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Incentive effect on inhibitory control in adolescents with early-life stress: An antisaccade study☆

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ABSTRACT

Objective: Early-life stress (ES) such as adoption, change of caregiver, or experience of emotional neglect may influence the way in which affected individuals respond to emotional stimuli of positive or negative valence. These modified responses may stem from a direct alteration of how emotional stimuli are coded, and/or the cognitive function implicated in emotion modulation, such as self-regulation or inhibition. These ES effects have been probed on tasks either targeting reward and inhibitory function. Findings revealed deficits in both reward processing and inhibitory control in ES youths. However, no work has yet examined whether incentives can improve automatic response or inhibitory control in ES youths.

Method: To determine whether incentives would only improve self-regulated voluntary actions or generalize to automated motoric responses, participants were tested on a mixed eye movement task that included reflex-like prosaccades and voluntary controlled antisaccade eye movements. Seventeen adopted children (10 females, mean age 11.3 years) with a documented history of neglect and 29 typical healthy youths (16 females, mean age 11.9 years) performed the mixed prosaccade/antisaccade task during monetary incentive conditions or during no-incentive conditions.

Results: Across both saccade types, ES adolescents responded more slowly than controls. As expected, control participants committed fewer errors on antisaccades during the monetary incentive condition relative to the no-incentive condition. By contrast, ES youths failed to show this incentive-related improvement on inhibitory control. No significant incentive effects were found with prepotent prosaccades trials in either group. Finally, co-morbid psychopathology did not modulate the findings.

Conclusions: These data suggest that youths with experience of early stress exhibit deficient modulation of inhibitory control by reward processes, in tandem with a reward-independent deficit in preparation for both automatic and controlled responses. These data may be relevant to interventions in ES youths.

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Introduction

Early-life stress (ES), in the form of physical or sexual abuse, or emotional neglect, confers risk for various forms of psychopathology (Green et al., 2010; Kilpatrick et al., 2003; Stein et al., 1996). ES is also experienced when toddlers and children are given up for adoption by their biological parents or are removed from their original caregivers because of maltreatment and placed into foster care (Nelson et al., 2007). Experience of these different types of maltreatment or stress during change of caregiver may significantly impact cognitive and motivational functioning. Cognitive functions, on the one hand, include diverse processes such as visual attention, self-regulatory control, or short and long-term memory. Motivation, on the other hand, can be defined as the energy invested to complete an action (or cognitive function). Positive incentives provided by reward or negative incentives provided by punishment can significantly enhance motivation. Within the context of maltreatment and early-stress, negative experiences with caregivers may alter sensitivity to rewarding or punishing incentives. Such ES-related changes in response to incentives may increase vulnerability for psychopathology. Indeed, psychopathologies associated with ES such as mood and anxiety disorders, are characterized by impaired responses to incentives (Eshel & Roiser, 2010; Figee et al., 2011).

Deficits in reward-related processing have been reported in adolescents (Guyer et al., 2006) and adults (Dillon et al., 2009) with a history of ES. For example, when given the opportunity to win money on a wheel-of-fortune task, one would expect participants to respond faster on reward trials than on trials where no such gains could be made. However, while this is indeed the case for healthy adolescents, ES youths fail to show speeded response times during incentive conditions (Guyer et al., 2006). Such motivational deficits are mirrored by changes in the underlying brain regions that subserve processing of incentives. A study in adults with a history of abuse has documented changes in basal ganglia reactivity to positive incentive (Dillon et al., 2009).

In parallel, executive function and associated self-regulatory control are critical cognitive skills required in everyday life. At a developmental level, cognitive control may refer to the ability to delay gratification of an immediate reward for a larger reward later on (Mischel, Shoda, & Rodriguez, 1989) or the ability to regulate and inhibit impulsive behavior and emotional outbursts (Fox & Calkins, 2003). Thus, one important question is whether providing positive or negative incentive in ES could facilitate self-regulatory inhibitory control in this group. A related question is whether a change in sensitivity to positive and negative incentives during the developmental period increases risk for later psychopathology. Developmental studies have suggested that typically developing children and adolescents can improve their performance on tasks that require strong inhibitory control when presented with the opportunity to gain a reward (Geier, Terwilliger, Teslovich, Velanova, & Luna, 2010; Jazbec et al., 2006). By contrast, cognitive control deficits have been reported in children and adolescents with ES (Bos, Fox, Zeanah, & Nelson, 2009; Carrion, Garrett, Menon, Weems, & Reiss, 2008; Lewis, Dozier, Ackerman, & Sepulveda-Kozakowski, 2007). For example, in a functional Magnetic Resonance Imaging (fMRI) study, we recently showed that ES adolescents responded slower than controls when they were required to inhibit a prepotent response and execute a less familiar response instead (Mueller, Maheu, et al., 2010). Again, in ES youths this impairment in inhibitory control was mirrored by changes in neural circuitry commonly associated with such processes including the striatum and prefrontal cortex.

The association of early adversity with deficits in both reward processing (Guyer et al., 2006) and cognitive control (Carrion et al., 2008; Lewis et al., 2007; Mueller, Maheu, et al., 2010) would suggest that a positive influence of incentive on cognitive control typically seen in unaffected controls might be impaired in children with a history of ES. An ideal way to examine whether positive or negative incentives as measured by potential monetary gains or losses influences inhibitory control is the antisaccade task. This task requires the inhibition of a prepotent eye movement to a peripherally appearing target (the prosaccade response), and the generation of an eye movement to the opposite direction (the antisaccade) (Hallett & Adams, 1980). Several advantages of the antisaccade task over other common cognitive control tasks that are performed with manual responses deserve mention.

First, the neural circuitry of pro- and antisaccades has been extensively investigated in human and non-human primates and the underlying neurobiology of this task is well-understood (Munoz & Everling, 2004). This knowledge permits us to formulate predictions about the seat of neural dysfunction associated with performance impairment on this task. Second, the saccade task provides the opportunity to compare the integrity of automatic responses (prosaccade) to that of cognitively controlled responses (antisaccades). Such comparison informs the extent to which impairments on this task might comprise pure motoric, cognitive control abilities, or both. Third, saccade tasks have been extensively used in clinical settings for the study of a range of psychopathologies (Biscaldi, Fischer, & Aiple, 1994; Klein, Raschke, & Brandenbusch, 2003; Mostofsky, Lasker, Singer, Denckla, & Zee, 2001; Mueller, Jackson, Dhalla, Datsopoulos, & Hollis, 2006; Rommelse, Van der Stigchel, & Sergeant, 2008), and in the developmental study of children, adolescents, and adults (Luna et al., 2001). Fourth, studies using this task have demonstrated utility in assessing the influence of incentives on inhibitory control. For example, studies have shown that antisaccade performance improves under (monetary) reward conditions relative to no reward (Duka & Lupp, 1997; Jazbec et al., 2006). This performance enhancement is deficient in youths with psychopathology such as anxiety disorder (Hardin et al., 2009; Jazbec, McClure, Hardin, Pine, & Ernst, 2005) or bipolar disorder (Mueller, Ng, et al., 2010). In addition, previous studies did not find an effect of maltreatment on motor processing in manual tasks (De Bellis, Hooper, Woolley, & Shenk, 2010). By contrast, antisaccade performance in youths with ES has not yet been investigated.

This study examines the impact of incentives on cognitive control using a validated version of the monetary incentive antisaccade task (Jazbec et al., 2005). We predicted that children with ES, much like children with mood and anxiety disorders,