On the Neuroscience of Self-regulation in Children with Disruptive Behavior Problems: Implications for Education

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Introduction
Self-regulation is increasingly recognized as a key predictor of academic and social competence. A multidisciplinary understanding of this ability is timely and can strengthen theory and practice. The present review aims to inform educators on what cognitive neuroscience can teach us about self-regulation. To do so, we will focus on a decade-long research program of Dr. Marc D. Lewis’ research group, examining children with disruptive behavior problems and their peers on neural measures of self-regulation. The ability of a child to manage their thoughts and emotions appropriately and flexibly adjust their internal goals and responses to the changing demands of a situation is often defined as self-regulation. A subset of students who show a persistent and maladaptive profile of aggression and rule-breaking can be diagnosed with oppositional defiant disorder or conduct disorder, and are often grouped under the term disruptive behavior problems. Disruptive behaviors problems (DBP) distract students from school work, contribute to parents and teacher burnout, take up school administrative resources, and can create severe social problems.

Research Questions
- The present review has two main objectives. Our first objective is to review research searching for neural indices of self-regulation. Is there a single set of neural indices of self-regulation that:
  a) differs between individuals with disruptive behavior problems and those who do not?
  b) changes in accordance with the developmental trajectory of self-regulation?
  c) change with successful treatment that targets self-regulation?
- Our second objective is to determine whether and how such measures can contribute to our theoretical understanding of disruptive behavior problems; and to discuss implications for education.

Methods
- EEG Indices of Self-regulation

Results
- Research Question 1: Can Neural Indices Explain Individual Differences in Disruptive Behavior Behaviors?
  Woltering, Granic, Lamm, and Lewis (2011) compared school-aged children (8 to 12 years old) referred by parents, police, or teachers for aggressive and rule-breaking problems with matched peers on N2 and P3 ERP components during a GoNogo task. Two studies (Woltering, Granic, Lamm, & Lewis, 2011; Granic, Ziolko, & Lewis, 2011) found increased activation for the disruptive behavior problem group compared to their peers. This was interpreted as a hypervigilant reaction to inhibiting a prepotent response tendency which, in real conflict situations, could translate into a rigid, threat-oriented behavior.

- Research Question 2: Do Changes in Neural Indices of Self-regulation Follow a Developmental Trajectory?
  Findings show a consistent attenuation of the N2 and P3 ERP components with age up to early adolescence (see Figure 3a, for P3). We note that these neural age effects were specific to the time period of response control, correlated with behavioral indices of self-regulation, and were source localized to the ACC. Figure 3b, from Liu et al., 2014, represents an area suggestive of the ACC where significant age effects were found with theta power during cognitive control. This increase in theta activity also partially mediated age related improvements in response control and was greatest in a condition that demanded greater effort.

- Research Question 3: Do Neural Indices of Self-regulation Change with Successful Treatment?
  To the best of our knowledge, Lewis et al. (2008), Woltering et al. (2011) and Woltering, Liao, Liu, and Granic (2015) are the only three studies to date that investigated changes in the neural correlates of self-regulation with treatment of disruptive behavior problems. Subjects in both studies were children (8-12 years old, previously described) who were divided into improvers and non-improvers after completing the Stop Now and Plan Program (SNAP-PTM). Woltering et al. (2011) did find changes in the N2 component (see Figure 4) for ‘improvers’ using a larger sample (about 35 per treatment group) and improved methods (Woltering, Bazargani, & Liu, 2013). Woltering, Liao, Liu, & Granic (2015) replicated this same pattern using theta power.

Implications for Education
- Objective 1: In our review, we focused primarily on the N2 and P3 ERP components as well as theta oscillations and source activation linked to ACC activation. We found these neural measures were sensitive in distinguishing between individuals with disruptive behavior problems; showing incremental changes from middle childhood and adolescence consistent with their gradually developing self-regulation ability; changing with successful treatment of subjects with emotion regulation problems.
- Objective 2: Because changes are found in neural systems involved with the flexible regulation of emotion, and considering that there was over-activation in these systems, this suggests these children are not callous or unemotional but that they overusing these systems. In other words, the externalizing behavior is not a lack of trying but more so a frustration in applying self-regulatory skills efficiently. Regulating takes their brains a lot more effort.
- These data support the Anxiety Model of Disruptive Behavior Problems (Granic, 2014), but see also Woltering & Lewis, 2013 which posits that anxiety and frustration drives and maintains aggression. Interventions at school or clinics should therefore not only focus on the much more noticeable externalizing problems, but should also help reduce and treat comorbid anxiety symptomatology.

Literature Cited
- Lewis, M. D., & Granic, A. (2013). Dynamic regulation in childhood: An individual differences approach.[*Corresponding Author.*]

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