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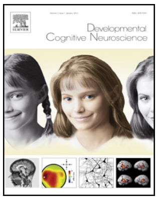

Neural evidence for enhanced attention to mistakes among school-aged children with a growth mindset

Hans S. Schroder[a,*], Megan E. Fisher[a], Yanli Lin[a], Sharon L. Lo[a], Judith H. Danovitch[b], Jason S. Moser[a]

[a] Department of Psychology, Michigan State University, East Lansing, MI 48824, United States
[b] Department of Psychological and Brain Sciences, University of Louisville, United States

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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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[*] Corresponding author.
E-mail address: schrod16@msu.edu (H.S. Schroder).

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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 $50 gift card for their participation. Although 10 five-year-olds were originally recruited, we found that these children were not yet able to perform the task appropriately and data from these participants were excluded from analysis. Data from five additional participants were lost due to computer error, and data from one child were excluded due to an excessive amount of EEG artifacts. The final sample used for analyses therefore included 123 children (62 girls, 61 boys; *M* age = 7.11 years, *SD* = 0.64, range: 6.01–8.26). The sample size was well over the sample size of N = 26 needed to detect the effect size in our correlational study of adults between mindset and Pe amplitude ($r = 0.52$, Moser et al., 2011). Parents identified their children as Caucasian (82.9%), Multiracial (9.76%), Asian-American (3.3%), Black (2.4%), or a racial/ethnic category that was not included on the demographic questionnaire (0.8%). Most children (82.1%) lived in two-parent households, and the distribution of parent-reported household incomes was: under $20,000-$40,000 (20.3%), $40,000-$80,000 (23.5%), and $80,000 to over $100,000 (49.6%); the remaining parents did not disclose their income.

Upon arrival to the laboratory, parents and children were given an overview of the study and completed consent and assent forms. Children were lead into a separate room to complete a series of tasks.[1] Eight questions were used to assess children's mindset endorsement. Four questions were growth-oriented (e.g., "Imagine a kid who thinks that you can get smarter and smarter all the time. . .how much do you agree with this kid?"), and four were fixed-oriented ("Imagine a kid who thinks that a person is a certain amount smart. . .how much do you agree with this kid?"; Gunderson et al., 2013; Heyman and Dweck, 1998). The experimenter read questions aloud, and children responded by pointing to one of five increasingly sized circles corresponding to "A little" (smallest circle) to "A lot" (largest circle). These responses were scored from 1 to 5, and were coded such that higher scores reflected greater growth mindset endorsement. Cronbach's alpha of the mindset measure was $\alpha = 0.72$.

2.2. Error-monitoring task

After completing the mindset measure, electrodes were applied (see below for details) and children were seated in front of a computer monitor to complete the error-monitoring task. The task was a developmentally appropriate go/nogo task used in other samples of young children to measure the ERN and Pe (Grammer et al., 2014; Lo et al., 2015). On each trial, a colorful zoo animal was presented at a central location on the computer monitor. Children were asked to help a zookeeper capture animals that had escaped from their cages by pressing the spacebar quickly and accurately when the animals appeared on the screen (go stimuli). They were also instructed that three orangutans (nogo stimuli) were helping the zookeeper put the animals back in their cages, and were told to withhold from pressing the spacebar when orangutans were presented. On each trial, a centrally located fixation cross appeared for 750 ms, followed by the animal stimulus (750 ms), and the intertrial interval was 500 ms. Practice blocks, consisting of 12 trials (9 go, 3 nogo), were repeated until children demonstrated an understanding of the task. The primary task used for analyses consisted of 8 blocks of 40 trials each (30 go trials and 10 nogo trials; 320 trials total) and lasted approximately 20 min. As described in previous studies (Grammer et al., 2014), the stimulus set in each block was balanced for animal size, color, and type. To obtain a sufficient number of errors for analysis, feedback was presented at the end of each block instructing children to respond faster if accuracy was above 90% and to respond more accurately if accuracy was below 75%.

2.3. Psychophysiological recording and data reduction

Continuous electroencephalographic activity was recorded using the ActiveTwo system (BioSemi, Amsterdam, The Netherlands). Recordings were taken from 64 Ag-AgCl electrodes embedded in a stretch-lycra cap according to the 10/20 system. Two additional electrodes were placed on the left and right mastoids. Electrooculogram activity generated by eye movements and blinks was recorded at FP1 and three additional electrodes placed inferior to the left pupil and on the left and right outer canthi. During data acquisition, the Common Mode Sense active electrode and Driven Right Leg passive electrode formed the ground. All signals were digitized at 512 Hz using BioSemi's ActiView software.

Offline EEG processing and analysis were performed using BrainVision Analyzer (Brain Products, Gilching, Germany). Scalp-electrode recordings were re-referenced to the mean of the mastoids and band-pass filtered with cutoffs of 0.1 and 30 Hz (12 dB/octave roll-off). Ocular artifacts were corrected using the method developed by Gratton et al., 1983. Response-locked data were segmented into individual epochs beginning 500 ms before response execution and continuing for 750 ms following the response. Physiological artifacts were detected with visual inspection and a computer-based algorithm. Specifically, trials in which the following criteria were met were rejected: a voltage step exceeding 50 μV between contiguous sampling points, a voltage difference of more than 200 μV within a trial, and a maximum voltage difference less than 0.5 μV within a trial.

