial and object recognition, audio perception and how these processes are related to each other in the brain. They were informed that prosopagnosics have trouble identifying faces but may also have acute sensitivities to different kinds of music and certain musical patterns and that many researchers argue that these deficiencies and/or sensitivities may be due to the audio perception region of the brain experiencing chronic increased stimulation which in turn causes a decrease in activity in the facial and spatial recognition regions of the brain. Participants thought then that they were part of a control group for prosopagnosics being run in the same study and that their efforts would provide insight in to how and why certain audio stimuli may affect one's attempts to accurately identify faces and objects that are located in different areas of one's visual field. In light of this cover story, no participants accurately identified the true purpose of the study.

image to the standard MNI T1 template, and then applying the resulting normalization parameters to each functional image (Ashburner and Friston, 1999). The normalized images were resliced to $3 \times 3 \times 3$ mm voxels and smoothed with an isotropic 6 mm FWHM Gaussian kernel. The time series in each voxel was high-pass filtered to 1/128 Hz and averaged over all voxels and scans within a session.

Functional images were analyzed using SPM2 with statistical analyses performed by first modeling neural activity with a delta function at stimulus onset; stimulus duration was defined according to length of presentation (for faces, either 32 or 525 ms; Williams *et al.*, 2006). The ensuing BOLD response was modeled by convolving these delta functions with a canonical hemodynamic response function (HRF; Friston *et al.*, 1995). The resulting time courses were downsampled to form covariates in a General Linear Model. Covariates were modeled for the canonical HRFs of the Black and White faces separately for each presentation speed in each condition previously described.

For manipulation checks, comparisons between the music and NM conditions were carried out, and confirmed that activation in the auditory cortex was observed within the context of music primes. In addition, comparisons between the face and no face (squares) conditions (collapsed across music) confirmed activation in the fusiform face area.

Region of interest and connectivity analyses

Contrasts of parameter estimates were used in a second-level analysis, which treated participants as a random effect (one-sample *t*-test); contrasts of interest taken to the second-level included fast Black > fast White faces and slow Black > slow White faces in each condition. Results from these analyses are presented for a priori regions of interest (ROI) based on previous research as outlined in the introduction (amygdala, OFC and DLPFC) thresholded at $P < 0.01$ with a small volume correction and cluster size threshold of three voxels (following methods consistent with previous studies on amygdala activity and face processing but with a more conservative threshold, e.g. Killgore and Yurgelun-Todd, 2004; Das *et al.*, 2005; Liddell *et al.*, 2005). For completeness, contrasts comparing fast White > fast Black and slow White > slow Black were also carried out. Results are presented in Supplementary Table S1 (significant results were only observed in the fast but not slow condition for these comparisons). Anatomical regional masks were based on standardized neuroanatomical divisions (Lancaster *et al.*, 2000; Tzourio-Mazoyer *et al.*, 2002).

We also conducted analyses comparing activation levels between the three conditions. Effect size estimates were extracted from the aforementioned regions of interest for each participant, focusing on the fast Black face > fast White face and slow Black face > slow White face contrasts. Repeated measures Analyses of Variance (ANOVA) were conducted to assess differences in neural activity between the three

conditions, and planned contrasts were conducted to assess for differences between the VMR condition compared to the other two conditions specifically.[3]

Psychophysiological interaction (PPI) analyses were carried out in order to determine how activity in the amygdala modulated activity in other brain regions specifically for Black > White faces (Friston *et al.*, 1997; as described in Das *et al.*, 2005). In those contrasts displaying amygdala activation at the group level, time series from individuals' volumes of amygdala activation (NM fast: $n = 14$; VMR fast: $n = 12$; VMR slow: $n = 9$) were extracted, and PPI models were created modeling the interaction with amygdala activity for Black > White faces. Resulting contrast maps were taken to a random effects analysis (one-sample *t*-test), the results of which are presented, set at a threshold of $P < 0.005$ with a small volume correction and cluster size threshold of three voxels (Friston *et al.*, 1997; Das *et al.*, 2005).

