Delay aversion in attention deficit/hyperactivity disorder is mediated by amygdala and prefrontal cortex hyper-activation

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Abstract

Background
Experimental research supports delay aversion as a motivational feature of attention deficit/hyperactivity disorder (ADHD). To investigate the neurobiology of delay aversion in ADHD, this study examined whether adolescents with ADHD display an unusually strong activation in affective brain regions in response to cues predicting forthcoming delay and whether these effects are (a) delay-dose dependent and (b) statistically mediate the association between ADHD and self-reported delay aversion.

Methods
Twenty-nine right-handed male adolescents with combined type ADHD and 32 typically developing controls (ages 10–18 years) performed a reaction time task in an MRI scanner. Pretarget cues indicated delay-related response consequences. One indicated that delay would follow the response irrespective of response speed (CERTAIN DELAY), a second that delay would only follow if the response was too slow (CONDITIONAL DELAY), and a third that no delay would follow the response whatever its speed (NO DELAY). Delay levels were 2, 6, or 14 s. Participants also rated their own delay aversion in everyday life.

Results
Individuals with ADHD rated themselves as more delay averse than controls. Significantly greater activation to CERTAIN DELAY cues relative to NO DELAY cues was found in participants with ADHD compared to controls (bilaterally) in amygdala, anterior insula, temporal pole, dorsolateral prefrontal cortex (DLPFC), and ventromedial prefrontal cortex. Amygdala and DLPFC activation strength were strongly and delay-dose dependently correlated with delay aversion ratings, and statistically mediated the relationship between ADHD status and delay aversion.

Conclusions
When presented with cues predicting impending delay, adolescents with ADHD, relative to controls, displayed a delay-related increase in activation in amygdala and DLPFC, regions known to be implicated in the processing of aversive events. Future studies should examine the specificity of these effects to delay aversion compared to aversive events in general.