

Differential response in the human amygdala to racial outgroup vs ingroup face stimuli

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Here we describe response in the human amygdala to the presentation of racial outgroup vs ingroup faces. Functional magnetic resonance imaging (fMRI) measures of brain activity were acquired while subjects who identified themselves as White or Black viewed photographs of both White and Black faces. Across all subjects, we observed significantly greater blood oxygen-level-dependent (BOLD) signal in the amygdala to outgroup vs ingroup faces, but only during later stimulus presentations. A region of interest (ROI)-based analysis of these voxels revealed a significant interaction between amygdala response to outgroup and ingroup faces over time. Specifically, the greater amygdala activation to outgroup faces during later stimulus presentations was the result of amygdala response

habituation to repeated presentations of ingroup faces with sustained responses to outgroup faces. The present results suggest that amygdala responses to human face stimuli are affected by the relationship between the perceived race of the stimulus face and that of the subject. Results are discussed as consistent with a role for the amygdala in encoding socially and/or biologically relevant information. We conclude that researchers seeking to study brain responses to face stimuli in human subjects should consider the relationship between the race of subjects and stimuli as a significant potential source of variance. Moreover, these data provide a foundation for future related studies in the neuroscience of social cognition and race. *NeuroReport* 11:2351–2355 © 2000 Lippincott Williams & Wilkins.

Key words: Amygdala; Brain; fMRI; Neuroimaging; Race; Social cognition

INTRODUCTION

The advent of functional neuroimaging has enabled investigators to explore the neural correlates of cognitive/behavioral function. One such avenue of research concerns normal human amygdala function as well as its potential dysfunction in the context of neuropsychiatric disorders. Several recent studies have utilized presentation of standardized stimuli consisting of photographs of human faces that vary in their emotional expressions as a means of producing amygdala activation. Such studies have documented that the amygdala exhibits differential response to facial expression [1–3] consistent with earlier animal and human findings, suggesting a role for the amygdala in social communication [4,5].

The social psychology literature provides evidence that experimental subjects respond differently to face stimuli that depict members of their own race (ingroup) compared with those of a different race (outgroup) [6]. For example, subjects are better able to recognize previously

presented ingroup faces compared to previously presented outgroup faces [7,8]. Conversely, outgroup faces are more quickly classified by race than ingroup faces [9,10]. These effects make it clear that the brain can fundamentally classify face stimuli by racial category and this categorization can affect a host of subsequent responses. Since the amygdala has demonstrated a propensity for response to face stimuli [1–5,11] and its activity can modulate both perceptual and response pathways [12,13], we sought to assess the effect that outgroup vs ingroup categories might have on amygdala response to faces of neutral expression. We reasoned that such information might impact the development of fMRI probes aimed at studying amygdala responses, since any representative cross-section of the population will be comprised of individuals from numerous racial groups. In the service of an efficient design, we chose to study Black and White subjects, though future studies could assess differences across a broader range of racial groups.

Using fMRI, we measured BOLD signal in Black and White subjects while they viewed pictures of Black and White individuals' faces. We predicted that when presented with face stimuli that subjects characterized as outgroup (i.e. Black faces for White subjects; White faces for Black subjects), the amygdala would demonstrate increased BOLD signal compared to stimuli subjects' characterized as ingroup. Importantly, all subjects viewed the exact same stimuli. However, since outgroup and ingroup categories are defined by the relation of the stimuli to the subjects, the very stimuli that were outgroup for one half of the subjects, were ingroup for the other half of the subjects. This design provides counterbalanced control for any systematic differences that might exist between the Black and White face stimuli. Thus, this study was explicitly designed to assess fMRI responses to outgroup *vs* ingroup faces across subjects of both races, rather than to assess any differences that might exist between subjects based upon race.

MATERIALS AND METHODS

Subjects were eight healthy, right-handed, adult males and females (20–35 years of age). Subjects identified themselves as either White or Black; half were Black and half were White. Also, within each race group, half were male and half were female. Handedness was verified by administration of the Edinburgh Handedness Inventory (see [3] for reference). All subjects were without significant psychiatric, neurologic or medical illness as determined by a brief clinical interview. No subjects were taking psychotropic or cardiovascular medications at the time of study or during the preceding 4 weeks. This investigation was conducted in accordance with the guidelines of the Subcommittee on Human Studies of the Massachusetts General Hospital; all subjects gave written informed consent for participation.