2.4. Data analysis strategy

2.4.1. Post-error behavioral data

Measurement of post-error behavioral indices is an evolving endeavor (Danielmeier and Ullsperger, 2011; Dutilh et al., 2012), and there are currently no consensus recommendations for their estimation across different types of tasks (e.g., flanker, go/nogo, Stroop). To be consistent with most previous studies, we calculated post-error adjustments (post-error slowing and post-error accuracy) by considering only trials that followed errors of commission (i.e., false alarms). That is, we did not consider trials that followed errors of omission (misses). Post-error slowing was calculated as response time (RT) on correct hits following false alarms (FA-CH) minus RT on correct hits following correct hits (CH-CH). Accuracy in go/nogo tasks is determined not only by correct hits and false alarms, but also by correct rejections on no-go trials and misses on go trials. Thus, post-error accuracy (PEA) was calculated as: PEA = (sum of number of correct hits and correct rejections that followed false alarms)/(sum of number of correct hits, correct rejections, misses, and false alarms that followed false alarms). Note that this calculation of post-error accuracy considers all available trial types. The calculation of post-correct accuracy (PCA) was identical, except that it considered trials that followed correct hits. Post-error accuracy difference was then calculated as post-error accuracy minus post-correct accuracy. In the analyses, we evaluated post-error slowing and post-error accuracy with separate 2 Accuracy (Post-error vs. Post-correct) repeated-measures analysis of variance (ANOVAs) to first examine basic post-error behavioral effects. To then examine how these post-error behavioral adjustments related to mindset, these same ANOVAs were conducted with the mindset measure added as a covariate.

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[1] Additional tasks were administered as part of a larger project examining relations between parent and child attitudes, implicit beliefs, intellectual humility, cognitive abilities, parent and child psychological symptoms, and neurophysiology. These other measures were not directly relevant to the current study, and were not considered in the present analyses.

2.4.2. ERP data

The ERN and the corresponding waveform on correct trials (the correct-response negativity, CRN) were evaluated in the 0–100 ms post-response time window and the Pe and Pe-correct were evaluated in the 200–500 ms post-response time window. All ERPs were calculated relative to a −150 ms to −50 ms pre-response baseline window. As previous work suggests the ERN and Pe are distributed more diffusely in children than in adults (Davies et al., 2004), we included five electrode sites along the midline in the analyses (Fz, FCz, Cz, CPz, Pz). To evaluate internal consistency of the ERPs, we calculated split-half reliability by correlating odd-numbered trials with even-numbered trials and then adjusting with the Spearman-Brown formula (see Meyer et al., 2014). The resulting coefficients were as follows for the ERN, CRN; Fz: 0.59, 0.92; FCz: 0.66, 0.91; Cz: 0.66, 0.92; CPz: 0.72, 0.93; Pz: 0.70, 0.93. For the Pe and Pe-Correct, the coefficients were: Fz: 0.88, 0.95; FCz: 0.91, 0.96; Cz: 0.88, 0.97; CPz: 0.86, 0.97; Pz: 0.85, 0.98. Repeated-measures ANOVAs were first conducted on ERP measures without regard to individual differences to establish basic error-monitoring effects. Specifically, we conducted a 5 Site (Fz, FCz, Cz, CPz, Pz) x 2 Accuracy (Error vs. Correct) ANOVA for the ERN and Pe separately to examine basic error-related brain activity effects. The self-reported mindset scale was then entered as a covariate in these analyses to evaluate links between mindset and error monitoring (see Moser et al., 2011 for an identical analytic approach).

Prior to analysis, data were screened to ensure that general linear model assumptions (normality, linearity, homogeneity of variance) were satisfied. None of the study variables violated these assumptions, although one outlier case (defined as $|Z| > 3$) was identified with ERN amplitude at electrode site Pz. Analyses were run with and without this case and none of the results was affected. Therefore, we included this case in the final analyses for greater power.

3. Results

3.1. Mindsets

Consistent with previous work, most children's mindset scores fell between the fixed and growth extremes and the full range of mindset endorsement was observed ($M = 3.49$, $SD = 0.87$, range: 1.5–5.0). Growth mindset endorsement was positively associated with age, such that older children tended to endorse more of the growth mindset ($r = 0.23$, $p = 0.009$).

3.2. Behavioral data

Performance data from the go-nogo task is presented in Table 1. Consistent with many studies of speeded-response tasks, RTs on false alarms were shorter than RTs on correct-hits ($t(122) = 25.76$, $p < 0.001$, $d = 1.68$). Unsurprisingly, age was correlated with a greater number of correct hits ($r = 0.20$, $p = 0.03$) and faster RT on correct hits ($r = 0.48$, $p < 0.001$), indicating older children were more accurate and faster on the task. Although growth mindset endorsement was also marginally related to the number of correct hits ($r = 0.17$, $p = 0.06$) and faster RT on correct hits ($r = -0.20$, $p = 0.03$), correlations were reduced after controlling for age (partial $r = 0.13$, $p = 0.14$ and partial $r = -0.10$, $p = 0.27$, respectively). This is consistent with prior research indicating that mindsets do not relate to overall performance (Dweck, 1999; Moser et al., 2011).

We next considered the post-error behavioral data. Consistent with a post-error slowing effect, the main effect of Accuracy (Post-error vs. Post-correct) was significant for RT ($F(1, 122) = 55.81$, $p < 0.001$, $\eta^2_p = 0.31$) such that RTs on correct-hits that followed false alarms were longer than RTs on correct-hits that followed correct-hits (see Table 1 for *M*s and *SD*s). When mindset was added as a covariate, there was no significant interaction between Accuracy and Mindset ($F(1, 121) = 0.003$, $p = 0.95$, $\eta^2_p = 0.00003$). In contrast to the significant post-error slowing effect, there was no effect of post-error accuracy, which replicates many previous studies of error monitoring (Danielmeier and Ullsperger, 2011; Schroder and Moser, 2014): Accuracy (%) following false alarms was not significantly different than accuracy following correct hits ($F(1, 121) = 0.33$, $p = 0.57$, $\eta^2_p = 0.003$). However, when mindset was added as a covariate, the main effect of Accuracy approached significance ($F(1, 120) = 3.77$, $p = 0.06$, $\eta^2_p = 0.030$), and, more importantly, there was a marginal interaction between Accuracy and Mindset ($F(1, 120) = 3.45$, $p = 0.07$, $\eta^2_p = 0.028$). Correlations revealed that higher growth mindset endorsement was significantly related to higher post-error accuracy ($r(120) = 0.23$, $p = 0.010$), but was not significantly related to post-correct accuracy ($r(120) = 0.11$, $p = 0.24$). The relation between growth mindset endorsement and the difference between post-error and post-correct accuracy was in the expected direction and was small in magnitude ($r(120) = 0.17$, $p = 0.07$).

