Motivational Orientation, Error Monitoring, and Academic Performance in Middle Childhood: A Behavioral and Electrophysiological Investigation

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ABSTRACT—Previous research suggests that academic motivation orientation relates to students' causal interpretations about academic outcomes and their emotional reactions to those outcomes. The current study examines how student motivation may relate to certain neurophysiological systems that are thought to underlie the processing of successes and failures. In the cognitive neuroscience literature, the error-related negativity (ERN) in the event-related potential has been associated with error processing and the degree of an individual's emotional investment in his or her performance. The current study examined the relation between academic motivational characteristics and ERN amplitude during a speeded reaction time task in 3rd- to 5th-grade students (n = 17). Intrinsically oriented students displayed larger amplitude ERN responses and made more internally directed attributions about their task performance. The findings suggest that students with high intrinsic orientation attribute performance to personal control and that their error-monitoring system is more strongly engaged by performance errors.

Psychologists and educators alike have long explored how personal attributes regulate students' academic achievement (e.g., Crandall, Katkovsky, & Crandall, 1965; Csikszentmihalyi & Csikszentmihalyi, 1988; Deci & Ryan, 1985; Eccles, Wigfield, & Schiefele, 1998; Rotter, 1966; Weiner, 1986, 1992; White, 1959; Wigfield, 1994; Zimmerman, 1989). Academic motivation orientation appears to play a formative role in this process, acting as the force that directs, energizes, and regulates students' scholastic behavior (e.g., Gottfried, 1990; Gredler, 2001; Schiefele, 1999). Theorists often conceptualize academic motivation orientation on a continuum, ranging from intrinsic to extrinsic polarities (e.g., Harter, 1981; Ryan & Deci, 2000). Students with an intrinsic orientation are inherently curious and often perform stronger academically than others (e.g., D'Ailly, 2003; Hagborg, 1992; Schmidt, 2005; Rowe & Lockhart, 2005). They are energized to seek out challenge, to explore, and to use and extend their knowledge and skills, signifying that the learning *process* itself is pleasurable for these students (Dweck, 1986; Lepper, Corpus, & Iyengar, 2005; Schiefele, 1999). Conversely, those with an extrinsic orientation gain pleasure from the *outcome* of the activity, such as earning satisfactory grades, teacher approval, or peer acceptance (Harter, 1981; Schiefele, 1999; Wolters, Yu, & Pintrich, 1996). The behavior is mainly instrumental in nature and may or may not be enjoyable to the extrinsically motivated student.

It has been suggested that individual differences in student motivation orientation are associated with differences in the affective and cognitive processing of performance errors (for a review, see Eccles & Wigfield, 2002). Reactions to failure depend on a cognitive appraisal of the situation in relation to goals, beliefs, and motivations, which in turn elicits certain emotions and behaviors (Bandura, 1997; Boekaerts, 2001; Harter, 1992; Lazarus, 1991). Goal theorists (e.g., Bandura,

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1997; Covington, 2000; Dweck, 1986) suggest that intrinsically oriented students view failures as a constructive tool to reevaluate their knowledge, strategies, and behaviors. As a result, intrinsically motivated students who encounter difficulties often show increased effort, persistence, and adaptive emotional reactions because their goals are to develop new skills and competencies (Boekaerts, 2001; Mantzicopoulos, 1997; Turner, Thorpe, & Meyer, 1998; Pintrich & Zusho, 2002). Conversely, students with extrinsic orientations may view failure as a distinct end state. Students value the *outcome* of the activity, often for its social implications, such as earning a good grade to please parents or teachers, to "look smart," or perform similarly to others in the class. For these students, failure often results in aversive social outcomes, negative emotions, and wariness/avoidance of additional attempts at similar tasks (Clifford, 1984; Gottfried, 1990; Mantzicopoulos, 1997; Turner et al., 1998). Thus, initial reactions to failure may correspond to distinct cognitive–affective processing patterns in intrinsically and extrinsically motivated students that are associated with different regulatory processes.

