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Emotion and Cognition: An Intricately Bound Developmental Process

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Regulatory aspects of development can best be understood by research that conceptualizes relations between cognition and emotion. The neural mechanisms associated with regulatory processes may be the same as those associated with higher order cognitive processes. Thus, from a developmental cognitive neuroscience perspective, emotion and cognition are dynamically linked and work together to process information and execute action. This article highlights the authors' recent efforts at integrating emotion regulation and cognitive processing during the first year of life by focusing on the methodological criteria outlined by Cole, Martin, and Dennis (this issue), and it discusses the idea that emotion and cognition are an intricately bound developmental process.

From a developmental cognitive neuroscience point of view, emotion and cognition, traditionally considered separate processes, are dynamically linked and work together to process information and execute action (e.g., Cacioppo & Berntson, 1999). In other words, regulatory aspects of development can best be understood by investigations that conceptualize relations between emotion and cognition. Cole, Martin, and Dennis (this issue) noted in their Summary and Conclusions section that developmental research can be enriched by studies of the role of emotions in organizing a child's thinking, learning, and action (emotions as regulating), and likewise by studies of the role of thinking, learning, and action in the regulating of emotions (emotions as regulated). In this commentary, we propose that those suggested developmental studies linking cognition and emotion would do more than simply enrich the child development field. Research integrating cognition and emotion is essential in any attempt to comprehend emotion regulation and to endorse it as a scientific construct because cognition and emotion represent an intricately bound developmental process.

Anterior Attention System

Cole et al. (this issue) proposed that, as a scientific construct, emotion regulation can be used to conceptualize the complex processes by which emotions relate to cognition and behavior. There already may be some neurological support for this linkage. Recent cognitive neuroscience findings suggest that the neural mechanisms underlying emotion regulation may be the same as those underlying cognitive processes, specifically, higher order cognitive processes such as volitional sustained attention or working memory. Recently, Posner and colleagues (Bush, Luu, & Posner, 2000) proposed that the attentional processes associated with the Anterior Attention System regulate both cognitive and emotional processing. One brain structure, in particular, has been associated with the Anterior Attention System. This is the anterior cingulate cortex (ACC), which has two major subdivisions to process separately cognitive and emotional information. The cognitive subdivision has interconnections with the prefrontal cortex, parietal cortex, and premotor and supplementary motor areas. This subdivision is activated by tasks that involve choice selection from conflicting information, which includes many working memory tasks (Bush et al., 2000). The affective subdivision has interconnections with the orbitofrontal cortex, amygdala, and hippocampus, among other brain areas. This subdivision is activated by affect-related tasks. It appears that there is suppression of the affective subdivision during cognitive processing and of the cognitive subdivision during affective processing; however, recent studies with adults point toward some interaction between cognition and emotion on Stroop-like or similar decision-making tasks (Bush et al., 2000). Thus, when considering the functionality and the neural connectivity of the ACC, the cognitive and emotion processes that were traditionally considered to be independent and separable can readily be understood as intricately bound and inseparable, especially on certain types of tasks.

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The Anterior Attention System has a long developmental process and begins to show some developmental changes in the last half of the first year of life, with major development occurring during toddlerhood (Derryberry & Rothbart, 1997; Rothbart, Derryberry, & Posner, 1994). This coincides with the development of self-initiated regulatory strategies noted by Cole et al. (this issue). Even during infancy, however, the Anterior Attention System may already begin to integrate thought and behavior and exert control on emotional experience and expression. This has led to speculation that self-regulation is driven not only by positive or negative affect, for example, but also at the cognitive level. Rothbart has hypothesized that high attentional control is associated with low negative affect (Rothbart et al., 1994). In fact, Rothbart has considered the state of attention to be incompatible with emotional distress, thus highlighting attention as a potential influence in emotion regulation (Ruff & Rothbart, 1996). Indeed, Rothbart's model of the development of temperament (i.e., emotion reactivity and emotion regulation) describes the process by which infants regulate distress using developing attentional abilities (Posner & Rothbart, 2000; Rothbart et al., 1994). These basic self-regulatory capacities are limited in effectiveness during infancy (Cole et al., this issue). Because of the beginnings of development of the Anterior Attention System in the first year of life, however, infants who react strongly to events may initially be irritable but later develop the ability for sustained attention (Ruff & Rothbart, 1996).

Frontal Brain Systems, Cognition, and Emotion Style

The Anterior Attention System is involved in cognitive processing when there is a resolution of conflict between two forms of stored information. The choice of hiding locations in an infant spatial working memory task may represent this type of conflict (Posner & Rothbart, 1998). In the developmental literature, Ruff and Rothbart (1996) have described a higher order attention system similar to the Anterior Attention System that is involved in the inhibition of responses and the planning of goal-directed behaviors. This attention system involves the frontal cortex and emerges in the last half of the first year of life. Although little detail is given of the specifics of this attention system, the skills described by Ruff and Rothbart are similar to those Diamond (1990) has demonstrated to be involved in the performance of the classic reaching A-not-B task and that we (Bell & Adams, 1999) have suggested are involved in the infant spatial working memory task. Our developmental cognitive neuroscience program of research has linked individual differences in infant spatial working memory to variations in frontal (and some posterior) brain electrical activity (Bell, 2001, 2003).