Table 1
Descriptive statistics of behavioral and ERP variables.

Variable	M	SD	Range
Number of False Alarms	32.48	10.49	12.00–60.00
Number of Correct Hits	235.41	5.16	202.00–240.00
Number of Correct Rejects	47.64	10.50	20.00–68.00
Number of Misses	4.44	5.18	0–38.00
False Alarm (FA) RT (ms)	418.11	50.00	313.04–557.09
Correct Hit (CH) RT (ms)	510.96	59.93	371.62–679.92
Post-FA CH RT (ms)	538.53	81.87	346.25–756.21
Post-CH CH RT (ms)	503.85	62.08	354.43–687.97
Post-Error Slowing (ms)	34.68	51.49	−132.76 to 190.91
Post-Error Accuracy (%)	88.08	8.00	60.00–100.00
Post-Correct Accuracy (%)	88.52	4.08	77.78–97.25
Post-Error Accuracy Difference (%)	−0.44	8.49	−30.35 to 15.29
FCz ERN (μV)	−3.30	6.02	−22.00 to 13.00
FCz CRN (μV)	4.86	3.79	−5.53 to 15.03
FCz ΔERN (μV)	−8.16	5.50	−23.35 to 6.00
Pz Pe (μV)	5.16	5.60	−14.17 to 17.03
Pz Pe-Correct (μV)	−2.94	4.75	−15.00 to 9.07
Pz ΔPe (μV)	8.11	5.45	−4.06 to 24.23

3.3. Error-related ERPs

Fig. 1 depicts response-locked ERP waveforms. The ANOVA in the 0–100 ms post-response time window confirmed the greater negativity on error trials relative to correct trials ($F(1, 122) = 164.33$, $p < 0.001$, $\eta^2_p = 0.57$), consistent with the presence of the ERN, the negative-going ERP preceding the Pe (Overbeek et al., 2005). This Accuracy main effect, along with a significant main effect of Site ($F(4, 488) = 8.76$, $p < 0.001$, $\eta^2_p = 0.07$), was qualified by a significant interaction between Site and Accuracy ($F(4, 488) = 106.59$, $p < 0.001$, $\eta^2_p = 0.47$). Consistent with previous research, difference in amplitude between error and correct trials was greatest at electrode site FCz ($t(122) = 16.44$, $p < 0.001$, $d = 1.62$; difference at Fz: $t(122) = 14.13$, $p < 0.001$, $d = 1.51$; difference at Cz: $t(122) = 13.99$, $p < 0.001$, $d = 1.33$; difference at CPz: $t(122) = 6.82$, $p < 0.001$, $d = 0.66$; difference at Pz: $t(122) = 0.35$, $p = 0.73$, $d = 0.04$). When Mindset was entered as a continuous covariate in the analysis, none of the Mindset interactions was significant (Site × Mindset: $F(4, 484) = 0.43$, $p = 0.79$, $\eta^2_p = 0.004$; Accuracy x Mindset: $F(1, 121) = 0.002$, $p = 0.96$, $\eta^2_p = 0.00002$; Site × Accuracy × Mindset: $F(4, 484) = 0.13$, $p = 0.97$, $\eta^2_p = 0.001$). The main effect of Mindset was also not significant ($F(1, 121) = 0.83$, $p = 0.37$, $\eta^2_p = 0.007$). In sum, consistent with our previous adult study (Moser et al., 2011), we found no relation between Mindset and the ERN.