Contemporary social-cognitive theorists (e.g., Boekaerts, 2001; Dweck, 1986; Harter, 1992; Pintrich, 2000; Zimmerman, 1989) suggest that the perceived cause of an academic outcome influences students' reactions to failure and subsequent performance. According to Weiner (1986, 1992), students seek an explanation for why they succeed or fail on an academic task, often attributing the outcome to causes that are either internal or external to themselves. For instance, effort represents a cause originating within the individual, whereas luck and task difficulty appear outside one's control. Expanding on this relationship, Dweck (1999) suggested that academic motivation orientation coincides with differences in students' interpretations about causality and their emotional reactions to their academic failures. Given their inherent desire for learning mastery, intrinsically oriented individuals are more likely to attribute their academic failures to internal, controllable causes (e.g., inappropriate study methods), to feel dissatisfied by their performance, and to regulate performance to enhance future success. Conversely, performance-oriented students may be more likely to attribute their failures to external, environmental factors in an effort to preserve positive social perceptions (e.g., Mantzicopoulos, 1997; Pintrich, 2000; Robins & Pals, 2002).

Although student motivation patterns (i.e., motivation orientation) appear to be associated with variations in cognitive–affective appraisals of academic failures and subsequent regulatory attempts, the neurophysiological correlates of these patterns have remained relatively unexplored. Of particular relevance, neurophysiological research has identified a performance monitoring system in the anterior cingulate cortex (ACC), which is an area of the frontal cortex involved in the modulation of attention, response selection, and emotion (e.g., Devinsky, Morrell, & Vogt, 1995; Segalowitz, Davies, Santesso, Gavin, & Schmidt, 2004; Vogt, 1993). The error-related negativity (ERN) is an event-related potential (ERP) that immediately follows performance errors on speeded reaction time tasks and has been theorized to partly represent the output of this error-monitoring system (e.g., Bush, Luu, & Posner, 2000; Dehaene, Posner, & Tucker, 1994; Pailing & Segalowitz, 2004; Kim, Iwaki, Imashiova, Uno, & Fujita, 2007). Specifically, the ERP amplitude in the first 150 ms following an incorrect response is usually more negative than the ERP amplitude following a correct response. Bernstein, Scheffers, and Coles (1995) found adults' ERN deviated with the degree of error on a reaction time task such that the magnitude of the ERN was larger when participants' motor responses were more incongruent with the correct response. Using a similar reaction time task, Segalowitz et al. examined the development of the ERN in children from 7 to 25 years of age and found that children also produced an ERN after errors, although the magnitude was significantly smaller than the adult ERN.

It has been suggested that the magnitude of the ERN may be related to the emotional salience of errors for an individual, with ERN amplitude reflecting the extent to which individuals are emotionally invested in their performance (Gehring, Goss, Coles, Meyer, & Donchin, 1993; Hajcak, Moser, Yeung, & Simons, 2005; Pailing & Segalowitz, 2004). For example, Hajcak et al. had participants complete a laboratory reaction task in which success in some trials was worth 5 points but was worth 100 points in others, with the points being converted to a monetary reward at the end of the experiment. In line with the above suggestion, ERN magnitude was greater when students made errors on 100-point trials, suggesting that the error-monitoring system in the ACC is sensitive to goals and reflects the emotional response to errors that affect those goals.

In the current study, we make a preliminary attempt at linking the ACC-based error-monitoring system that has been delineated in the cognitive neuroscience literature with the motivation processing patterns described in the educational psychology literature. The present study involved a common laboratory reaction time task (an Eriksen flanker task), which was intended to elicit a combination of successful and failed responses in 3rd- to 5th-grade children. Our first hypothesis arises from the social-cognitive theories of motivation discussed earlier. Children who have a higher level of internal attributions concerning task performance feel that failures are due to exerted effort or ability and may feel disappointed by the discrepancy between their actual performance and their goals (Boekaerts, 2001; Dweck, 1986; Harter, 1992; Mantzicopoulos, 1997; Zimmerman, 1989). This discrepancy would relate to stronger engagement of the error-monitoring system, and thus, we expected internal attributions about task performance to be associated with a higher magnitude ERN response (Gehring et al., 1993; Hajcak et al., 2005; Pailing & Segalowitz, 2004).