Stereotactic coordinates were generated in the standard MNI brain by SPM, and are reported here in MNI space.

Behavioral measures

Post-scanning, participants were asked to rate how each song made them feel ($1 =$ very negative, $7 =$ very positive), how stereotypic of Black Americans each song was ($1 =$ not stereotypic, $7 =$ very stereotypic), and whether they owned a copy of the song. None of the participants owned a copy of the songs used. To assess explicit prejudice levels, participants were asked to complete the Modern Racism Scale (MRS, 4-point scale; McConahay, 1986) and the Motivation to Respond Without Prejudice Scale (MRWPS, 9-point scale; Plant and Devine, 1998).

RESULTS

Behavioral measures

Participants reported explicit prejudice levels ($M = 2.34$, s.d. $= 0.31$) that were significantly below the scale midpoint (3), $t(20) = -9.57$, $P < 0.001$. Participants also reported being more internally motivated to respond without prejudice ($M = 7.82$, s.d. $= 1.32$) compared to the scale midpoint (5), $t(20) = 9.77$, $P < 0.001$, and marginally more externally motivated ($M = 5.81$, s.d. $= 1.90$), $t(20) = 1.95$, $P = 0.06$. Thus, our sample reported being explicitly non-prejudiced and motivated to regulate bias.

Repeated measures analyses revealed that participants rated the VMR ($M = 3.86$, s.d. $= 1.39$) and DM ($M = 3.19$, s.d. $= 1.69$) songs as comparable in the negative affect they engendered, $F(1, 20) = 1.89$, $P = 0.18$. Participants also rated the VMR song ($M = 5.81$, s.d. $= 0.81$) as more stereotypic of Blacks than Whites ($M = 4.00$, s.d. $= 1.82$), $F(1, 20) = 14.14$, $P < 0.01$, and the DM song as more stereotypic of Whites

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[3]Caution is stressed in interpretation of these comparisons because the no music condition was always first and there is a tendency for the amygdala response to habituate to stimuli (albeit at a slower rate) over time (Hart *et al.*, 2000; Olsson *et al.*, 2005).
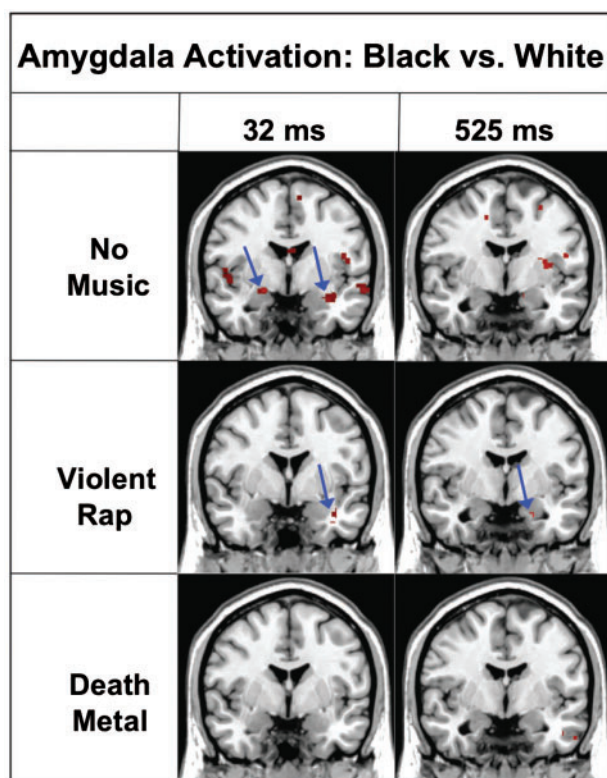
Fig. 1 Amygdala activation for Black > White faces as a function of fast (32 ms) or slow (525 ms) presentation speeds.