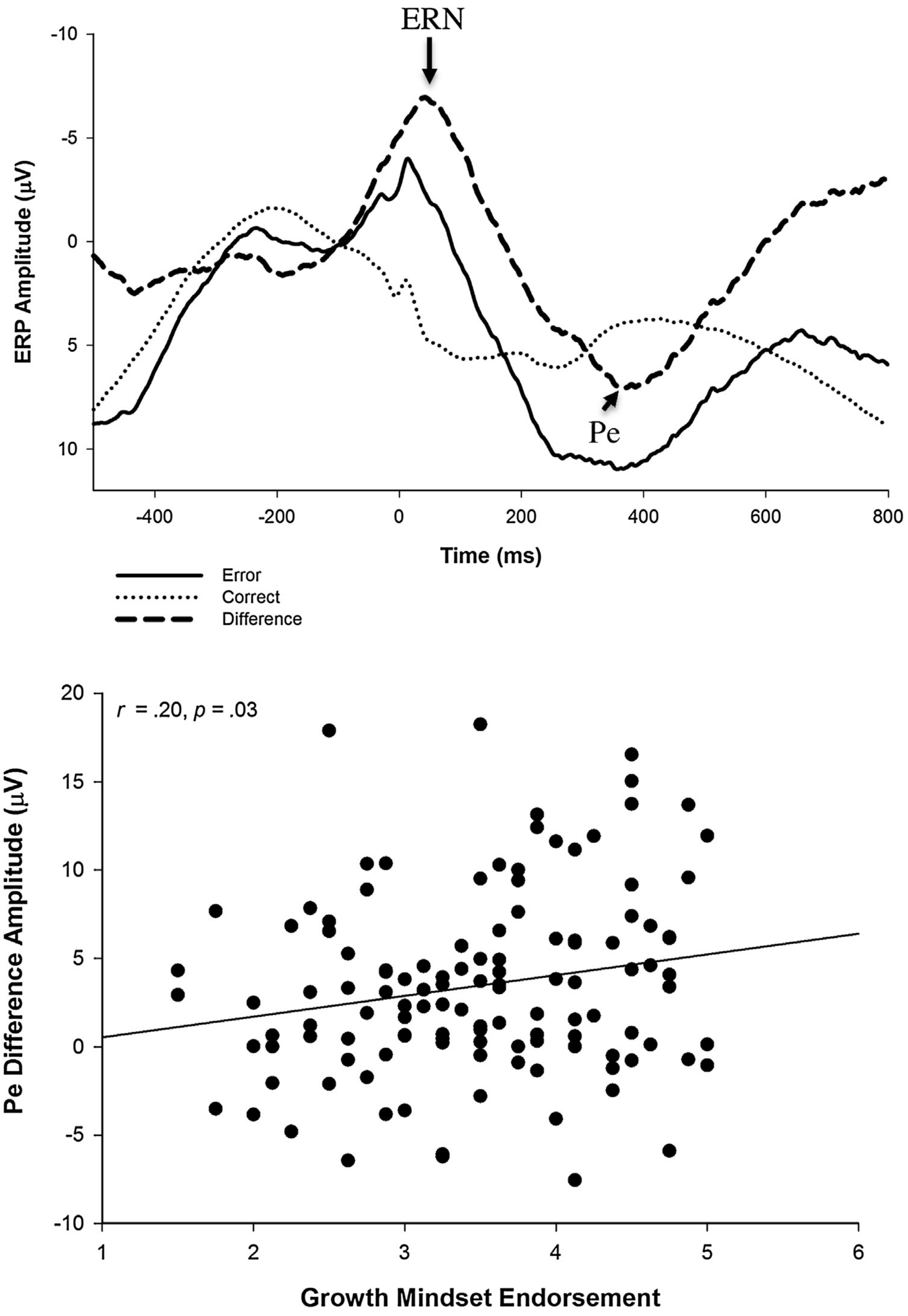

Fig. 1. Top: Grand averaged response-locked waveforms pooled across five midline sites (Fz, FCz, Cz, CPz, Pz). Time 0 is response onset. Bottom: Scatter plot depicting the relation between growth mindset endorsement and Pe difference amplitude pooled across five midline sites.

The Site x Accuracy ANOVA in the Pe window produced significant main effects of Site ($F(4, 488) = 102.25$, $p < 0.001$, $\eta^2_p = 0.46$) and Accuracy ($F(1, 123) = 54.11$, $p < 0.001$, $\eta^2_p = 0.31$), which were qualified by a Site x Accuracy interaction ($F(4, 492) = 169.30$, $p < 0.001$, $\eta^2_p = 0.58$). As expected from previous work, the difference in amplitude between error and correct trials in the time window of the Pe was largest at site Pz ($t(122) = 16.50$, $p < 0.001$, $d = 1.57$; difference at CPz: $t(122) = 14.31$, $p < 0.001$, $d = 1.35$; difference at Cz: $t(122) = 7.58$, $p < 0.001$, $d = 0.71$; difference at FCz: $t(122) = 1.20$, $p = 0.27$, $d = 0.11$; difference at Fz: $t(122) = -5.60$, $p < 0.001$, $d = -0.53$).

Importantly, when Mindset was entered as a covariate in the Pe ANOVA, the predicted Accuracy x Mindset interaction emerged ($F(1, 122) = 4.80$, $p = 0.03$, $\eta^2_p = 0.04$). Consistent with our previous study of adults (Moser et al., 2011) and with our current hypotheses, correlational analyses demonstrated that higher growth mindset endorsement was associated with larger Pe difference (calculated as the difference between positivity on error trials relative to that on correct trials) averaged across the midline electrode sites ($r = 0.20$, $p = 0.03$; see Fig. 1).[2] Mindset was not significantly related

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[2] An exploratory analysis examined the effects of gender on this relationship using a 5 Site x 2 Accuracy x 2 Gender x Mindset mixed-model ANCOVA. The interac-

to error-trial Pe ($r = 0.12$, $p = 0.17$), nor the correct-trial Pe ($r = -0.08$, $p = 0.38$). Covarying out the effects of age did not change the statistical significance of the Accuracy x Mindset interaction ($F(1, 120) = 4.75$, $p = 0.03$, $\eta^2_p = 0.04$).[3]

3.4. Brain-behavior relationships

Our final analysis considered the interrelations between mindset, error-related brain activity and post-error performance. Based on our previous studies (Moser et al., 2011; Schroder et al., 2012) and the correlations presented above, we limited our brain-behavior analyses to the Pe variables and the post-error accuracy variables. Table 2 presents these correlations. As can be seen in the table, the Pe on error trials was significantly related to post-error accuracy. Although mindset was also related to post-error accuracy, recall that mindset was not significantly related to error-trial Pe but to the difference wave (Pe error minus Pe correct). Thus, mediation was not present in this sample of young children as we had expected and found in our adult study (Moser et al., 2011).

