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An fMRI investigation of race-related amygdala activity in African-American and Caucasian-American individuals

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Functional magnetic resonance imaging (fMRI) was used to examine the nature of amygdala sensitivity to race. Both African-American and Caucasian-American individuals showed greater amygdala activity to African-American targets than to Caucasian-American targets, suggesting that race-related amygdala activity may result from cultural learning rather than from the novelty of other races. Additionally, verbal encoding of African-American targets produced significantly less amygdala activity than perceptual encoding of African-American targets.

The amygdala has long been known to play a role in responding to the emotionality of a stimulus, activating to images containing threatening, novel or highly arousing features[1]. Given the emotionality associated with racial interactions between Caucasian-American and African-American individuals, it is perhaps not surprising that recent studies have also shown that the amygdala is associated with race-related processing and that the amount of amygdala activity correlates with race-related prejudice[2–4]. Previous studies suggest that the amygdala plays a role in race-related processes, but the nature of that role and the conditions under which it is instantiated remain unclear.

The current study was conducted to investigate two aspects of race-related processing in the amygdala. The first goal was to examine the differential responses in the amygdala of African-American and Caucasian-American participants to African-American and Caucasian-American faces. Most previous studies have not directly addressed or have lacked the statistical power to effectively address the issue of whether African-American and Caucasian-American individuals produce similar or different amygdala responses to African-American and Caucasian-American faces.

The second goal of this investigation was to examine whether the manner of encoding race-related stimuli affects the amygdala's response to target race. Previous paradigms have examined only the perceptual encoding of target race, examining neural responses to images of same- or other-race faces. One possibility is that verbal encoding of the race of African-American targets should result in greater amygdala activity than perceptual encoding because perceptual encoding of African-American targets allows attention and thought to be focused on any number of target characteristics such as gender or age, whereas verbal encoding focuses attention and thought primarily on race[5]. Alternatively, a second possibility is that verbal processing of the race of African-American targets should result in less amygdala activity than perceptual processing because of the general role of language and resource-limited cognitive abilities, known as controlled processes, in correcting and overriding automatic impulses, such as those generated by the amygdala[6–8].

The current study examined, for both African-American and Caucasian-American participants, the consequences of both perceptual and verbal processing of race on the amygdala. On perceptual encoding trials, participants chose the face (from a pair of faces at the bottom of the screen) that was of the same race as the target face at the top of the screen (see **Fig. 1a** and **Supplementary Note** for methodological details). On verbal encoding trials, participants chose the race label (from a pair of labels at the bottom of the screen) that indicated the race of the target at the top of the screen. Half of the verbal and perceptual encoding trial blocks had predominantly African-American targets and half had predominantly Caucasian-American targets.

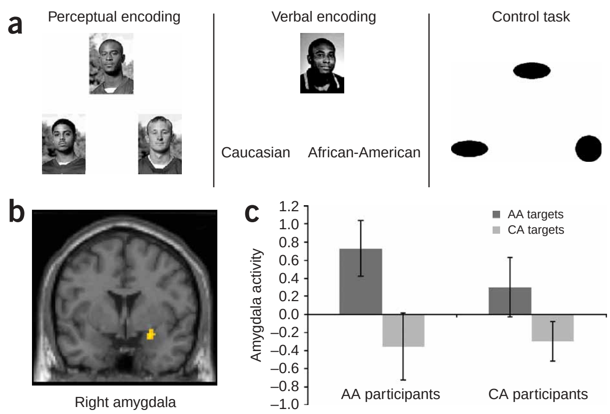

Figure 1 Task and amygdala responses. (**a**) Sample stimuli from the perceptual encoding task, the verbal encoding task and the control task. From the pair of stimuli at the bottom of the screen, participants always chose the stimulus that best matched or described the target at the top of the screen. For half of the trial blocks, most targets were African-American faces, and for the other half of the trial blocks, most targets were Caucasian-American faces. (**b**) The region of right amygdala (26, 2, −14) that was more active during the presentation of African-American faces than during the presentation of Caucasian-American faces, across both participant races and encoding tasks. (**c**) Amygdala activity as a function of participant race and target race during perceptual encoding of African-American and Caucasian-American targets. Results are in terms of parameter estimates of signal intensity, relative to the control task, in ROI analyses of the right amygdala. Error bars represent s.e.m. Informed written consent was obtained from all participants.