Our subsequent questions concerned the relation of the data from the laboratory reaction time task to children's academic motivation orientation. We hypothesized that individuals with an intrinsic academic motivation orientation would report increased internal attributions about their performance on the reaction time task (Mantzicopoulos, 1997) and that they would also display higher ERN amplitudes, reflecting the increased salience of errors in an affective–motivational pattern that cues self-regulatory processes (Boekaerts, 2001; Clifford, 1984; Gottfried, 1990; Turner et al., 1998; Wolters, Yu, & Pintrich, 1996). Additionally, we explored the relation between intellectual abilities and these motivation regulation patterns.

One of the aims in the current study was to attempt to build a bridge between measures of error monitoring (as measured in the laboratory) with constructs that have more direct educational relevance (motivation orientation, causal attributions of performance). If children's attributions and brain responses on the laboratory reaction time task were indeed related to children's self-reported motivation orientation, this would suggest that laboratory-based measures of error processing may have wider relevance for the theories of academic motivation orientation. We chose the 3rd–5th grade range because children's academic motivation is transitioning at this point, with the aim of seeing a wide range in motivation orientation. Motivation researchers have shown children in their early primary years (e.g., 3rd and 4th grades) display intrinsic motivation orientations but by middle to late childhood (5th, 6th, and 7th grades), they developed predominantly extrinsic motivation orientations (e.g., Gottfried, 1990; Harter, 1981). Additionally, students are more likely to share common academic experiences in elementary school, whereas children in junior/senior high school vary in chosen course topics and schedule.

METHOD

Participants

Families with children in the 3rd–5th grades were recruited from urban and suburban environments in the northeast United States using commercially available mailing lists and listservs. Prior to participant recruitment and participation, the study had been approved by the institutional review board at the investigators' university. Families with children who showed atypical academic performance, who had experienced chronic developmental problems, who used long-term medication or were homeschooled were excluded from the study. Parents and children were fully informed about the study prior to participation, and those who were interested completed consent forms (for parents) and assent forms (for children). Testing took place during one laboratory visit lasting approximately 2.5 hr. After informed consent procedures and an initial description of the study, the parent or guardian of the child sat in a viewing area adjacent to the testing room.

A total of 36 children participated in the study (22 male and 14 female) with a mean age of 9.53 years (SD =0.84). The sample was diverse in terms of ethnicity (Caucasian = 10, African American = 12, Hispanic/Latino = 1, and Other = 3). Children typically came from dual-income homes where both parents had some education beyond a high school diploma. Each family received a small toy and $25 for participation.

Measures

Harter's Scale of Intrinsic Versus Extrinsic Motivational Orientation in the Classroom

This is an academic motivation orientation measure for children with diverse backgrounds (e.g., age, learning ability, and socioeconomic status) and, unlike other measures, employs an answer format that is less susceptible to socially desirable responses (e.g., true vs. false; Harter, 1981). Thirty items are verbally administered in a forced-choice format with item scores ranging from one to four. Out of five subscales, three were particularly relevant to the current study: (a) preference for challenging work versus easy work, (b) learning for curiosity versus pleasing the teacher/getting a good grade, and (c) incentive to work for personal mastery of material versus dependence on teacher to learn material. Mean scores were calculated for each subscale, with higher values indicating increased intrinsic motivation and lower values indicating increased extrinsic motivation. To obtain an overall score of motivation orientation, scores across the three subscales were averaged (M =2.93, SD = 0.40).

Wechsler Intelligence Scale for Children—4th Edition

A General Ability Index (GAI; Raiford, Weiss, Rolfus, & Coalson, 2005) was calculated from four subscales of the WISC-IV: block design, similarities, vocabulary, and matrix reasoning (standard score = 100). The sample showed a wide range in general intellectual ability (M = 110.94, SD = 19.01).