To further understand the link between mindset and error processing in this age range, we conducted an exploratory moderation analysis examining mindset, Pe difference, and their interaction with a linear regression model predicting post-error accuracy (predictors were mean-centered prior to analysis). The overall model predicted 11% of the variance in post-error accuracy. As can be seen in Table 3, a significant interaction between mindset and Pe emerged and was suggestive of moderation. This interaction, presented in Fig. 2, indicates that the relation between mindset and post-error accuracy differed significantly between those with large versus small Pe difference amplitudes[4] – corresponding to high and low attention allocation to mistakes, respectively. As can be seen in Fig. 2, growth mindset was significantly related to post-error accuracy for children with small Pe amplitudes ($b = 0.04$, $p = 0.001$, 95% CI: 0.02–.06) but not for children with large Pe amplitudes ($b = -0.001$, $p = 0.92$, 95% CI: −0.02 to 0.02).

4. Discussion

This study examined the relation between growth mindset endorsement and neural correlates of error processing among school-aged children. Although the association between mindset and resilience to mistakes has been noted across development, nearly all research has used self-report or behavioral observation methods, precluding insights into the moment-to-moment cognitive processes that occur immediately after mistakes are made. Using a neurocognitive approach, we confirmed our prediction that growth-minded children demonstrated enhanced amplitude of the Pe, an ERP linked with attention allocation. We also found that growth-minded children had better accuracy after mistakes. Both of these findings replicate correlational work in adult samples (Mangels et al., 2006; Moser et al., 2011). Finally, exploratory analyses found that the Pe difference moderated the association between growth mindset and post-error accuracy, such that growth mindset was most related to post-error accuracy for children with smaller Pe amplitudes.

This is the third ERP study linking mindsets with later, as opposed to earlier, ERPs related to error and feedback processing (Mangels et al., 2006; Moser et al., 2011) and the first study to demonstrate this association among school-aged children. The consistency and specificity of these results across development suggests that the cognitive processes occurring around 200–500 ms following errors – in the time window of the Pe – may be important to consider in the wider mindset nomological network. We suggest enlarged Pe among growth-minded individuals reflects greater attention allocation to mistakes and/or greater error awareness, an interpretation in line with the functional significance of the Pe (Nieuwenhuis et al., 2001; O'Connell et al., 2007; Ridderinkhof et al., 2009; Steinhauser and Yeung, 2010) and with studies demonstrating a greater tendency of growth-minded children, compared to fixed-minded children, to direct attention toward their mistakes in order to improve their subsequent performance (Diener and Dweck, 1978, 1980; Dweck, 1999). Others have suggested the Pe reflects greater emotional responsivity to errors (e.g., Falkenstein et al., 2000), but this hypothesis has not been well articulated or supported (Overbeek et al., 2005). Rather, it is likely that the processes reflected in the Pe are more nuanced than mere affective reactivity. Of note, the Pe shares many characteristics (scalp distribution, temporal dynamics, associations with attentional processes) with the stimulus-locked P3b (Davies et al., 2004; Leuthold and Sommer, 1999; Ridderinkhof et al., 2009), an ERP component thought to reflect a number of processes, including the mobilization of attentional resources to motivationally-relevant task events (e.g., Nieuwenhuis et al., 2005; Polich, 2007). Seen in this light, the generally larger Pe among growth-minded children may provide neural evidence for two key predictions from mindset theory: 1) that growth-minded children view errors as more motivationally relevant events than fixed-minded children, and 2) that they expend more cognitive resources (i.e., effort) involved in processing and adjustment following mistakes (Dweck, 1999; Dweck and Leggett, 1988; Hong et al., 1999). Clearly, future research is needed to further understand the importance of engagement vs. disengagement of attentional resources following errors among growth-minded individuals across development.

Unlike our study of adults (Moser et al., 2011), we did not find support for our hypothesis that Pe would mediate the link between growth mindset and post-error accuracy in this sample of school-aged children. This discrepancy suggests the functional significance of the Pe (i.e., how it relates to behavior and mindset, Schroder and Moser, 2014) may differ across development. In adults, more attention allocation to errors (Pe) may be a necessary mechanism linking the growth mindset belief with the tendency to bounce back from mistakes. In contrast, attention allocation is *not* necessary for growth-minded children to bounce back (the Pe does not have the same mediational role). This suggests there are additional mechanisms among growth-minded children that promote post-error resilience.

It is worth noting the correlation between mindset and Pe difference uncovered here was rather modest in size ($r = 0.20$) and smaller than the correlation found in our adult study ($r = 0.52$, Moser et al., 2011), meaning that although on average growth-minded children tended to have larger Pes, there were plenty of growth-minded children who had average or below-average Pes (see Fig. 1 scatterplot). The exploratory analyses revealed that growth mindset endorsement was most related to post-error accuracy among children with smaller Pe difference amplitudes. In contrast, growth mindset was unrelated to post-error accuracy among children with larger Pe difference amplitudes. This finding is interesting as it may suggest that growth mindset compensates for lower attentional allocation to errors in young children: despite attending less to their errors, children with growth mindset still performed well. This is reminiscent of the mindset literature in

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tion between Accuracy and Mindset remained significant ($F(1, 119) = 4.38$, $p = 0.04$, $\eta^2_p = 0.04$), and there were no significant interaction effects of Gender ($ps > 0.25$).

[3] Although growth mindset was positively correlated with the composite IQ score from the Kaufman Brief Intelligence Test-2 (K-BIT-2; Kaufman and Kaufman, 2004) at $r = 0.23$, $p = 0.011$, controlling for cognitive ability did not alter the significance of any of the primary results: partial r between growth mindset and Pe difference: $r = 0.20$, $p = 0.011$; partial r between growth mindset and post-error accuracy: $r = 0.21$, $p = 0.02$.

[4] The moderation results were unchanged when using the error-trial Pe compared to the Pe difference amplitude.

Table 2
Brain-behavior correlations.