Table 1 Activation for Black compared to White faces at fast (32 ms) presentation speeds in a priori regions of interest

Condition Brain Region	L/R	T-value	MNI			No. of voxels
			x	y	z	
No music						
Amygdala	L	4.36	−20	−4	−12	22
	R	3.24	32	−2	−18	15
Orbital frontal	L	4.83	−34	54	−2	79
	L	4.28	−32	54	0	87
	L	4.29	−32	54	−2	155
	R	2.87	26	50	−2	7
	R	3.02	28	48	−4	21
	R	3.72	28	60	−14	112
Dorsolateral PFC	L	3.28	−48	34	22	20
	L	2.77	−44	36	22	6
Violent rap						
Amygdala	R	2.71	36	2	−24	3
Orbital frontal	L	2.69	−46	48	−6	5
	R	2.94	38	56	0	10
Death metal						
N/A						

All activations significant at $P < 0.01$, small volume corrected with a cluster threshold of three voxels.
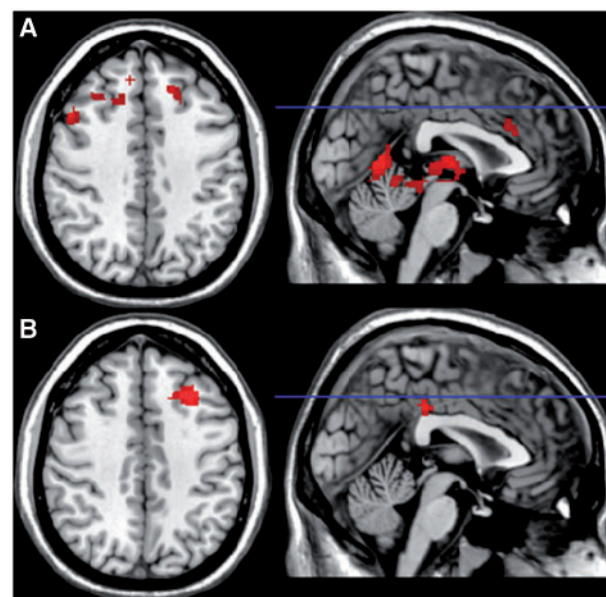L, left; R, right; PFC, prefrontal cortex; N/A, not applicable.

$(M = 4.81,\ \text{s.d.} = 1.47)$ than Blacks $(M = 2.81,\ \text{s.d.} = 1.66)$, $F(1, 20) = 17.14,\ P < 0.01$.

ROI and connectivity analyses: NM condition

As predicted, when participants heard NM in the background, fast exposure to Black faces, compared to White faces, elicited bilateral amygdala activation, replicating Cunningham *et al.*'s (2004) findings (Figure 1). Greater activity was also found in bilateral OFC and left DLPFC in response to Black > White faces at fast exposure (Table 1). Furthermore, PPI analyses revealed that amygdala activity negatively covaried with activity in left OFC and bilateral DLPFC (Figure 2 and Table 3). Therefore, even though we observed greater activation for Black compared to White faces in both amygdala and prefrontal regions, further analyses suggested a more subtle inverse relationship between these regions.

Slower exposure to faces revealed no differential amygdala activity for Black > White faces (Figure 1). Consistent with the interpretation that individuals were able to successfully downregulate initial amygdala activity at slower presentation speeds, exposure to Black (*vs* White) faces for 525 ms elicited greater activity in right DLPFC (Table 2). Given that there was no differential amygdala activation present at slow presentation speeds, PPI analyses were not conducted in this condition.

Fig. 2 PPI analyses demonstrating regions of the DLPFC that negatively covaried with amygdala activity in response to fast exposure to Black faces in the (A) No Music condition and (B) VMR condition.