Academic Performance

Formal academic progress reports were used to assess current academic performance from the most recent grading period. Parents brought children's most recent quarter grade card, and grades were recorded by an experimenter. Grades were converted to a 4.0 grade point average (GPA) scale. GPA data were computed for 33 out of the 36 children, with the mean GPA being 3.40 (SD = 0.63). Three children attended schools that used measures of mastery progress, which could not be appropriately converted to a GPA scale.

Eriksen Flanker Task

Following preparation for recording of the electroencephalogram (EEG; see below), participants completed a computerized flanker task (Eriksen & Eriksen, 1974). The flanker task is a speeded reaction time task commonly used to assess behavioral and neurophysiological reactions to success or failure. One flanker trial consisted of three parts. First, a fixation point was displayed in the middle of the screen for 200 ms. Second, a flanker stimulus array was presented for 200 ms. This array was one of the four possibilities, in which the middle arrow was congruent ("› › › › ›" or "‹ ‹ ‹ ‹ ‹") or incongruent ("‹ ‹ › ‹ ‹" or "› › ‹ › ›") with the surrounding arrows. Participants had to indicate the direction of the central arrow (left and right) via a button press on a two-button response box within a certain time frame (see below). After a latency of 500 ms following the child's button press, an icon indicating whether the child chose the correct response was displayed on the screen. A schematic happy face indicated a correct response, and a schematic sad face was displayed when the participant had pressed the wrong button or did not press either button in the allotted time frame.

Participants first completed a 20-trial training session to become acclimated to the flanker task. Because children naturally vary in processing time and motor responsiveness, the number of errors the participant produced during this training session determined the difficulty level of the subsequent flanker testing session. If the participant made eight or fewer errors, the window for a button press was limited to 650 ms after the onset of the flanker array, after which a button press would no longer register. If more than eight errors were produced in the training session, the window for button press responses was extended to 800 ms (for a similar methodology, see Henderson et al., 2006). Results from pilot testing suggested that these time windows were adequately challenging for most students in terms of producing enough errors without eliciting feelings of overt distress. After the training trials, the main task consisted of three blocks, with 60 trials per block presented in a random order (15 trials across each of the four possible flanker arrays). The flanker task lasted approximately 12 min.

Attributional Style Concerning Flanker Task Performance

For the purposes of examining the children's situation-specific attributions about their flanker task performance, children responded to six statements assessing internal and external performance attributions for correct and incorrect responses on the flanker task (see Appendix). An experimenter verbally administered each question and stated two possible answers. Participants were asked to finish each statement by choosing one of the two answer choices. Items were scored on a two-point scale (1 = *external attribution*, 2 = *internal attribution*) and summed to create an attribution composite score, which ranged from 6 (predominantly external attributions) to 12 (predominantly internal attributions).

EEG collection and Processing

During the flanker task, EEG was collected using a Lycra cap in combination with Electro-Gel conducting gel. Recording sites were two midline sites (Fz, Pz) and eight lateral pairs of electrodes (FP1/2, F3/4, F7/8, C3/4, T7/8, P3/4, P7/8, and O1/2). Scalp electrode impedances were always under 40 kilohms and usually under 20 kilohms. Eye movement was digitized using the vertical electrooculogram (EOG) recorded from above and below the left eye. Signals were amplified by optically isolated, high input impedance custom bioamplifiers from SA Instrumentation (San Diego, CA) and were digitized onto the hard drive of a Pentium IV PC using a 16-bit A/D converter (+/− 5 V input range). Bioamplifier gain was 4,000 for the EEG channels, 1,000 for the EOG channel, and the hardware filter (12 db/octave roll-off) settings were .1 Hz (high pass) and 100 Hz (low pass). The signal was collected referenced to the vertex (Cz) with an AFz ground, and all EEG data were re-referenced off-line to an average mastoids reference prior to further analysis. Eyeblinks were regressed out of the EEG using standard procedures (Lins, Picton, Berg, & Scherg, 1993). An artifact detection algorithm was used to flag epochs containing artifact, including large horizontal EOG changes as determined from the EEG signal at F7 and F8. Any epoch containing such artifacts was not included in the computation of the event-related waveforms. The EEG data were also visually inspected to verify the accuracy of the artifact detection and blink regression procedures.

