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Neural development of mentalizing in moral judgment from adolescence to adulthood

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ABSTRACT

The neural mechanisms underlying moral judgment have been extensively studied in healthy adults. How these mechanisms evolve from adolescence to adulthood has received less attention. Brain regions that have been consistently implicated in moral judgment in adults, including the superior temporal cortex and prefrontal cortex, undergo extensive developmental changes from adolescence to adulthood. Thus, their role in moral judgment may also change over time. In the present study, 51 healthy male participants age 13–53 were scanned with functional magnetic resonance imaging (fMRI) while they viewed pictures that did or did not depict situations considered by most individuals to represent moral violations, and rated their degree of moral violation severity. Consistent with predictions, a regression analysis revealed a positive correlation between age and hemodynamic activity in the temporo-parietal junction when participants made decisions regarding moral severity. This region is known to contribute to mentalizing processes during moral judgment in adults and suggests that adolescents use these types of inferences less during moral judgment than do adults. A positive correlation with age was also present in the posterior cingulate. Overall, the results suggest that the brain regions utilized in moral judgment change over development.

Functional neuroimaging studies of moral judgment in adults have consistently demonstrated the critical role of several brain regions related to social and affective processing. These regions include the medial prefrontal cortex, posterior temporal cortex including the superior temporal sulcus and temporo-parietal junction, precuneus, posterior cingulate, and the anterior temporal cortex including the temporal poles and amygdala (Greene and Haidt, 2002; Moll et al., 2005). While the involvement of these regions has been demonstrated in many studies of adult moral judgment, their involvement in moral judgment during adolescence, and potential changes from adolescence to adulthood, has been less studied. This represents a significant gap in the literature, given the substantial development that occurs during adolescence in brain structure and function (Toga et al., 2006; Blakemore and Choudhury, 2006; Blakemore, 2008), and moral sensitivity and judgment (Kohlberg, 1969; Murphy and Gillligan, 1980). The goal of this study was to investigate whether the role of brain regions implicated in moral judgment in adults changes between adolescence and adulthood.

Despite the consistency of the neural circuitry underlying moral judgment in adults, the specific contributions of different regions to moral judgment is not fully understood. One region where notable progress has been made is the temporo-parietal junction/TPJ. Studies by Young and

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colleagues have provided strong evidence for the role of this region in mentalizing, defined as the attribution of mental states such as beliefs and intentions to others, or theory of mind (Frith and Frith, 2003), during moral judgment. Young et al. (2007) reported increased TPJ activity associated with beliefs that an individual intended to harm another, but not when harm was judged to be accidental. They also demonstrated that temporary disruption to TPJ function via transcranial magnetic stimulation led participants to judge attempted harms as less morally wrong and more morally permissible (Young et al., 2010).

Mentalizing (inferring beliefs and/or intentions in others) can be considered a specific type of perspective taking, the latter referring to the general apprehension of another's internal states. Perspective taking skills are generally considered critical in moral development (Kohlberg, 1969; Eisenberg et al., 1983; Eisenberg, 1986). Theories of moral development typically describe early stages as being characterized by hedonistic perspectives (focus on the needs of the self, e.g. avoiding punishment), then progressively integrating perspectives beyond the self (understanding and concerns for the needs and welfare of others). Studies have shown that the more one is able (and inclined) to consider the perspectives of others, the more likely they are to engage in prosocial behavior (e.g. helping others), and the less likely they are to engage in antisocial behavior (e.g. harming others)—in other words, the more likely they are to 'act morally' (Roberts and Strayer, 1996; Cohen and Strayer, 1996). Regarding mentalizing in particular, higher levels of performance on mentalizing tasks (false-belief) in early childhood have been shown to predict more sophisticated moral reasoning skills (more frequent references to other-oriented vs. hedonistic needs when making decisions about moral dilemmas) at a later age (Lane et al., 2010).