	Growth Mindset	Pe Error	Pe Correct	Pe Difference	Post-Error Accuracy	Post-Correct Accuracy	Post-Error Accuracy Difference
Growth Mindset	–						
Pe Error	0.12	–					
Pe Correct	−0.08	0.45**	–				
Pe Difference	0.20*	0.71**	−0.30**	–			
Post-Error Accuracy	0.23*	0.27**	0.17	0.16	–		
Post-Correct Accuracy	0.11	0.09	−0.01	0.10	0.13	–	
Post-Error Accuracy Difference	0.17	0.22*	0.17	0.10	0.88**	−0.36**	–

Note: Pe variables here were pooled across five midline sites (Fz, FCz, Cz, CPz, Pz).

* $p < 0.05$.

** $p < 0.01$.

Table 3
Regression model predicting post-error accuracy.

Predictor	R^2	ΔR^2	β	b	95% Confidence Interval (Lower, Upper) for b	p
Overall Model	0.11	–	–	–	–	0.003
Growth Mindset			0.20	0.02	0.002, 0.03	0.03
Pe difference			0.15	0.002	−0.0004, 0.005	0.10
Mindset x Pe difference		0.04	−0.21	−0.004	−0.007, −0.001	0.02

Note: Pe variables were pooled across five midline sites.

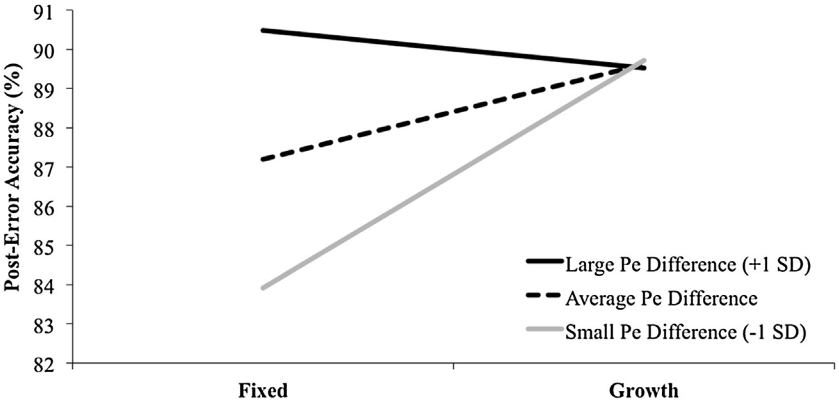

Fig. 2. Relations between mindset and post-error accuracy differ by Pe difference amplitude.

the academic achievement domain, which indicates the growth mindset is especially helpful for students with limited economic resources (Claro et al., 2016; Yeager et al., 2016). Similarly, our results suggest the growth mindset is most helpful for children who have limited attentional resources to allocate to errors. However, these conclusions should be considered speculative as they are derived from an exploratory analysis. Nonetheless, future research aimed at understanding this subset of children may shed light how the growth mindset preserves post-error resilience in the absence of attention.

Our results may offer some practical implications for parents and educators as well. It is a seemingly natural reaction to comfort children when they make mistakes. However, subtle linguistic cues intended to comfort struggling students (e.g., “it’s OK, you’re still smart in other subjects”) can backfire in significant ways (Brummelman et al., 2014; Gunderson et al., 2013; Mueller and Dweck, 1998; Rattan et al., 2012). Past mindset work focused on motivational remedies such as attributing errors to a lack of effort rather than a lack of ability (e.g., Dweck, 1975). Our findings, as well as previous ERP findings in adults (Mangels et al., 2006; Moser et al., 2011) also highlight the importance of paying attention to mistakes as a crucial mechanism of recovery. It is possible that adults’ attempts to comfort children may hinder the learning process by influencing the extent to which children attend to and make sense of their mistakes. That is, adults may inadvertently distract children from learning from their errors. This is an exciting avenue for future research to explore.

Future studies will also need to examine how experimentally induced mindsets impact error-related brain activity in young children. There may be important differences between “trait” mindsets and experimentally induced “state” mindsets in terms of attention allocation to the task and post-error performance. Only one study has examined this question and it was conducted in an adult sample. College students were led to believe that intelligence was either driven primarily by the environment (a growth mindset message) or by genetic factors (a fixed mindset message) before completing the flanker task (Schroder et al., 2014). Schroder et al. (2014) found that individuals exposed to the growth mindset actually had smaller Pe amplitudes to both error and correct responses, compared to those exposed to the fixed mindset message. However, the Pe amplitude was associated with less post-error slowing (indicative of more efficient post-error behavior) only among those exposed to the growth mindset. Understanding how similar interventions (e.g., Blackwell et al., 2007; Mueller and Dweck, 1998) impact error-processing ERPs among school-aged children would be especially important given the increasing usage of growth mindset messages in schools.

In sum, our findings add to the growing evidence that neurocognitive indicators of error processing may play an important role in explaining how growth mindset relates to post-error performance.

Our results illustrate the link between mindset and internally generated error processing is present by the time children begin formal schooling. Whether or not this greater attention to mistakes relates to resilience in the classroom remains to be tested. We look forward to future investigations using neurophysiology to develop a deeper understanding of how these beliefs impact learning and resilience.

Conflict of interest

None.

Author contributions

J.S.M. and J.H.D. designed study; M.E.F. recruited participants and collected data; H.S.S., M.E.F., Y.L., S.L.L., and J.S.M. processed the data; H.S.S. carried out data analyses; H.S.S. drafted the paper and all authors discussed the results and commented on the manuscript.

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References

Bempechat, J., London, P., Dweck, C., 1991. Children's conceptions of ability in major domains: an interview and experimental study. Child Study J. 21, 11–36.

