Judgment of Moral Certainty: Developmental fMRI Patterns

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INTRODUCTION: Moral judgment involves the acquisition of rules and concepts that guide personal decisions and actions according to interests beyond the self. Social-moral considerations are at the heart of formal legal and governmental institutions, but also apparent in many ordinary social interactions. The implications of these processes are substantial as anti-social behavior is at the root of numerous social problems, abuses and criminality [1]. A small number of functional brain imaging in healthy adults have identified neural activation patterns associated with cognition and emotion involved in moral judgments [2,3,4] but no studies have investigated these substrates in children, therefore, we used fMRI to investigate the neural activations responsible for moral judgment in children as well any developmental effects.

METHODS:

Study Participants

The sample was comprised of 10 volunteers between the ages of 10-17 years (4 male, 5 female) who had no history of medical, neurological or psychiatric illness, learning disability, or current medication usage. Participants were administered standardized tests of general intellect, academic achievement and executive functions, and completed inventories of emotional intelligence and social behavior in order to characterize several aspects of cognitive, emotional, and social development relevant to the experimental protocol.

fMRI Study Procedures

fMRI studies were conducted on a 3.0 T MRI scanner. During fMRI scanning, participants were instructed to respond to visual stimulation by pressing either the left or right button with their respective thumb on a 2-button handheld device. A boxcar fMRI paradigm was used, which consisted of interleaved time intervals of baseline and cognitive activation. The experimental statements contained moral social situations. There were 15 experimental blocks, 15 baseline blocks, and 5 rest periods. Experimental blocks were divided equally into three conditions: Moral Right (6 blocks), Moral Wrong (6 blocks), and Ambiguous (3 blocks). Each block lasted 27 seconds, consisting of 3 statements presented for 6 seconds with an additional 3 seconds per statement for the subject to respond using the two-button handheld device. The subject was asked to judge whether they believed the statement was right or wrong by pressing either the right or left key respectively. The total in-magnet time for this paradigm was 12 minutes 57 seconds. 259 images were acquired. Functional images were acquired with an echo planar imaging sequence (TR / TE = 3000 ms / 35 ms, flip angle = 90º, FOV = 23 × 23 cm^2, 24 5-mm-thick axial slices with no gap between slices, acquisition matrix = 64 × 64, number of average = 1).

Data Analysis

fMRI image data were processed with SPM2 software [5]. Group analysis was undertaken to generate an average activation map (one-sample *t*-test, p<.005, voxel threshold = 10). Simple regressions between age and SPM2-derived z-scores were then computed in order to identify areas of positive and negative correlation with age.

RESULTS:

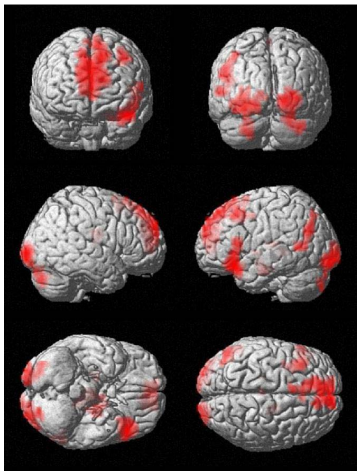
Behavioral

During fMRI testing, subjects performed with an average accuracy and reaction time of 98%, 95%, and 57%, and 3803.7, 3712.41, 5007.33 for Moral (excluding Ambigous), Nonmoral, and Ambigous statements, respectively (this latter finding was expected due to the high degree of variability in responses to the Ambiguous statements). There were no significant differences in accuracy or reaction time between Moral (excluding Ambiguous) and Nonmoral conditions. Subjects also rated stimuli out-of-magnet based on the level of moral content (5-point Likert scale), 0 being no moral content and 5 being a high level of moral content. The rated moral content between Moral and Nonmoral statement groups was significantly different (1.04E-46, two-tailed t-test).

fMRI

When averaging across the moral activation tasks (Moral Right, Moral Wrong, and Ambiguous) and subtracting out the baseline (Nonmoral judgments) in a one-sample t-test (p<0.005, v=10), the following regions of activation were observed: bilateral prefrontal ventrolateral, the bilateral temporoparietal junction, the bilateral inferior middle occipital, the bilateral caudate-thalamus, midline superior frontal, midline thalamus, left superior frontal, left posterior mid temporal, and anterior and posterior cingulate. These average activation results are summarized in Figures 1 and 2. More robust activation in the bilateral anterior temporal lobe was correlated to increasing age (p<0.05). Decreasing activations in areas of the bilateral middle and superior temporal cortex, right dorsal lateral prefrontal cortex, left putamen, mid cingulum, and right insula were observed (p<0.01).

DISCUSSION: Our results support the majority of adult findings indicating that moral judgment in the brain involves regions important for the processing of social perception, agency/intentionality, judgment, emotion response, and behavior planning, such as the prefrontal cortex, temporoparietal junction, and limbic regions. The similarity found between children moral judgment activation and adult judgment activation suggests that neural underpinnings dedicated to moral processing are developed relatively early in life.



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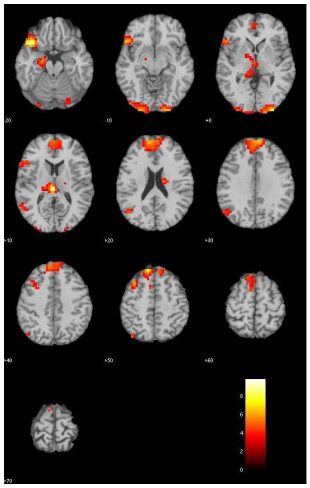

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Figure 1. Average brain activation during all moral judgment conditions overlayed on a 3-D rendered image (p<.005, v=10). Figure 2. All Moral Activation (p<.005, v=10) overlayed on multi-slice axial images.