ROI and connectivity analyses: death metal condition

When participants received fast exposure to faces during DM, no differential amygdala, OFC or DLPFC activity was observed in response to Black > White faces. DM also did not elicit any differential amygdala activity in response to Black > White faces presented at slower exposure rates

Table 2 Activation for Black compared to White faces at slow (525 ms) presentation speeds in a priori regions of interest

Condition Brain Region	L/R	T-value	MNI			No. of voxels
			x	y	z	
No Music						
Dorsolateral PFC	R	2.88	28	−2	56	14
Violent Rap						
Amygdala	R	3.06	22	−4	−24	3
Orbital frontal	L	2.83	−38	30	−4	9
Dorsolateral PFC	L	2.84	−42	2	46	6
Death metal						
Orbital frontal	R	2.94	42	52	−16	11
	R	3.03	26	56	−14	11
Dorsolateral PFC	R	2.77	38	36	34	5

All activations significant at $P < 0.01$, small volume corrected with a cluster threshold of three voxels.
L, left; R, right; PFC, prefrontal cortex.

(Figure 1), but greater activation to Black > White faces was observed in right OFC and right DLPFC (Table 2). In light of there being no differential amygdala activation at either presentation speed, PPI analyses were not conducted within the DM condition. Thus, exposure to DM appeared to create a context where Black and White faces were perceived in a similar manner at fast presentation speeds. At slower presentation speeds, greater OFC and DLPFC activation to Black faces is consistent with an interpretation that exposure to Black faces still cued individuals to engage in more controlled processing.

ROI and connectivity analyses: VMR condition

Our key hypotheses concerned patterns of activation in the context of racially stereotypic (VMR) music. Consistent with the NM condition, fast exposure to Black (*vs* White) faces in the context of VMR elicited greater activity in the right amygdala (Figure 1) and bilateral OFC (Table 1).

Examining overall neural responses to Black faces with slow exposure in a negative stereotypic context also revealed a pattern consistent with predictions. Although participants in the NM condition seemed to have downregulated their amygdala response at slow presentation speeds, when listening to VMR, participants exhibited greater right amygdala activity during slow exposure to Black compared to White faces (Figure 1). In addition, consistent with the interpretation that participants might still have been motivated to try to control stereotype activation, exposure to VMR also resulted in increased left OFC and DLPFC activity for Black > White faces (Table 2).

PPI analyses revealed other intriguing points of contrast to the NM Condition. At fast exposure rates, amygdala activity for Black > White faces *positively* covaried with activity in left OFC and left DLPFC but *negatively* covaried with activation in a more extensive region of right DLPFC than that seen in

Table 3. Regions of activation that positively or negatively covaried with amygdala activation for Black compared to White faces at fast (32 ms) and slow (525 ms) presentation speeds

Condition Brain Region	L/R	T-value	MNI			No. of voxels
			x	y	z	
32 ms						
Positive: No Music fast						
N/A						
Negative: No Music fast						
Orbital frontal	L	3.25	−40	32	−8	19
Dorsolateral PFC	L	3.51	−18	40	26	59
	L	4.62	−48	18	42	45
	L	3.20	−32	30	40	21
	L	3.71	−12	38	44	67
	R	2.93	22	44	28	3
	R	3.88	22	32	34	84
	R	3.71	18	46	28	32
Positive: Violent Rap fast						
Orbital frontal	L	3.36	−42	52	−2	68
	L	3.07	−28	48	−4	6
Dorsolateral PFC	L	2.96	−22	10	60	5
Negative: Violent Rap fast						
Orbital frontal	R	3.46	46	38	−14	41
Dorsolateral PFC	R	4.64	28	26	44	241
525 ms						
Positive: Violent Rap slow						
Dorsolateral PFC	R	3.41	22	24	54	8
Negative: Violent Rap slow						
Orbital frontal	L	4.12	−30	34	−2	22

All activations significant at $P < 0.005$, small volume corrected with a cluster threshold of three voxels.
L, left; R, right; PFC, prefrontal cortex; N/A, not applicable; Positive, positive covariation; Negative, negative covariation.