Blackwell, L.S., Trzesniewski, K.H., Dweck, C.S., 2007. Implicit theories of intelligence predict achievement across an adolescent transition: a longitudinal study and an intervention. Child Dev. 78, 246–263.

Blair, C., 2002. School readiness: integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. Am. Psychol. 57, 111–127.

Brummelman, E., Thomaes, S., de Castro, B.O., Overbeek, G., Bushman, B.J., 2014. That's not just beautiful –that's incredibly beautiful! The adverse impact of inflated praise on children with low self-esteem. Psychol. Sci. 25, 728–735.

Burnette, J.L., O'Boyle, E.H., VanEpps, E.M., Pollack, J.M., Finkel, E.J., 2013. Mind-sets matter: a meta-analytic review of implicit theories and self-regulation. Psychol. Bull. 139, 655–701.

Butterfield, B., Mangels, J.A., 2003. Neural correlates of error detection and correction in a semantic retrieval task. Cogn. Brain Res. 17, 793–817.

Cain, K.M., Dweck, C.S., 1995. The relation between motivational patterns and achievement. Cognitions through the elementary school years. Merrill Palmer Q. 41, 25–52.

Claro, S., Paunesku, D., Dweck, C.S., 2016. Growth mindset tempers the effects of poverty on academic achievement. Proc. Natl. Acad. Sci. 113, 8664–8868.

Danielmeier, C., Ullsperger, M., 2011. Post-error adjustments. Front. Psychol. 2, 233.

Davies, P.L., Segalowitz, S.J., Gavin, W.J., 2004. Development of response-monitoring ERPs in 7–25-year-olds. Dev. Neuropsychol. 25, 355–376.

Diener, C.I., Dweck, C.S., 1978. An analysis of learned helplessness: continuous changes in performance, strategy and achievement cognitions following failure. J. Pers. Soc. Psychol. 36, 451–462.

Diener, C.I., Dweck, C.S., 1980. An analysis of learned helplessness II: the processing of success. J. Pers. Soc. Psychol. 39, 940–952.

Duncan, G.J., Dowsett, C.J., CLaessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L., Feinstein, L., Brooks-Gunn, Engel M., Sexton, H., Duckworth, K., Japel, C., 2007. School readiness and later achievement. Dev. Psychol. 43, 1428–1446.

Dutilh, G., Vandekerckhove, J., Forstmann, B.U., Keuleers, E., Brysbaert, M., Wagenmakers, E.J., 2012. Testing theories of post-error slowing. Atten. Percept. Psychophys. 74, 454–465.

Dweck, C.S., Leggett, E.L., 1988. A social-cognitive approach to motivation and personality. Psychol. Rev. 95, 256–273.

Dweck, C.S., Reppucci, N.D., 1973. Learned helplessness and reinforcement responsibility in children. J. Pers. Soc. Psychol. 25, 109–116.

Dweck, C.S., Chiu, C., Hong, Y., 1995. Implicit theories and their role in judgments and reactions: a world from two perspectives. Psychol. Inq. 6, 267–285.

Dweck, C.S., 1975. The role of expectations and attributions in the alleviation of learned helplessness. J. Pers. Soc. Psychol. 31, 674–685.

Dweck, C.S., 1999. Self-Theories: Their Role in Motivation, Personality and Development. Psychology Press, Philadelphia.

Falkenstein, M., Hoormann, J., Christ, S., Hohnsbein, J., 2000. ERP components on reaction errors and their functional significance: a tutorial. Biol. Psychol. 51, 87–107.

Gehring, W.J., Goss, B., Coles, M.G.H., Meyer, D.E., Donchin, E., 1993. A neural system for error detection and compensation. Psychol. Sci. 4, 385–390.

Gehring, W.J., Liu, Y., Orr, J.M., Carp, J., 2012. The error-related negativity (ERN/Ne). In: Luck, S.J., Kappenman, E. (Eds.), Oxford Handbook of Event-Related Potential Components. Oxford University Press, New York, NY, pp. 231–291.

Grammer, J.K., Carrasco, M., Gehring, W.J., Morrison, F.J., 2014. Age-related changes in error processing in young children: a school-based investigation. Dev. Cogn. Neurosci. 9, 93–105.

Gratton, G., Coles, M.G., Donchin, E., 1983. A new method for off-line removal of ocular artifact. Electroencephalogr. Clin. Neurophysiol. 55, 468–484.

Gunderson, E.A., Gripshover, S.J., Romero, C., Dweck, C.S., Goldin-Meadow, S., Levine, S.C., 2013. Parent praise to 1- to 3-year-olds predicts children's motivational frameworks 5 years later. Child Dev. 84, 1526–1541.

Henderson, V.L., Dweck, C.S., 1990. Motivation and Achievement. Harvard University Press, Cambridge, MA.

Herbert, C., Dweck, C.S., 1985. Mediators of Persistence in Preschoolers. Unpublished Manuscript. Harvard University, Cambridge, MA.

Herrmann, M.J., Rommler, J., Ehlis, A.-C., Heidrich, A., Fallgatter, A.J., 2004. Source localization (LORETA) of the error-related negativity (ERN/Ne) and positivity (Pe). Cogn. Brain Res. 20, 294–299.

Heyman, G.D., Dweck, C.S., 1998. Children's thinking about traits: implications for judgments of the self and others. Child Dev. 69, 391–403.

Hong, Y., Chiu, C., Dweck, C.S., Lin, D., Wan, W., 1999. Implicit theories, attributions and coping: a meaning system approach. J. Pers. Soc. Psychol. 77, 588–599.

Kaufman, A.S., Kaufman, N.L., 2004. Kaufman Brief Intelligence Test, 2nd ed. Pearson, Bloomington, MN.