Mentalizing skills begin to develop in childhood, and continue to do so well into adolescence and adulthood (Dumontheil et al., 2010). This development is accompanied by extensive changes in the structure of brain regions involved in mentalizing, including the superior temporal cortex and the prefrontal cortex (Giedd et al., 1999; Gogtay et al., 2004; Sowell et al., 1999; for reviews see Toga et al., 2006; Blakemore and Choudhury, 2006; Blakemore, 2008). The developmental trajectory differs depending on the specific region; for example, gray matter density in the lateral and superior prefrontal cortex increases until the onset of puberty, followed by a decline throughout adolescence and early adulthood. The superior temporal cortex also shows an increase in gray matter density until puberty followed by a decline, but the decline is substantially more protracted, continuing well into adulthood. The posterior superior temporal cortex, in particular, matures at a relatively later age (Gogtay et al., 2004). Functional neuroimaging studies of mentalizing have also reported age-related changes in activity within these regions. Blakemore et al. (2007) found that adults and adolescents both showed increased activity in the posterior superior temporal sulcus/pSTS and adjacent temporo-parietal junction/TPJ when making attributions about intentional vs. physical causality. Relative to adolescents, adults showed increased activity in the STS. Burnett et al. (2009) found that adults showed increased activity relative to adolescents in the left temporal pole when thinking about social emotions that involved mentalizing, relative to emotions that did not.

Given that mentalizing and its underlying neural substrates undergo extensive developmental changes from adolescence to adulthood, and the demonstrated role of these brain regions in moral judgment, we hypothesized that their involvement in moral judgment would change over time. To investigate this hypothesis, we used functional magnetic resonance imaging (fMRI) to scan 51 healthy adolescent and adult males, age 13–53, as they completed a task in which they viewed three types of pictures: '*moral*' pictures were unpleasant pictures that depicted situations considered by most people to represent moral violations (e.g. a hand breaking into a house), '*non-moral*' pictures were unpleasant pictures that did not depict moral violations (e.g. a mutilated hand), and '*neutral*' pictures were neither unpleasant nor pleasant and did not depict moral violations (e.g. a hand being fingerprinted) and rated the degree of moral violation severity in each picture on a scale from 1 (none) to 5 (severe). We predicted that viewing and making severity decisions about pictures depicting moral violations, relative to non-moral and neutral pictures that did not depict moral violations, would activate brain regions involved in moral judgment including the medial PFC, STS/TPJ, posterior cingulate/PCC, precuneus, and anterior temporal cortex including the amygdala and temporal poles, as we have found in our previous studies in adults (Harenski et al., 2008, 2010). We further predicted that the engagement of the STS/TPJ and temporal poles in response to moral pictures would be positively correlated with age. These predictions were based on previous findings that the involvement of these regions in mentalizing changes from adolescence to adulthood (Blakemore et al., 2007; Burnett et al., 2009; Güroğlu et al., 2011; Decety et al., 2011), and our expectation that the involvement of mentalizing in moral judgment would also change from adolescence to adulthood. Although the non-moral and neutral pictures depicted similar social situations as the moral pictures and may also engage mentalizing, we did not predict significant age correlations in these conditions with for two reasons: first, prior studies have shown that STS/TPJ and temporal pole activity is stronger in response to moral relative to non-moral or neutral stimuli (Greene and Haidt, 2002; Moll et al., 2005). Second, only our moral pictures depicted intentional harm caused to others. The TPJ has been particularly implicated in making harm intent attributions (Young et al., 2007, 2010). Thus we expected that overall STS/TPJ/temporal pole activation and age correlations would be stronger in the moral condition. Previous studies have reported positive correlations between age and activity in the anterior medial prefrontal cortex/aMPFC during mentalizing tasks (Blakemore, 2008). The task used in the present study has been shown to activate the ventromedial prefrontal cortex, but not the more dorsal aMPFC (Harenski et al., 2008, 2010), thus we did not predict correlations with age in this region. Whether ventromedial prefrontal activity would be correlated with age was an open question. A recent study found no significant correlations between age and prefrontal activity during a moral judgment task; however,