NM (Figure 2 and Table 3). At slow exposure rates, these relationships reversed: amygdala activity to Black > White faces positively covaried with right DLPFC activity, but negatively covaried with left OFC activity (Figure 3 and Table 3). We consider possible interpretations of these relationships below.[4]

ROI comparisons between music conditions

Repeated measures ANOVAs and planned contrasts (VMR = 2, NM = −1, DM = −1) were conducted on effect size estimates extracted from the ROIs to assess the unique effects of negative stereotypic primes on participants' neural response to the exposure of fast and slow Black faces. We focus on right lateralized comparisons.

Amygdala Activity. With respect to fast exposure to Black faces, we found a main effect for right amygdala activity, $F(1, 20) = 5.35$, $P < 0.01$, that resulted from greater amygdala

[4]Participants in the fMRI experiment also rated each song on how positive or negative it made them feel, how stereotypic it was of Black or White Americans, tempo, how violent it was and how much they liked each song and each music genre post-experiment. We extracted effect size estimates from the amygdala ROI and entered all of the aforementioned variables in to a simultaneous regression analysis predicting amygdala activity in response to black faces presented at either fast or slow presentation times. These analyses yielded no significant effects for any of the variables, all *P*'s > 0.10.
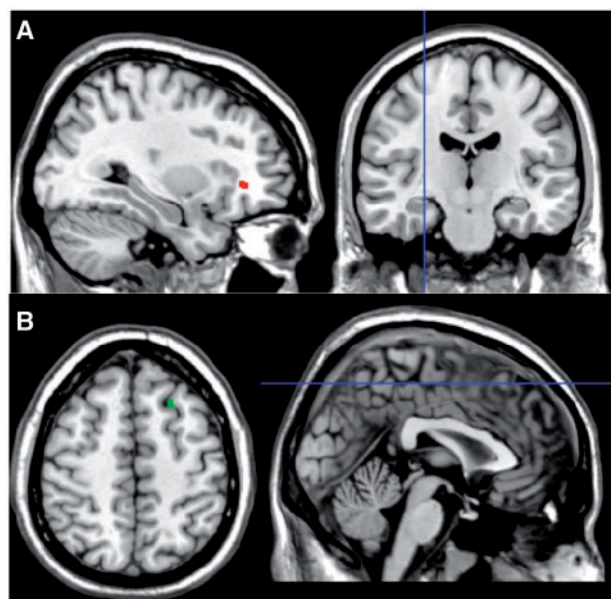
Fig. 3 PPI analyses conducted on amygdala activation in the VMR condition in response to slow exposure to Black faces revealed (A) negative covariation between the amygdala and OFC (red voxels), but (B) positive covariation between the amygdala and DLPFC (green voxels).

activity in the VMR condition compared to the NM and DM conditions, $F(1,20) = 7.08$, $P < 0.02$. As predicted, this pattern persisted in response to slow exposure to Black faces, $F(1,20) = 5.01$, $P < 0.02$; planned contrasts revealed greater amygdala activity in VMR compared to the NM and DM conditions, $F(1,20) = 5.01$, $P < 0.04$.

OFC Activity. Analyses conducted on OFC activity in response to fast exposure of Black faces yielded a main effect for condition, $F(1,20) = 3.71$, $P < 0.04$; participants elicited somewhat more OFC activity in response to Black faces when primed with VMR compared to NM and DM, $F(1,20) = 4.13$, $P = 0.056$. Although there was also a main effect for response to slower exposure of Black faces, $F(1,20) = 12.01$, $P < 0.001$, planned contrasts revealed greater OFC activity in the NM and DM conditions compared to the VMR condition $F(1,20) = 12.02$, $P < 0.01$.

