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Neural evidence for enhanced attention to mistakes among school-aged children with a growth mindset

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ABSTRACT

Individuals who believe intelligence is malleable (a growth mindset) are better able to bounce back from failures than those who believe intelligence is immutable. Event-related potential (ERP) studies among adults suggest this resilience is related to increased attention allocation to errors. Whether this mechanism is present among young children remains unknown, however. We therefore evaluated error-monitoring ERPs among 123 school-aged children while they completed a child-friendly go/no-go task. As expected, higher attention allocation to errors (indexed by larger error positivity, Pe) predicted higher post-error accuracy. Moreover, replicating adult work, growth mindset was related to greater attention to mistakes (larger Pe) and higher post-error accuracy. Exploratory moderation analyses revealed that growth mindset increased post-error accuracy for children who did not attend to their errors. Together, these results demonstrate the combined role of growth mindset and neural mechanisms of attention allocation in bouncing back after failure among young children.

1. Introduction

Mindsets – or implicit beliefs about the malleability of intelligence – have been linked with differential responding to setbacks and failures. Whereas individuals with more of a *growth mindset* – the belief that intelligence is expandable with learning and effort – tend to readily bounce back from their errors, those with more of a *fixed mindset* – the belief that intelligence is a stable entity – tend to feel helpless after encountering failures (e.g., Dweck, 1999; Henderson and Dweck, 1990; Hong et al., 1999; Moser et al., 2011). In fact, the connection between mindsets, attributions, and differential reactions to failure is well established across much of development (Dweck, 1975; Dweck and Reppucci, 1973; Hong et al., 1999; Mueller and Dweck, 1998). Mindset-like beliefs are present as early as kindergarten and first grade (Bempechat et al., 1991; Cain and Dweck, 1995; Herbert and Dweck, 1985; Smiley and Dweck, 1994), and have been shown to distinguish students who "thrive" from those who "dive" across middle school (Blackwell et al., 2007; Romero et al., 2014), high school (Yeager et al., 2014), and college (Yeager et al., 2016). As such, disseminating the growth mindset belief on a national scale has become a research priority across grade levels (Paunesku et al., 2015; Yeager et al., 2013; Yeager et al., 2016).

So how exactly are growth mindsets linked with resilience to setbacks? Research has primarily focused on the associations between mindsets and motivational variables such as attributions and achievement goals to address this question (Dweck et al., 1995; Dweck and Leggett, 1988; Hong et al., 1999; Mueller and Dweck, 1998; see Burnette et al., 2013 for a review). Whereas growth-minded individuals tend to attribute failure to a lack of effort and adopt learning goals to learn as much as possible when approaching a new task, fixed-minded individuals attribute failure to a lack of ability and adopt performance goals – they strive to outperform others (Dweck and Leggett, 1988). An illustrative series of studies (Diener and Dweck, 1978, 1980; as reviewed in Dweck and Leggett, 1988) compared reactions to failures between late grade school-age children classified as *mastery-oriented* (who attributed failure to a lack of effort, akin to the growth mindset) and those classified as *helpless* (who attributed failure to a lack of ability, akin to the fixed mindset). Children's verbalizations of their thoughts and feelings were recorded as they worked through an increasingly difficult concept formation task. Prior to encountering failure, there were no differences in verbalizations or performance between the two groups. However, several distinctions were found immediately

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following the onset of failure. Most notably, compared to mastery-oriented children, helpless children tended to 1) report negative self-cognitions such as blaming their deficient memory or intelligence for their failure, 2) express more negative affect, and 3) divert their attention away from their failed task performance, for example by speaking of their talents in other domains. These cognitive and affective differences were accompanied by a sharp decline in performance following failure among the helpless children.

These findings illustrate the far-reaching impacts of mindsets on important motivational processes following setbacks and mistakes. Yet, this research has almost exclusively relied on self-report and behavioral observation methods. As such, these studies cannot speak directly to the underlying cognitive processes occurring immediately following failure. It is also possible that requiring participants to verbalize their own attributions, feelings, goals, and strategies after setbacks alters the experience of the performance situation itself and limits generalizability. Fortunately, recent work has used cognitive neuroscience methods to better understand the neurocognitive mechanisms related to mindsets, mistakes, and adjustments in a minimally intrusive manner. We briefly review two mindset studies that used event-related brain potentials (ERPs), a methodology that allows for the precise measurement of distinct cognitive processes as they unfold over time (Luck, 2014).