ERN Computation

Complete ERP data were available for 17 participants (Male = 9). The remainder of the sample did not contribute ERP data to the analyses due to technical problems with EEG recording ($n = 8$), child inattentiveness preventing the completion of the task ($n = 5$), or lack of appropriate response level for ERP computation (i.e., fewer than 10 trials in their ERP for the error condition, $n = 6$). After low-pass filtering (20 Hz cutoff), ERPs to correct responses and to errors of commission were computed relative to a baseline of 50–150 ms prior to the button press (Henderson et al., 2006). The mean number of trials in the ERP to correct responses was 113 ($SD = 30$), and the mean number of trials in the ERP to incorrect responses was 27 ($SD = 14$). In line with prior studies showing that the ERN is maximal at frontal midline sites, the ERN was computed as the minimum peak value in the difference waveform (error minus correct) at Fz in the 0- to 150-ms period after response execution.

RESULTS

Across the 17 children with ERP data, the mean ERN amplitude was −3.27 μV ($SD = 4.94$). Figure 1 shows the grand mean

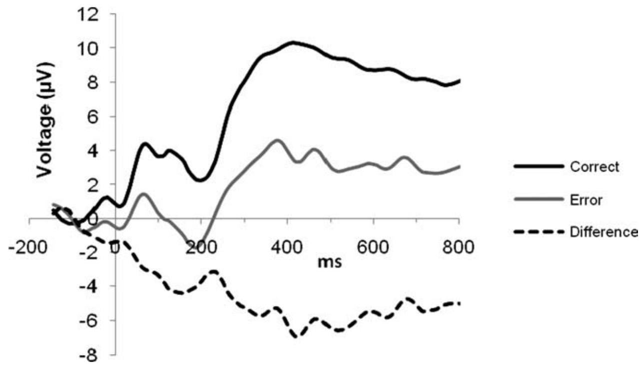

Fig. 1. Grand mean event-related potential waveforms at Fz following correct and error responses. The difference waveform represents the subtraction of the "correct" waveform from the "errors" waveform. The ERN was assessed as the most negative point in the difference waveform between 0 (the point of the button press response) and 150 ms.

waveforms from correct and error trials. The morphology of the grand mean waveforms in the current study is similar to other studies of the ERN in this age range in terms of not seeing distinctive peaks in the grand means, as well as an early and long-lasting divergence of the waveforms to correct and error trials and a small positivity in the first 100 ms after the button press (e.g., Segalowitz et al., 2004). The lack of a distinct negativity in the grand means is most likely due to interindividual variation in the latency of the ERN: The majority of the participants showed a small but distinct ERN within the latency range examined.

As seen in Table 1, multiple significant relations were evident among study variables. Our first question concerned the relation between children's attributions about their performance on the flanker task and the amplitude of the ERN. As hypothesized, the Pearson's correlation between an ERN amplitude and the performance attribution score was significant ($r = -.56$, $p < .05$), indicating those who reported more internal attributions about performance on the flanker task also displayed larger ERN amplitudes.

Table 1

Bivariate Correlation Matrix of Motivation Orientation, Attributions on Flanker Task Performance, Error-Related Negativity (ERN) Amplitude, General Ability Index, and Grade Point Average (GPA)

	1	2	3	4	5
1. Motivation Orientation	1.00	.35*	−.60**	.34*	.41*
2. Flanker Task Attributions		1.00	−.56*	.23	.44**
3. ERN Amplitude			1.00	−.08	−.45†
4. General Ability Index				1.00	.35*
5. GPA					1.00

Note. ERN, $n = 17$; GPA, $n = 33$; All other scales, $n = 36$.
†$p < .10$. *$p < .05$. **$p < .01$.

The second question concerned the relations between academic motivation orientation, attributional style on the flanker task, and ERN magnitude. Across the whole sample, the correlation between the academic motivation orientation score on the Harter scale and the performance attribution score from the flanker task was $r = .35$ ($p < .05$, $n = 36$). As predicted, high intrinsic motivation orientation on the Harter scale was associated with more internal attributions about performance on the flanker task as well as with larger ERN amplitude ($r = .35$, $p < .05$, $n = 17$ and $r = -.60$, $p < .05$, $n = 17$, respectively).