DLPFC Activity. Finally, analyses conducted on DLPFC activity revealed condition main effects in response to both fast exposure, $F(1,20) = 7.34$, $P < 0.01$, and slow exposure, $F(1,20) = 3.20$, $P = 0.05$, of Black faces. Planned contrasts indicated that greater DLPFC activity was elicited in the NM and DM conditions compared to the VMR condition $(F\text{'s} > 4.83$, $P\text{'s} < 0.05)$.[5]

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[5]It should be noted that we also found decreased right DLPFC activity in slow White > Black face contrasts in the VMR condition compared to the NM and DM conditions, suggesting that VMR is generally reducing right DLPFC activity compared to other regions for reasons that are unclear. Conversely, we found greater increases in left DLPFC activity in slow Black > White face contrasts in the VMR condition compared to the NM and DM conditions, which is consistent with within condition effects. Nevertheless, it is ultimately difficult to interpret these between condition comparisons because activity in the PFC could stem from different kinds of psychological processing varying by context.

Behavioral follow-up

A follow-up behavioral study tested our assumption that prolonged exposure to VMR primes engenders more negatively biased perceptions of novel Black faces. After completing a between-subjects version of the same face priming task that our primary sample completed in the scanner, 41 White participants with high motivation to be non-prejudiced ($M_{\text{EMNP}} = 6.81$, $\text{MD}_{\text{EMNP}} = 6.40$; $M_{\text{IMNP}} = 7.73$, $\text{MD}_{\text{IMNP}} = 7.80$) were asked to estimate the number of Black and White faces they saw during the task that were angry and happy (in actuality, all faces had neutral expressions). We hypothesized that participants would estimate having seen a greater number of angry Black faces when making this judgment if they had completed the face priming task while listening to VMR. Given prior evidence that individuals are more likely to perceive anger in out-group faces (Hugenberg and Bodenhausen, 2003; Dunham, 2011), we reasoned that if VMR makes negative racial stereotypes salient (i.e. Rudman and Lee, 2002), this evaluative bias would be accentuated.

A 3 (Condition: NM, VMR and DM) × 4 (Face type: Angry Black, Angry White, Happy Black and Happy White) mixed factors ANOVA with repeated measures on the latter variable yielded a main effect for condition ($P < 0.01$) and face type ($P < 0.001$), which was qualified by a significant interaction, $F(1,38) = 3.90$, $P = 0.001$. Participants in the VMR condition reported seeing more angry black faces ($M = 67.88$, s.d. $= 31.34$) compared to angry white faces ($M = 53.76$, s.d. $= 33.20$; $P < 0.001$) and more angry black faces compared to individuals listening to either NM ($M = 21.86$, s.d. $= 27.54$; $P < 0.001$) or DM ($M = 35.00$, s.d. $= 31.62$; $P < 0.01$). There were no differences in percentage of angry black faces reported between participants in the DM and NM conditions ($P\text{'s} = 0.30$). These patterns provide further evidence that exposure to VMR elicits biased perceptions toward novel out-group members that are consistent with the negative stereotypic prime, despite chronic egalitarian goals.

DISCUSSION

This study examined whether people attempt to and succeed at downregulating a biased response to an out-group individual even when the context primes a negative stereotype. The findings were consistent with the interpretation that, although White individuals are successful at controlling an initial arousal reaction to a Black target in a neutral (NM) context, this arousal response is not downregulated in the presence of negative stereotypical cues (while listening to VMR). Specifically, findings in a neutral context replicated earlier work by Cunningham *et al.* (2004) by showing that fast exposure to Black faces engendered an enhanced amygdala response. Functional connectivity analyses extended past work by indicating that increased amygdala activity at fast presentation speeds was negatively associated with activation of the OFC and DLPFC.