During fMRI scanning, we presented grayscale pictures of male and female faces described as Black or White by these subjects. Subjects were instructed to decide if the face was male or female and respond by pressing one of two buttons on a keypad provided to them in the scanner. The order of presentation for the Black and White face stimuli was counterbalanced within subjects (i.e. across scans) and across subjects. Blocks of 20 s consisted of 1 s presentations (ISI=2 s) of 10 Black (B) or 10 White (W) faces consisting of equal numbers of each gender, or a fixation cross (+). For example, one scan would consist of the following 20 s blocks: +; W; B; +; W; B; +; W; B; +. Thus, subjects viewed each face three times, seeing 30 outgroup and 30 ingroup faces per scan. The two scans were separated by a 2 min break period during which subjects rested quietly in the scanner. Upon exiting the scanner, subjects were asked to describe the stimuli presented and any subjective feelings/reactions they had to these stimuli.

Presented stimuli consisted of grayscale face stimuli selected from the Facial Recognition Technology (FERET) database of facial images, US Army Research Laboratory. Our selection of stimulus faces from this database was based upon pilot data we collected on other subjects of similar age and race who characterized these stimuli as Black or White, and of neutral expression. While neuroimaging studies of the amygdala have most often assessed its response to facial expressions such as fear, initial response

to faces of neutral expression that then habituates has been reported previously [2,14].

fMRI data were acquired as described previously [3] with the following exceptions: image acquisition was performed with a 3 T MR scanner (General Electric, Waukesha, WI). Eighteen coronal oblique high-resolution structural images and gradient echo (TR/TE/Flip=2000/30/60) functional images were obtained (voxel size = 3.125 × 3.125 × 3 mm). Our slice selection covered a brain area that extended from the anterior extent of the genu of the corpus callosum to the posterior extent of the splenium of the corpus callosum. Thus, we achieved excellent visualization of the amygdala, hippocampus, insular cortex, mid-cingulate cortex, and motor and somatosensory cortices. Conversely, we did not visualize prefrontal cortex, the anterior or posterior cingulate or the occipital lobe.

fMRI data were analyzed as described in detail previously [3]. Briefly, images were motion-corrected, normalized, Talairach transformed and concatenated (averaged) across subjects. Parametric t-statistic maps were used to identify significant voxels of activation within the amygdala associated with the outgroup *vs* ingroup contrast. The maximally activated voxel within the amygdala had to exceed our *a priori* statistical threshold of $p < 6.6 \times 10^{-4}$, representing a Bonferroni correction for the number of voxels within the amygdala search volume [see 3]. Since our previous studies have demonstrated habituation of limbic fMRI responses with repeated stimulus presentations [3,15], we created separate t-statistic maps for scan 1 (early presentations), scan 2 (later presentations), and then for all stimulus presentations (scans 1 and 2). Statistically significant voxels located within the amygdala were then subjected to a ROI-based repeated measures analysis of variance assessing outgroup *vs* ingroup response over time (scan 1 *vs* scan 2; for previous application of this approach, see [16]). A significant finding in an omnibus test would then be tested for four planned comparisons using a Bonferroni correction for multiple comparisons ($p < 0.0125$) as follows: outgroup *vs* ingroup at scan 1 and scan 2, as well as comparison of scan 1 *vs* scan 2 within outgroup and ingroup.

RESULTS

Figure 1a depicts a coronal slice through the amygdala demonstrating a significant increase in BOLD signal during later stimulus presentations (i.e. scan 2) for the outgroup *vs* ingroup contrast. Significant differences were not observed in the amygdala either in scan 1 alone or for both scans considered together (see Table 1). A repeated measures ANOVA of these significantly activated amygdala voxels for scan 2 revealed no main effect of condition or scan (all $p > 0.05$), but revealed a significant interaction of condition by scan ($F(1,7) = 7.5$, $p = 0.029$). Figure 1b depicts this interaction presenting BOLD signal intensity for the significantly activated amygdala voxels displayed in Fig. 1a. Planned comparisons revealed that BOLD signal intensities did not significantly differ to ingroup and outgroup stimuli during scan 1 ($p > 0.15$), but did between outgroup *vs* ingroup at scan 2 ($t(7) = 3.04$, $p = 0.0093$). Response to the ingroup stimuli significantly habituated with repeated presentations (ingroup scan 1 *vs* ingroup scan 2; $t(7) = 3.11$; $p = 0.0085$), while BOLD signal intensity