The first study asked fixed- and growth-minded college students to complete a very difficult general knowledge task (Mangels et al., 2006). On each trial after participants provided a response, they received performance feedback (i.e., "correct/incorrect") followed by learning feedback (i.e., the right answer). Findings indicated that whereas differences were rather small between the mindset groups in terms of the immediate good/bad categorization of the performance feedback– as reflected by the feedback-related negativity (Holroyd and Coles, 2002), a much larger difference emerged following the learning feedback, such that growth-minded individuals exhibited greater sustained left temporal negativity (Butterfield and Mangels, 2003). The authors suggested that this was reflective of greater attention allocation to the learning feedback. Growth-minded individuals also had superior performance on a surprise retest of the questions they had initially answered incorrectly, perhaps because they paid more attention during the learning feedback phase.

In the second study, Moser et al. (2011) examined ERPs elicited immediately after the response in a very simple two-choice flanker task among college students. Two well-known and dissociable ERPs are elicited after errors in such tasks – the error-related negativity (ERN; Gehring et al., 1993) and error positivity (Pe; Overbeek et al., 2005). The ERN is a frontocentrally maximal ERP localized to anterior cingulate cortex (Herrmann et al., 2004), peaks within 50–150 ms post-response, and is associated with immediate, perhaps unconscious and automatic error-correction processes (Gehring et al., 2012; Yeung and Summerfield, 2012). The Pe, in contrast, is more broadly distributed across centroparietal electrode sites, localized to numerous brain regions including anterior cingulate, anterior insula, and parietal cortex (Herrmann et al., 2004; Ullsperger et al., 2010), reaches its maximum between 200 and 500 ms after errors, and has been linked with conscious error awareness and attention allocation to errors (O'Connell et al., 2007; Overbeek et al., 2005; Ullsperger et al., 2010; Wessell et al., 2011). Moser et al. (2011) found that endorsement of the growth mindset was associated with greater amplitude of the Pe, but was unrelated to the ERN. That study also found that growth mindset endorsement predicted higher accuracy after mistakes (i.e., post-error accuracy) and that Pe amplitude mediated the relationship between growth mindset and post-error accuracy. In other words, processes indexed by the Pe – such as attention allocation to errors – explained growth-minded individuals' superior post-error performance. These results extended previous self-report and behavioral studies, as they demonstrated a relation between mindset and moment-by-moment neural processes occurring within half of a second of making a mistake.

Together, the two ERP studies indicate that, in addition to dissociations in self-reported attributions, goals, and behaviors, mindsets are also dissociated by the neurocognitive correlates of feedback and error monitoring. The two studies paint a rather similar picture: mindsets were *not* related to the initial reaction to failure (i.e., feedback-related negativity and response-locked ERN), but they were linked to the later processing which may be reflective of attention allocation (sustained left temporal negativity and Pe). It is interesting to consider these results in the context of Diener and Dweck's (1978, 1980) finding of helpless children who diverted their attention away from the task following failure such that the Pe may reflect this attentional disengagement as early as 250 ms following an error and may explain subsequent post-error performance.

Critically, however, both ERP studies were conducted with undergraduate samples consisting of students with many years of experience in formal educational settings. Although mindsets are still academically relevant for students in this age range (Hong et al., 1999; Yeager et al., 2016), the studies offer no insights into how these mechanisms act for children who are just beginning to transition into formal school settings. This is an important gap in the literature for at least two reasons. First, this transition is characterized by a plethora of opportunities for both new learning and failure experiences. Understanding whether similar or different neural mechanisms are relevant for mindsets in this younger age range may be especially useful given that it is during these difficult transitions that mindsets have their most noticeable impact on academic achievement (Blackwell et al., 2007; Dweck, 1999; Dweck et al., 1995; Yeager et al., 2014). Second, functioning during the transition to school and early elementary years is thought to "set the stage" for later achievement and experience with school settings (Duncan et al., 2007). This is reflected in the abundant efforts to identify and assist students early on in a preventative fashion (e.g., Blair, 2002). It is possible that neural mechanisms associated with errors may precede children's ability to articulate how they feel about mistakes – providing novel insights into the error monitoring process that may have previously been missed.

In sum, understanding more precisely how mindsets relate to the processes that occur immediately after mistakes in this younger age range may open novel avenues for research and intervention to improve resilience. Thus, in the current study, school-age children performed a developmentally appropriate error-monitoring task while we recorded the ERN, Pe and post-error performance. On the basis of previous correlational research of mindsets and ERPs (Mangels et al., 2006; Moser et al., 2011) as well as those from the earlier mindset studies (Dweck and Leggett, 1988) we hypothesized that children who endorsed more of a growth mindset would 1) demonstrate greater amplitude of the Pe, 2) demonstrate greater post-error accuracy, and 3) that greater post-error accuracy would be accounted for by increased Pe amplitude.

2. Method

2.1. Participants

A total of 139 children ages 5–8 were recruited from the greater East Lansing community between June 2013 and July 2014 and received a $50 gift card for their participation. Although 10 five-year-olds were originally recruited, we found that these children were not yet able to perform the task appropriately and data from these participants were excluded from analysis. Data from five