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Results indicated that both African-American and Caucasian-American participants produced a greater response in the right amygdala to African-American targets than to Caucasian-American targets. However, this effect was modulated by encoding task such that increased amygdala activity to African-American targets was present only during perceptual encoding. Additionally, a general pattern emerged such that brain regions involved in affect and motivational processing were more active to African-American than to Caucasian-American faces regardless of participant race, whereas brain regions involved in social perceptual processes that are less affective[9] were more responsive to in-group faces than out-group faces for each participant group.

When examining neural activation to African-American target faces relative to Caucasian-American target faces across all participants and tasks, region of interest (ROI) analyses of the amygdala were not significant in either hemisphere ($P > 0.3$); however, whole-brain analyses indicated greater right amygdala activity to African-American than to Caucasian-American target faces (**Fig. 1b**; Talairach coordinates: 26, 2, −14; $t_{18} = 3.26$, $P < 0.005$; **Supplementary Note**). Participant race did not interact with target race in ROI ($t_{18} = 0.22$, $P > 0.3$) or whole-brain analyses of the amygdala, indicating that the amygdala of African-American and Caucasian-American participants did not differ significantly in their responses to African-American and Caucasian-American target faces (**Fig. 1c**).

Whole-brain analyses were conducted to identify other brain regions that showed more activity during viewing of African-American than during viewing of Caucasian-American target faces. In addition to the amygdala, ventromedial prefrontal cortex (18, 26, −12; $t_{18} = 3.36$, $P < 0.005$), hippocampus (38, −22, −16; $t_{18} = 4.02$, $P < 0.005$) and the midbrain in the area of substantia nigra (10, −22, −20; $t_{18} = 4.39$, $P < 0.005$) were all more active in response to African-American than in response to Caucasian-American targets. No brain regions were more active to Caucasian-American targets than to African-American targets.

Most analogous to previous studies, perceptual encoding yielded greater right amygdala activity in response to African-American than to Caucasian-American targets across all participants in ROI ($t_{18} = 2.11$, $P < 0.05$) and whole-brain analyses (14, 0, −18; $t_{18} = 3.16$, $P < 0.005$). Unlike perceptual encoding, however, verbal encoding of African-American versus Caucasian-American targets did not produce increased amygdala activity in ROI ($t_{18} = 1.62$, $P > 0.1$, corrected) or whole-brain analyses. When comparing verbal to perceptual encoding, ROI analyses yielded marginally less amygdala activity during verbal encoding, relative to perceptual encoding, of the African-American targets ($t_{18} = 1.76$, $P < 0.1$, corrected) but no difference for Caucasian-American targets ($t_{18} = 0.08$, $P > 0.4$). A whole-brain analysis (**Fig. 2a**, left) demonstrated an interaction in the amygdala between the encoding task and target race (16, −9, −20, $t_{18} = 2.84$, $P = 0.005$) such that there was less amygdala activity during verbal encoding, relative to perceptual encoding, of African-American targets (16, −9, −20; $t_{18} = 3.01$, $P < 0.005$) but no effect of encoding for Caucasian-American targets (16, −9, −20, $t_{18} = 0.96$, $P > 0.15$).