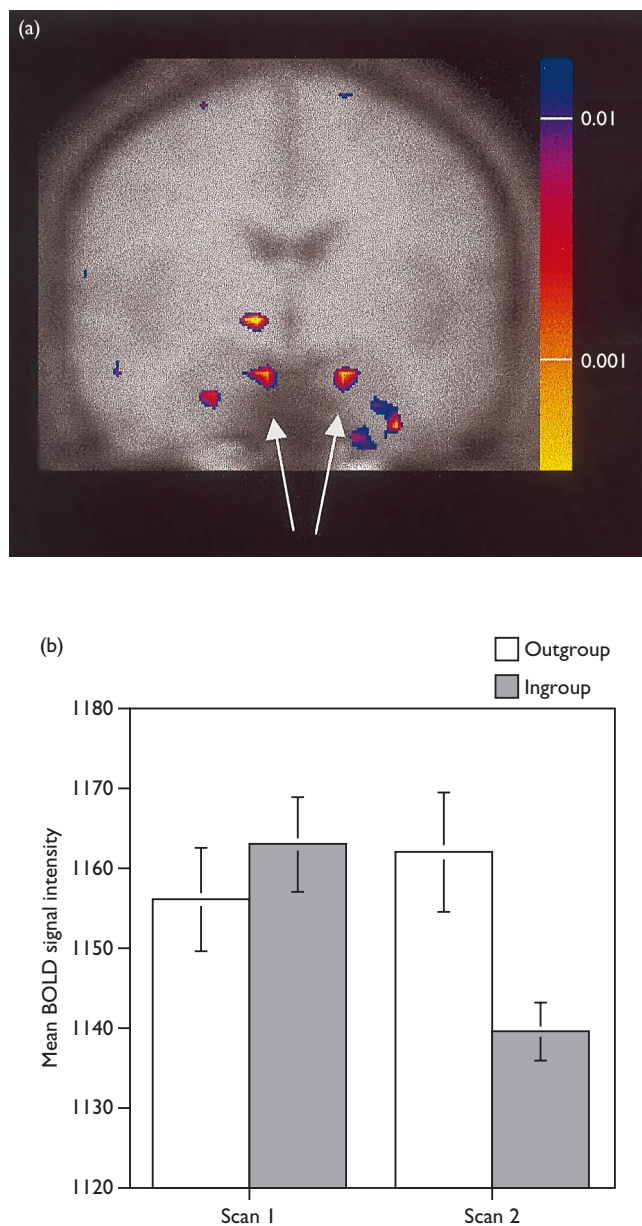


Fig. 1. (a) Coronal slice depicting bilateral amygdala activation (arrows) across all subjects for the outgroup vs ingroup contrast for later stimulus presentations only (i.e. scan 2). Images are displayed according to radiological convention (i.e. right = left) and have been smoothed using a Hanning nine voxel 1:2:1 kernel filter. Both the left and right composite activation across all subjects exceeded the *a priori* statistical threshold for the amygdala ($p < 6.6 \times 10^{-4}$, see Materials and Methods) and are superimposed here over the averaged structural image across all subjects. Note also comparable activation of left ventral temporal lobe ($x = -31$, $y = -6$, $z = -31$) and right ventral thalamus ($x = 9$, $y = -6$, $z = 0$) depicted in this slice. (b) Bar graph depicting statistically significant interaction of amygdala BOLD response to outgroup and ingroup faces over time for the significantly activated amygdala voxels depicted in (a) (i.e. maximally activated voxel on each side). Planned comparisons revealed that the interaction is a result of significant habituation of amygdala response to outgroup and ingroup faces from scan 1 to scan 2, creating a significant difference between outgroup vs ingroup at scan 2. The difference between ingroup and outgroup at scan 1 was not significant, nor was the difference between scan 1 and scan 2 for outgroup (see Results).

in the amygdala to outgroup faces did not change significantly ($p > 0.15$). Thus, the significant difference observed to outgroup *vs* ingroup faces during scan 2 is a function of significant habituation of response in the amygdala to ingroup faces over time, while response to outgroup faces was sustained.

The statistical threshold used to determine amygdala activation may not be appropriately applied to other brain regions. In addition, our slice selection did not allow for whole brain coverage (see Materials and Methods). Thus, this study was not designed to detail all brain regions responsive to outgroup *vs* ingroup faces. To obviate bias, we report that other brain regions exceeding the significance threshold set for the amygdala included, for both scans, hippocampus ($x = -21$, $y = -18$, $z = -15$), temporal cortex (possibly peri- or entorhinal, $x = 21$, $y = -6$, $z = 21$), superior temporal gyrus ($x = 59$, $y = -12$, $z = 6$), parietal cortex ($x = -59$, -24 , 18). Scan 1 only: insular cortex ($x = 43$, $y = -12$, $z = -3$), substantia innominata ($x = 15$, $y = -9$, $z = -9$). Scan 2 only: ventral thalamus ($x = 9$, $y = -6$, $z = 0$), brain stem (9 , -21 , -28). Brain regions listed for both scans are not listed again for scan 1 and 2.

We analyzed the reaction time data on the gender discrimination task for six subjects just as the ROI-based fMRI data were analyzed. Due to a computer malfunction, reaction time data were lost for two subjects (one White male and one Black male). Analyses revealed no significant main effects or interaction to outgroup *vs* ingroup stimuli over time (all $p > 0.15$).

Upon exiting the scanner, all subjects were able to report that stimuli varied based upon race (i.e. Black or White). When asked to describe any subjective feelings to these stimuli, subjects unanimously reported that they had no strong emotional reaction to the stimuli in general and, more specifically, they noted no difference in their emotional reaction to the outgroup *vs* ingroup stimuli.