Leuthold, H., Sommer, W., 1999. ERP correlates of error processing in spatial S-R compatibility tasks. Clin. Neurophysiol. 110, 342–357.

Lo, S.L., Schroder, H.S., Moran, T.P., Durbin, C.E., Moser, J.S., 2015. Neurophysiological evidence of an association between cognitive control and defensive reactivity processes in young children. Dev. Cogn. Neurosci. 15, 35–47.

Luck, S.J., 2014. An Introduction to the Event-related Potential Technique, 2nd ed. MIT Press, Cambridge, MA.

Mangels, J.A., Butterfield, B., Lamb, J., Good, C., Dweck, C.S., 2006. Why do beliefs about intelligence influence learning success? A social cognitive neuroscience model. Soc. Cogn. Affect. Neurosci. 1, 75–86.

Meyer, A., Bress, J.N., Proudfit, G.H., 2014. Psychometric properties of the error-related negativity in children and adolescents. Psychophysiology 51, 602–610.

Moser, J.S., Schroder, H.S., Heeter, C., Moran, T.P., Lee, Y-h., 2011. Mind your errors: evidence for a neural mechanism linking growth mind-set to adaptive posterror adjustments. Psychol. Sci. 22, 1484–1489.

Mueller, C.M., Dweck, C.S., 1998. Praise for intelligence can undermine children's motivation and performance. J. Pers. Soc. Psychol. 75, 33–52.

Nieuwenhuis, S., Ridderinkhof, K.R., Blom, J., Band, G.P.H., Kok, A., 2001. Error-related brain potentials are differentially related to awareness of response errors: evidence from an antisaccade task. Psychophysiology 38, 752–760.

Nieuwenhuis, S., Aston-Jones, G., Cohen, J.D., 2005. Decision-making, the P3 and the locus coeruleus-norepinephrine system. Psychol. Bull. 131, 510–532.

O'Connell, R.G., Dockree, P.M., Bellgrove, M.A., Kelly, S.P., Hester, R., Garavan, H., Robertson, I.H., Foxe, J., 2007. The role of cingulate cortex in the detection of errors with and without awareness: a high-density electrical mapping study. Eur. J. Neurosci. 25, 2571–2579.

Overbeek, T.J.M., Nieuwenhuis, S., Ridderinkhof, K.R., 2005. Dissociable components of error processing on the functional significance of the Pe vis-a-vis the ERN/Ne. J. Psychophysiol. 19, 319–329.

Paunesku, D., Walton, G.M., Romero, C., Smith, E.N., Yeager, D.S., Dweck, C.S., 2015. Mind-set interventions are a scalable treatment for academic underachievement. Psychol. Sci. 10.

Polich, J., 2007. Updating P300: an integrative theory of P3a and P3b. Clin. Neurophysiol. 118, 2128–2148.

Rattan, A., Good, C., Dweck, C.S., 2012. It's ok–not everyone can be good at math: instructors with an entity theory comfort (and demotivate) students. J. Exp. Soc. Psychol. 48, 731–737.

Ridderinkhof, K.R., Ramautar, J.R., Wijnen, J.G., 2009. To Pe or not to Pe: a P3-like ERP component reflecting the processing of response errors. Psychophysiology 46, 531–538.

Romero, C., Master, A., Paunesku, D., Dweck, C.S., Gross, J.J., 2014. Academic and emotional functioning in middle school: the role of implicit theories. Emotion 14, 227–234.

Schroder, H.S., Moser, J.S., 2014. Improving the study for error monitoring with consideration of behavioral performance measures. Front. Hum. Neurosci. 8, 178.

Schroder, H.S., Moran, T.P., Moser, J.S., Altmann, E.M., 2012. When the rules are reversed: action-monitoring consequences of reversing stimulus-response mappings. Cogn. Affect. Behav. Neurosci. 12, 629–643.

Schroder, H.S., Moran, T.P., Donnellan, M.B., Moser, J.S., 2014. Mindset induction effects on cognitive control: a neurobehavioral investigation. Biol. Psychol. 103, 27–37.

Smiley, P.A., Dweck, C.S., 1994. Individual differences in achievement goals among young children. Child Dev. 65, 1723–1743.

Steinhauser, M., Yeung, N., 2010. Decision processes in human performance monitoring. J. Neurosci. 30, 15643–15653.

Ullsperger, M., Harsay, H.A., Wessel, J.R., Ridderinkhof, R., 2010. Conscious perception of errors and its relation to the anterior insula. Brain Struct. Funct. 214, 629–643.

Wessell, J.R., Danielmeier, C., Ullsperger, M., 2011. Error awareness revisited: accumulation of multimodal evidence from central and autonomic nervous systems. J. Cogn. Neurosci. 23, 3021–3036.

Yeager, D.S., Miu, A.S., Powers, J., Dweck, C.S., 2013. Implicit theories of personality and attributions of hostile intent: a meta-analysis, an experiment and a longitudinal intervention. Child Dev. 84, 1651–1667.

Yeager, D.S., Johnson, R., Spitzer, B.J., Trzesniewski, K.H., Powers, J., Dweck, C.S., 2014. The far-reaching effects of believing people can change: implicit theories of personality shape stress, health and achievement during adolescence. J. Pers. Soc. Psychol. 106, 867–884.

Yeager, D.S., Walton, G.M., Brady, S.T., Akcinar, E.N., Paunesku, D., Keane, L., Dweck, C.S., 2016. Teaching a lay theory before college narrows achievement gaps at scale. Proc. Natl. Acad. Sci. U. S. A. 113, E3341–E3348.

Yeung, N., Summerfield, C., 2012. Metacognition in human decision-making: confidence and error-monitoring. Philos. Trans. R. Soc. B 367, 1310–1321.