In contrast, when faces were encountered in a racially stereotypic context (via VMR exposure), we observed increased amygdala activity in response to fast exposure to Black faces as well as increased activation in the OFC (but not in the DLPFC) that was greater than that found in Black stereotype-neutral contexts (i.e. NM and DM). Furthermore, this increased amygdala activity in response to Black faces was evident even at slower exposure rates, suggesting that in this context, the initial arousal elicited by exposure to a Black face was not downregulated. Participants in the VMR condition also showed increased activation in the left OFC and DLPFC to Black *vs* White faces. Importantly, these results were unique to situations that primed negative stereotypes of Blacks, as these patterns were not evident when Black faces were presented to participants in a negative affective context alone (i.e. the DM condition). In conjunction with the behavioral findings, these patterns suggest that in negative Black stereotypical contexts, Whites who on average are motivated to be non-prejudiced, might still react with bias to members of a racial out-group.

Functional connectivity analyses provided further insight into the potential neural dynamics underlying these findings. The standard account of down-regulating a negative affective response suggests a negative relationship between neural regions associated with control (e.g. DLPFC) and those associated with arousal (e.g. amygdala). When Black faces were presented at fast exposure rates, there was a negative association between activation in the amygdala and right DLPFC in both the NM and VMR conditions. However, only in the VMR condition did we observe a *positive* association between amygdala activation and activation in both the left OFC and DLPFC to fast presented Black faces. In contrast, at slow exposure rates amygdala activation to Black (*vs* White) faces negatively covaried with activation in the OFC and positively covaried with activation in the right DLPFC.

There are two possible interpretations for the lack of down-regulation observed in a stereotypic context. On the one hand, exposure to an ongoing stereotypic context could elicit a prolonged negative response that taxes processing demands in regions implicated in cognitive control. As a result, efforts to control bias are initiated but unsuccessful at down-regulating affect. This interpretation is consistent with other evidence that reduced executive functioning predicts greater biases in response to exposure to out-group members (Richeson *et al.*, 2003; Payne, 2005). Our participants were highly motivated to respond without prejudice and thus likely to engage in bias control (Amodio *et al.*, 2003). At the same time, our task did not require participants to overtly control stereotypic responses, and we have no direct evidence that attempts to control bias were initiated in the VMR condition. Thus, we cannot conclusively interpret activity in the DLPFC as control in particular.

An alternative explanation for the pattern of findings is that VMR reinforces the initial negative response to Black faces and elicits biased elaboration of it. Crandall and Eshleman's (2003) suppress–justification account of prejudice suggests that certain stereotyped contexts could lead Whites to feel justified in viewing Blacks in a negative light. Thus, when listening to VMR, controlled processes (as evidenced by increases in the DLPFC) could be recruited to justify rather than suppress biased appraisals of the faces. Other research has found evidence of increased activation in a large portion of lateral PFC when perceivers apply stereotypes to targets (Mitchell *et al.*, 2009). Further evidence is needed to disambiguate these two accounts; however, the coordinates within DLPFC that covaried with amygdala activity in this study were much more consistent with those found in studies involving cognitive control of emotional distractors (e.g. Warren *et al.*, 2010), than they were with findings from studies such as Mitchell *et al.* (2009).

A seemingly surprising finding in this study was the evidence for OFC and DLPFC activity in response to fast exposure to Black faces. Prior research on the neural substrates involved in prejudice control has suggested that the OFC and DLPFC regulate biases through more explicit or slow processing.[6] We not only observed evidence of overall activation in these regions after fast exposure to black faces, but OFC and DLPFC were differentially, yet reliably, associated with amygdala activity at both fast and slow presentation speeds. Such findings imply that processes involved in monitoring and control of racial bias might be initiated quite quickly if not automatically, and indeed, research utilizing event-related brain potential (ERP) methodology provides direct evidence that conflict induced by racial primes can initiate neural control mechanisms as early as 50 ms after a given prime (Amodio *et al.*, 2004; Amodio *et al.*, 2008; for a recent review, see Bartholow, 2010).