DISCUSSION

The strongest conclusion that can be drawn from our data is that the rate of response habituation within the amygdala to face stimuli is dependent upon an interaction between the race of the subjects and the perceived race of the face stimuli. Specifically, habituation rates were prolonged to outgroup *vs* ingroup stimuli, yielding the observed relative amygdala activation for the outgroup *vs* ingroup contrast during scan 2. Thus, interpretation of these results must account for both the absence of a difference at the outset as well as the emerging difference over time.

A recent neuroimaging study demonstrated that the amygdala exhibits greater responses to unfamiliar than familiar neutral face stimuli [14]. Our current results are consistent with this concept, to the extent that subjects may be less familiar with outgroup *vs* ingroup faces in a categorical sense. However, initially, there is no difference in subjects' familiarity with the specific face stimuli in either group, nor in amygdala activation to outgroup *vs* ingroup stimuli. Consequently, an explanation of the observed phenomenon based on familiarity would depend on the notion that item-specific familiarity progresses more rapidly for ingroup *vs* outgroup faces. Thus, the pattern of amygdala recruitment presented here parallels a more

Table 1. Group data: location of significant BOLD signal differences within the amygdaloid region for the outgroup vs ingroup contrast.^a

Brain region	x	y	z	p value
Scan 1 (early stimulus presentations)	–	–	–	ns
Scan 2 (later stimulus presentations)	–15	–6	–15	2.9×10^{-4}
	9	–6	–15	5.0×10^{-4}
Both scans (all stimulus presentations)	–	–	–	ns

^aCoordinates are presented in millimeters according to the convention of Talairach and Tournoux [17]. While the Talairach atlas suggests that these activations may be medial to the amygdala, structural MRI data from these subjects, as well as other brain atlases [18], suggest that the Talairach atlas does not appreciate the medial extent of the amygdala or the temporal lobe. Figure 1a illustrates that when superimposed over the composite structural image for the group, the activation on the left side is clearly within the amygdala and the activation on the right side is located at the medial border of the amygdala comprising contiguous voxels within the confines of the amygdala. ns, not significant.

rapid familiarization of subjects with ingroup *vs* outgroup face stimuli.

This interpretation might have implications for behavioral studies that have addressed recall and recognition rates to outgroup *vs* ingroup face stimuli, since amygdala activity is related to eventual recall and recognition, especially in response to stimuli that are socially and/or biologically relevant [19,20] (see [4] for discussion of social relevance). In behavioral studies [7,8], a recall/recognition bias has been observed to ingroup *vs* outgroup faces over a range of stimulus repetitions comparable to the number presented in scan 1 of the current study. Further, improved identification of outgroup faces with repeated exposure has recently been reported [21], as has an elimination of the ingroup *vs* outgroup bias following periods of training [22,23]. Taken together, these previously published behavioral results resonate with the present finding of prolonged response to outgroup faces with continued presentations.

Although this study focused upon the amygdala, other areas not detailed here are likewise implicated (see Results). For instance, we also observed activation in numerous limbic regions, including the hippocampus and insular cortex, that exceeded the significance threshold set for the amygdala. These areas, along with the amygdala, might represent elements of a brain system that functions to increase encoding of biologically relevant facial or social characteristics as a function of information value or experience [24]. Further studies will be necessary to define the full extent of this system and characterize its role in processing face stimuli as well as other socially relevant cognitive functions.

While this line of inquiry has significant social implications, it is important not to draw premature conclusions. For example, future studies might seek to assess the relative contributions that each racial group (i.e. Black or White) makes to the amygdala response reported here. Since outgroup stimuli differ for each experimental group, such studies will require stimuli that are carefully matched for variables other than racial category (e.g. degree of neutrality of expression between stimulus groups). In addition, whether the present effect will generalize to other racial groups is another important question for further study. Finally, perhaps the present results have implications for racial stereotyping. Indeed, the observed differ-

ence in habituation profile to outgroup stimuli is consistent with the notion that the amygdala might be sensitive to learned racial stereotypes or participate in their development. However, as noted above, such an interpretation would have to account for the lack of difference observed during initial stimulus presentations.

We should anticipate that neuroimaging studies regarding the role of the amygdala in health and disease will continue to proliferate [25]. While participants in such studies may belong to various racial groups, to date, the majority of experiments have utilized stimuli of White (i.e. Caucasian) faces only. An important implication of the present data for research in this domain is that the interaction between the race of subjects and face stimuli will contribute a significant source of variance, dictating that potential comparison groups be matched for race. Moreover, these initial findings, together with complementary efforts from independent laboratories [26,27], may serve to stimulate future related neuroimaging studies into the neuroscience of social cognition and race.

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