

Functional MRI Responses of the Human Dorsal Amygdala/Substantia Innominata Region to Facial Expressions of Emotion

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KEYWORDS: MRI responses; facial expressions; emotions; dorsal amygdala; substantia innominata; ventral amygdala

Neuroimaging studies have demonstrated greater amygdala responsivity to fearful facial expressions than to neutral or happy expressions.^{1–5} We recently documented activation of the human amygdaloid region when fearful facial expressions were contrasted with angry facial expressions.⁶ This activation was located within the dorsal amygdala/sublenticular substantia innominata (SI) region. In these same subjects, a valence-based contrast of fearful versus neutral faces revealed greater activation within the ventral amygdala. We hypothesized that activation of the human dorsal amygdaloid/SI region may, in part, reflect that fearful expressions, unlike angry expressions, leave the source of their eliciting event ambiguous.⁷ Since surprised facial expressions are not necessarily negatively valenced, a demonstration of activation of the dorsal amygdaloid/SI region in response to these expressions would be consistent with this hypothesis. Because spatial resolution issues in functional magnetic resonance imaging (fMRI) make it difficult to discuss activation of sub-components of the amygdaloid region, we use a Talairach cutoff of $z = 10$ as an initial strategy to discuss dorsal versus ventral response distinctions.

During four scans (3 min, 28 s in length), eight healthy female subjects viewed standardized pictures of facial expressions⁸ presented in alternating 16-second blocks. Each block consisted of 32 face presentations (four identities repeated eight times; 200-ms duration; 500-ms interstimulus interval, ISI). For two scans, subjects viewed alternating blocks of faces with surprised expressions or neutral faces matched for identity. Each subject provided a surprise vs. neutral statistical contrast map, which was later combined across subjects for second-level random-effect anal-

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Ann. N.Y. Acad. Sci. 985: 533–535 (2003). © 2003 New York Academy of Sciences.

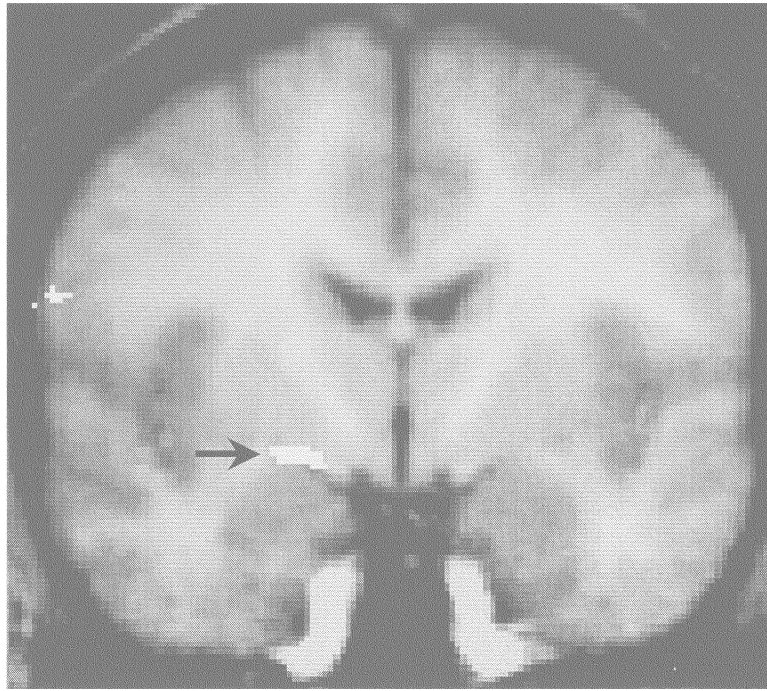


FIGURE 1. Statistical map for surprised versus neutral facial expressions demonstrating activation of the dorsal amygdaloid/SI region (*arrow*). The image was generated with a threshold of $P < 0.005$ (uncorrected). The maximum activated voxel is located at Talairach⁹ coordinate $x = 18, y = -5, z = -6$; $P < 0.00036$ (uncorrected). The image is presented according to radiological convention (that is, left = right, and right = left).

ysis. For comparison with previous studies, subjects underwent two additional scans in which alternating fear and neutral blocks were presented. The presentation order of surprise and fear scans was counterbalanced. After scanning, seven subjects provided valence ratings [scale = 1 (very positive) – 9 (very negative)] of these blocks of surprised, fearful, and neutral faces.

Consistent with our hypothesis, the dorsal amygdaloid/SI region was responsive to the facial expression of surprise when contrasted with neutral faces (FIG. 1: max voxel located at $x = 18, y = -5, z = -6$; $P < 0.00036$). In these same subjects, fearful facial expressions activated the ventral amygdala when contrasted with neutral facial expressions (max voxel located at $x = -21, y = -3, z = -16$, $P < 0.0062$). In addition to these dorsal/ventral distinctions, maximal response to surprised and fearful facial expressions differed with respect to laterality. That is, in relation to neutral faces, surprised faces activated the right amygdaloid/SI region while, consistent with previous studies,^{1–4} fearful faces activated the left amygdala.

Amygdala activation to surprised facial expressions was not related to subjects mistaking these facial expressions for fearful faces because (a) subjects labeled the expressions correctly and (b) the valence ratings that subjects gave these expressions

were significantly more negative for fearful versus surprised faces. A repeated measures ANOVA demonstrated a significant main effect for expression ($F(2, 6) = 16.61, P = 0.00035$), and planned simple main-effect contrasts demonstrated that this was due to significantly greater negative valence ratings for fear (mean = 7.79) than for surprise (mean = 4.36; $t(6) = 4.18, P = 0.0057$) and neutral (mean = 5.25; $t(6) = 11.47, P < 0.0001$). In addition, fMRI responses throughout the amygdaloid region discriminated between these two expressions with the response to fearful expressions being located within the left ventral amygdala, while the response to surprised expressions was located in the right dorsal amygdaloid/SI region.

This is the third time we have documented a dissociation between the dorsal amygdaloid/SI region and the ventral amygdala in the human in response to facial expressions of emotion.^{5,6} Activation of the ventral amygdala appears to be consistent with the detection and/or discrimination of valence in the environment and may well reflect responses based upon what this system has learned in the *past* about the predictive value of fearful facial expressions. Activation of the dorsal amygdaloid/SI region, particularly on the right side, may be related to attempts to discern what predictive value these expressions have in the *present* context and does not seem to depend upon valence since (a) it is responsive to surprised versus neutral faces in subjects who do not rate these faces negatively, (b) it is responsive to fearful versus angry faces,⁶ a contrast that might essentially “subtract” away negative valence; and (c) it is responsive to both fearful and happy faces,^{2,5} documenting perhaps their salience or arousal value over their valence.

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