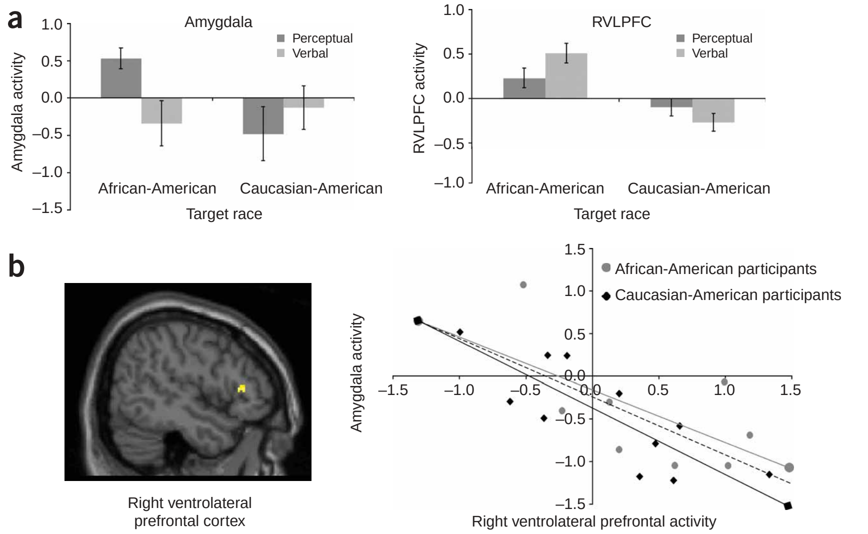

Figure 2 Amygdala and RVLPFC responses to target race and encoding task. (**a**) Interaction of target race and encoding task effects in the amygdala (left) and RVLPFC (right). (**b**) Correlational plot of RVLPFC (50, 26, 8) and right amygdala (16, −9, −20) during verbal encoding, relative to perceptual encoding, of African-American targets. Each point represents one participant's activity in the two neural regions. The dashed line is the best fit for all of the participants ($r = -0.68$). The gray line anchored by circles is the best fit for the African-American participants ($r = -0.61$). The black line anchored by diamonds is the best fit for the Caucasian-American participants ($r = -0.80$).

Previous investigations have observed activity in right ventrolateral prefrontal cortex (RVLPFC) during verbal encoding, relative to perceptual encoding, of emotionally evocative stimuli and have found this activity to be inversely correlated with amygdala activity, indicating its possible role in dampening amygdala reactivity[6] (**Supplementary Note**). Consequently, we conducted a whole-brain analysis to determine whether RVLPFC was performing a similar role during the verbal encoding of target race. A whole-brain analysis (**Fig. 2a**, right) showed an interaction in RVLPFC between the encoding task and target race (52, 20, 8, $t_{18} = 3.60$, $P < 0.005$) such that greater RVLPFC activity was observed during verbal, relative to perceptual, encoding of African-American targets (52, 22, 8; $t_{18} = 3.35$, $P < 0.005$) but not for the encoding of Caucasian-American targets (52, 20, 8, $t_{18} = -1.83$, $P > 0.01$). Additionally, activations in the amygdala and RVLPFC (50, 26, 8; $r = -0.68$, $P < 0.005$; **Fig. 2b**) were negatively correlated during verbal, relative to perceptual, encoding of African-American faces. No significant correlations were observed between the amygdala and RVLPFC during the encoding of Caucasian-American targets.

Additionally, there were no three-way interactions between participant race, target race and mode of encoding on amygdala activity in ROI ($P > 0.5$) or whole-brain analyses of the amygdala, suggesting that the amygdala of Caucasian-American and African-American participants did not respond differently to target races in either perceptual or verbal encoding tasks. Thus, during perceptual encoding, African-American participants produced greater amygdala activity to African-American targets than to Caucasian-American targets in an ROI analysis (**Fig. 1c**; $t_7 = 2.63$, $P < 0.05$). Similarly, during perceptual encoding, Caucasian-American participants produced greater amygdala activity to African-American targets than to Caucasian-American targets in a whole-brain analysis (16, −6, −16; $t_{10} = 5.20$, $P < 0.005$), although the related ROI analysis of Caucasian-American participants was not significant ($t_{10} = 1.46$, $P < 0.2$ corrected). The amygdala was not significantly activated during verbal encoding of African-American targets, relative to Caucasian-American targets, for either African-American or Caucasian-

American participants in ROI or whole-brain analyses (all P values > 0.2). Finally, correlations between amygdala (16, 9, −20) and RVLPFC (50, 26, 8) activity during verbal encoding, relative to perceptual encoding, was similar for African-American participants ($r = -0.61$, $P < 0.1$) and Caucasian-American participants ($r = -0.80$, $P < 0.005$).