Concerning the relation of academic motivation orientation to academic performance and general cognitive ability, there were significant correlations between the Harter scale score and the GPA ($r = .41$, $p < .01$, $n = 33$) and with GAI ($r = .34$, $p < .05$, $n = 36$). The performance attribution score from the flanker task was also significantly associated with GPA ($r = .44$, $p < .01$, $n = 33$) but not with GAI ($r = .23$, $p = .18$, $n = 36$). Within the subset of children with ERP data, ERN amplitude was not significantly associated with GAI ($r = -.08$, $p = .75$) or GPA ($r = -.45$, $p = .09$), although the latter correlation approached significance.

DISCUSSION

The present study is a preliminary exploration of how academically relevant motivational processes relate to neurophysiological measures of error monitoring. The literature shows that children's academic orientations promote distinct cognitive–affective processing patterns in response to failure (Licht & Dweck, 1984; Petri, 1991; Weiner, 1992). Our study adds to this existing literature primarily in two ways. First, our findings suggest that children's perception of their performance in laboratory-based tasks provides insight into factors relating to academic achievement. Although laboratory tasks sometime seem far removed from the classroom setting or academic knowledge, children's *perceptions* of themselves and the context are influential factors relating to performance outcomes across situations (e.g., Fischer et al., 2007; Rotter, 1966; Weiner, 1986). Our results show children who attribute their performance on the flanker task to internal causes (e.g., exerted effort) were more intrinsically motivated and had higher GPAs in school. Motivation theorists suggest orientation styles reflect specific cognitive processing patterns that often transcend contexts, in which causal attributions of performance play an influential role in coping styles and behavior regulation strategies across situations (Dweck, 1986; Weiner, 1985; Wigfield, 1994).

Second, our findings suggest that children with strong academic intrinsic motivation make more internal attributions about their successes/failures on nonacademic tasks and also have stronger neurophysiological reactions to failure (as indexed by increased ERN amplitude) on these tasks compared to more extrinsically motivated children. The key question here is why an intrinsic motivation orientation would be associated with a larger ERN. There are a variety of possibilities: The larger ERN amplitude could reflect stronger emotional investment in error monitoring, deeper cognitive processing strategies, or an interaction between the two. In terms of emotional investment, previous research has shown ERN amplitude corresponds to degree of value an individual places on the learning outcome (e.g., Hajcak et al., 2005). As suggested in the education literature, individuals often place differential value on the learning process and academic outcomes for various reasons. Intrinsically oriented students continually strive toward mastery and acquisition of new knowledge, whereas others value the performance outcome for external incentives (e.g., respect or praise for good performance; Deci & Ryan, 1985; Dweck, 1986; Gottfried, 1990). For intrinsically motivated students, performance errors reflect their progress toward learning mastery and, ultimately, self-improvement. This may correspond to a stronger investment in error monitoring compared to those who are motivated by external rewards, a possibility that should be explored in future research.

A complementary possibility is that the variation in ERN amplitude reflects differences in cognitive processing. Research has shown students' motivational orientations correspond to distinct attributional patterns and performance strategies (e.g., Mantzicopoulos, 1997; Turner et al., 1998). Particularly, mastery oriented students often attribute performance to internal causes and are more likely to engage in deeper cognitive processing strategies to maximize performance after an error compared to extrinsically oriented students. The current findings show ERN magnitude also corresponds to the orientation/attribution patterns described in the literature, which may reflect differences in underlying processing strategies.

As noted by Lazarus (1991), cognition, emotion, and motivation are inherently intertwined. It may be the case that causal attributions are tied to variations in emotional reactivity, which in turn, mediates cognitive processing of errors. For example, for intrinsically oriented students making internal, situation-specific attributions about errors, failure may elicit neutral or moderate emotions (e.g., recognition and acceptance that failure is a result of personal actions). In turn, this "subdued" emotional reactivity acts as a driving force that fosters positive coping strategies and future performance regulation. Conversely, those who make external attributions are likely to experience strong, aversive emotional states that impede the self-regulatory process. Findings from the education literature provided evidence of these general patterns; however, to our knowledge, few have explored possible mediating effects (Mantzicopoulos, 1997; Turner et al., 1998).