To better understand these effects, it could be useful to conceive of automatic/implicit/fast and controlled/explicit/slow cognitive processes as lying on a temporal continuum of control as opposed to representing two orthogonal constructs (e.g. Cunningham and Johnson 2007; Devine and Sharp, 2009; Forbes and Grafman, 2010). The OFC may aid in selecting and actively inhibiting neural circuits associated with arousing responses anywhere along this continuum, i.e. either quickly or more slowly, possibly through a dynamic interaction between regions such as the amygdala and DLPFC (Rule *et al.*, 2002). In conjunction with known neuroanatomical feedforward and feedback loops, functional and anatomical connectivity between cortical and subcortical regions and neural transmission speeds on the order of 0.5–50 m/s within the cortex in general (Fuster, 1997; Buzsaki, 2006), it is difficult to imagine how the OFC and DLPFC could only be involved in the

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[6]Although note that Cunningham *et al.* (2004) also found increased activity in left superior frontal sulcus ($x = -21$, $y = 30$, $z = 39$), a region located in Brodmann's area 9 and considered to be part of the DLPFC, in the B > W face contrast in the fast condition.

dynamic modulation of behavior later in the information processing stream (e.g. 525 ms or slower). Consistent with this reasoning, evidence suggests that ventromedial PFC regions are equally involved at fast and slow speeds of processing of self-relevant schematic material (Rameson *et al.*, 2010), and egalitarian minded individuals activate goals to regulate their racial biases after subliminal exposure to Black face primes (Moskowitz *et al.*, 2000); goals that are likely represented in medial and lateral PFC regions specifically (Barbey *et al.*, 2009). Thus, our evidence of OFC and DLPFC activation after only brief exposure to affectively charged primes adds to a growing literature supporting a more continuum-based view of fast and slow social cognitive processes.

We acknowledge the limitations of drawing strong temporal conclusions from these data given the sub-optimal temporal resolution of fMRI methodology. Although our scanning parameters were optimized for our rapid event-related design, including a jittered inter-stimulus interval that allowed us to deconvolve the signal, the nature of the hemodynamic response limits the ability to obtain pure assessments of neural responses to stimuli presented at fast exposure times. Conducting PPI analyses bolstered our ability to make some inferences by allowing us to identify regions that reliably covaried with amygdala activity at both fast and slow presentation speeds. However, future studies are needed using electroencephalography in conjunction with fMRI, or phase coherence analyses to assess the degree to which medial and lateral PFC regions thought to underlie these different cognitive processes fire synchronously, i.e. communicate, with one another on the order of milliseconds (e.g. Cavanagh *et al.*, 2009).

In addition, it is important to acknowledge the current limitations on drawing strong inferences from patterns of neural activation. As detailed by Cunningham (2010) and Poldrack (2006), inferences drawn from patterns of neural activation are only as good as the prior research mapping that activation onto mental states and operations and the selectivity of activation in a given region. We have attempted to interpret the findings from the current study in a theoretical framework based on prior human and primate neurophysiological studies (fMRI, EEG and lesion) implicating activation in brain regions observed in our study with certain cognitive processes (e.g. dorsolateral PFC with cognitive control, amygdala with arousal and negative emotional processing). We acknowledge, however, that fMRI data are correlational and that our paradigm and analyses do not provide sufficient evidence to claim directionality or causality of neural processing. Therefore, we interpret and present our results in a manner consistent with prior evidence and interpretations by others (e.g. negative arousal associated with amygdala activation is down-regulated by control processes associated with DLPFC activation). Though our PPI analyses provide some evidence that amygdala and DLPFC are co-activated in our task, it remains possible

that they are activated independently and process different aspects of the task. The differential co-activation observed in the different task conditions argues against this interpretation, but the possibility cannot be ruled out with current methods.

Using a social neuroscience approach, this study provides insight into how non-prejudiced individuals sometimes perceive Black Americans in a negative stereotypic way when something as subtle as a rap song is played in the background. Our results suggest that non-prejudiced Whites might not control a negative response to Black targets encountered in a negative stereotypic context due to a complex interaction between neural systems involved in arousal, inhibition and control.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

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