Whole-brain analyses were conducted to identify brain regions that were more active for participants when viewing targets of their in-group race relative to targets of their out-group race. Between-group analyses indicated that in-group race effects were present in the lateral fusiform gyrus region, typically associated with face processing (42, −52, −12; $t_{17} = 3.86$, $P < 0.005$), in the superior temporal sulcus (56, −32, 4; $t_{17} = 3.40$, $P < 0.005$) and bilaterally in the temporal poles (left: 38, 18, −34; $t_{17} = 4.17$, $P < 0.005$; right: 32, 20, −32; $t_{17} = 4.40$, $P < 0.005$). The fusiform activation replicates previously observed in-group race effects[2]. The only brain region demonstrating out-group race effects, such that each group of participants produced greater activity to out-group race than in-group race targets, was the insula, bilaterally (left: −34, −16, −6: $t_{17} = 3.73$, $P < 0.005$; right: 34, 24, −4; $t_{17} = 3.28$, $P < 0.005$).

The current finding that both African-American and Caucasian-American participants demonstrated greater amygdala activity to African-American faces than to Caucasian-American faces may provide some insight into the function of the amygdala in race-related processing. Because the amygdala is involved in responding both to threat and to novelty[1], it has remained unclear as to whether previous findings of race-related amygdala activity in Caucasian-American participants reflects culturally learned messages that African-American individuals are potentially threatening or whether it reflects the novelty of African-American faces to most Caucasian-American participants. With the inclusion of African-American participants, these two explanations for amygdala activity can begin to be disentangled: among African-American participants, novelty effects should be associated with more amygdala activity to Caucasian-American than African-American faces, whereas negative cultural associations would be associated with more amygdala activity to African-American than Caucasian-American faces. Although no single study can conclusively address this issue (see **Supplementary Note** for discussion of alternative explanations), the present study suggests that the amygdala activity typically associated with race-related processing may be a reflection of culturally learned negative associations regarding African-American individuals.

The second major finding from this investigation is that the mode of encoding race-related information can lead to different patterns of amygdala activation. Unlike previous studies that have focused primarily on amygdala responses to visual images of African-American and Caucasian-American faces, this study has examined neural responses to images as well as to verbal labels of race, and has demonstrated that the verbal encoding of African-American targets results in less amygdala activity than the perceptual encoding of African-American targets. Additionally, consistent with other studies examining the verbal encoding of affective stimuli[4], verbal labeling of African-American targets recruited RVLPFC, and to the extent that RVLPFC was active in this condition, the amygdala was less active. This suggests that RVLPFC may have been functionally inhibiting the amygdala, possibly by activating inhibitory interneurons in the basolateral nucleus of the amygdala[10,11], although correlational analyses do not establish a direction of causality. This account is also consistent with a number of studies linking RVLPFC to general inhibitory processes[12]. It should be noted that although the current design did not encourage individuals to regulate their affective responses, the intention to regulate one's affect may produce results different from those observed here[13]. For a discussion addressing potential limitations of the current study, see the **Supplementary Note**.

An issue related to the verbal encoding task that needs further investigation is whether verbal encoding, strictly speaking, is responsible for disrupting amygdala activity, or whether symbolic processes or controlled processes more generally cause this effect. Although the current data do not speak directly to this issue, it is possible that verbal processing may be one of a number of symbolic processes than can have this disruptive effect. Regardless of the various forms this symbolic process may take, it seems that the content of this process must be focused on the affective or evaluative nature of the stimulus for RVLPFC to be activated and for the disruption process to occur. Multiple studies have found that affective evaluation and labeling, particularly negative evaluation and labeling, selectively activates RVLPFC relative to non-affective controlled processing[14].

The verbal encoding results may seem surprising in light of previous behavioral work that has used race-related words as primes to increase the cognitive accessibility of affectively-congruent words[15]. These studies seem to suggest that race-related words increase negative affect, whereas our results suggest that the controlled processes recruited by race-related words inhibit the affect-related activity of the amygdala. It may be the case that controlled processing of race-related words activates linguistic representations of affect while simultaneously inhibiting the affect itself.

One intriguing possibility suggested by these results is that verbal processing of race diminishes the experience of threat and thus might be reinforcing. In other words, the controlled processes invoked by verbal stereotyping may provide some degree of emotional relief from the threat associated with the presence of negatively stereotyped group members, and thus may have promoted the further development of verbal stereotypes. Such a dynamic may have been useful during our evolution to allow controlled processing responses to threat to override automatic responses, but may now contribute to the ubiquitous development of intergroup stereotyping.

Note: Supplementary information is available on the Nature Neuroscience website.

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COMPETING INTERESTS STATEMENT

The authors declare that they have no competing financial interests.

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