Additional evidence for differential cognitive and affective processing of errors comes from comparative, neuropsychological, and neuroimaging studies of error monitoring (Bush et al., 2000), which suggests that the ACC may be delineated into cognitive and affective divisions in the dorsal and rostral portions of the ACC, respectively (Taylor, Stern, & Gerhing, 2007). According to Bush et al., the cognitive division is part of an attentional network associated with sensory or response selection relating to motivation and error detection. The affective division is primarily involved in assessing the emotional salience of errors as well as regulating emotional responses. A combination of ERP and functioning imaging research would prove useful in differentiating the cognitive and affective activation patterns associated with variation in motivation orientation. Other areas for future exploration could also involve how ERN amplitude may vary in function of the type and intensity of emotions relative to certain goals (e.g., Higgins, Shah, & Friedman, 1997), to specific aspects of academic motivation orientation (Ryan & Deci, 2000), and other dimensions of situation-specific causal attributions (e.g., Weiner, 1986).

We note that our conclusions are based on a small data set with a limited range in motivation orientation and in this sense may be premature. A larger sample size would be required to test meditational effects and would assist with clarifying the generalizability of the findings. However, this themes presented here may provide a novel direction for research attempting to link educational constructs with neurophysiological measures, an endeavor that has drawn its fair share of criticism (Hirsh-Pasek & Bruer, 2007) but which also promises some applied success (Ansari & Coch, 2006; Blakemore & Frith, 2005; Christoff, 2008; Szcs & Goswami, 2007; Willingham & Lloyd, 2007). Although more research is needed, we can begin to see how neurocognitive studies examining error monitoring and motivation may relate to educational issues. Although the current study may not directly apply to educational practices, it does add an additional dimension of understanding concerning how motivation may relate to differences in error-monitoring behavior and processing patterns. The current research is an initial attempt to explore how educationally relevant cognitive and motivational components may parallel neurophysiological reactions to performance outcomes in middle childhood. Our novel findings set the stage for future research exploring the parallels between motivational processes and the ACC-based error-monitoring system as indexed through the ERN response.

Acknowledgments—We thank the families and children who participated in the study. Grant support was provided by an Esther Katz Rosen award to PJM from the American Psychological Foundation.

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APPENDIX 1

Questions Assessing Attribution Style in the Flanker Task

1. I saw some happy faces during the computer game, meaning I pressed the correct arrow button. I pressed the correct button because:
   The symbols used in the game were really easy to match for most people.
   I am really good at matching symbols.
2. Seeing happy faces after I pressed the button also meant I pressed the correct arrow button before time ran out. I saw the happy face because:
   I am good at pressing buttons fast.
   There was enough time in the game to press the correct button.
3. I saw some unhappy faces during the task, meaning I may have pressed the wrong arrow button. If I pressed the wrong button, it was because:
   Sometimes the symbols were difficult to match. Anyone would make mistakes.
   Sometimes I wasn't good at pressing the right button.
4. Seeing unhappy faces during the task may also mean that I pressed the correct button but did not press it before the time ran out. If I did not press the correct button in time, it was because:
   Sometimes the game was too fast for me to push the button in time.
   Sometimes I am slow at pushing the button.
5. The smiley and unhappy faces were displayed after I pressed one of the arrows. I believe the game:
   Showed smiley or unhappy faces based on my right or wrong arrow pressing.
   I was right sometimes but I think the computer said I was wrong.
6. In general, I think I did
   Really well on the game.
   Did not do well on the game.

Why do you think this?
   If answer to the question was "really well":
      I received many smiley faces.
      I earned many smiley faces
   If your answer to was 'did not do well':
      I received many unhappy faces.
      I earned many unhappy faces.

Note. Scoring: Responses in italic indicate items scored as reflecting intrinsic (internal) attributions about task performance. Other responses (not in bold face) were scored as reflecting extrinsic (external) attributions.