Likewise, developmental evidence seems to suggest that electrophysiological differences in affective style, or temperament, may be evident as early as the first year of life. Fox and colleagues have shown that infants who cry at maternal separation are more likely to exhibit right frontal brain electrical activation during rest (Fox, 1994; Fox, Calkins, & Bell, 1994). In addition, infants who display negative affect and high motor activity at 4 months of age are reported to exhibit right frontal activation at 9 months and inhibited behavior at 14 months (Calkins, Fox, & Marshall, 1996). For many infants, these individual differences in affective style and brain electrical activation persist throughout the preschool years (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Fox (1994) has developed a model of differential activation of the left and right frontal cortices that relates differential asymmetry patterns to individual differences in emotion reactivity and regulation (i.e., temperament). Fox has proposed both cortical and subcortical influences on these brain electrical patterns. Thus, different levels of regulatory ability may be associated with frontal lobe activation asymmetries.

To summarize, there are separate lines of evidence in the developmental literature to suggest that the processes associated with the Anterior Attention System may be involved in cognitive processing as well as emotion processing (Bush et al., 2000). Indeed, there is the suggestion that cognition and emotion are integrated by school age (Blair, 2002). Whether this integration is due to very early infant relationships is open to question. Our current research focuses on emotion regulation and cognitive development and is designed to answer that question.

Research Program Integrating Cognition and Emotion Regulation

We have begun attempts at integrating the study of cognition and emotion in the first year of life by examining the development of regulatory processes in infants at 5 and 10 months of age. The groundwork for this current short-term longitudinal study came from our previous work with infants and young children in which we examined interrelations among cognition, temperament, and emotion (Bell, 2003; Wolfe & Bell, 2004). We focused on activated

emotions (i.e., emotion reactivity), rather than emotion regulation, and used those findings as an aid in conceptualizing our current focus on the developmental dynamics of cognition and emotion regulation.

In those foundation studies, we discovered that infants with better working memory performance had parents who ranked them high on duration of orienting, which was not surprising, but also high on activity level and distress to limitations, which was not hypothesized and in fact is contrary to other reports (but see Belsky, Friedman, & Hsieh, 2001). This counterintuitive finding linking these emotion traits with enhanced cognitive performance on the spatial working memory task may mean that infants with high distress to limitations and activity levels require more parental interaction than infants with lower distress and activity levels (emotions as regulated). Conceivably, then, these infants attain more parental support in the development of their attentional skills, a result that may lead to enhanced cognitive skills as the infants get older if that support from the parent is appropriate and sensitive (emotions as regulating). This proposition coincides with the developmental sequence proposed by Cole et al. (this issue) in which an infant first has limited self-regulatory capacities and then takes part in mutually regulatory exchanges with mother.

Indeed, sensitive maternal behaviors are related to regulatory behaviors in infants (Calkins & Johnson, 1998; Calkins, Smith, Gill, & Johnson, 1998) and to cognitive behaviors in young children (Stams, Juffer, & van IJzendoorn, 2002). The view that maternal sensitivity is vital for healthy psychosocial growth is incorporated into classic psychological theories and research paradigms (Thompson, 1998). Although the caregiving environment has been given an essential role in an infant's social development, not much attention has been given to the role of that same caregiving environment to the development of complex infant cognition. It may be, however, that by supporting infants in the development of attentional skill, in part to relieve infant distress (Ruff & Rothbart, 1996), caregivers are contributing to the attentional skills associated with later emotion regulation, as well as later complex cognitive processing.

In our current work we are studying the role that regulatory processes play for cognitive development in infancy. The gist of this work is that individual differences in emotion reactivity, the moderating effects of maternal regulation of infant emotion state, and the infant's regulatory processes associated with emotion and attention contribute to individual differences in cognitive processing during infancy, especially cognitive processes linked to frontal lobe functioning such as working memory. For our current study, the focus is on temperamental distress because we agree with Cole et al. (this issue) that regulation strategies are more likely when the infant is distressed. One of our hypotheses is that infants high in distress who have mothers skilled at regulating infant emotion state will have enhanced regulatory capabilities. These regulatory skills are linked to working memory performance. Thus, the moderating effect of maternal regulatory abilities influences the infant self-regulation variable, which in turn affects infant cognitive development.

According to Cole et al. (this issue), if emotion regulation is to achieve status as a scientific construct, care must be taken with the methodology used in studies in which researchers purport to examine emotion regulation either as having a regulating effect or as being regulated itself. We are using a short-term longitudinal design in which research participants and their mothers visit our research laboratory at 5 and 10 months of age. These ages allow us to observe the beginnings of emotion regulation before developmental changes in the Anterior Attention System (i.e., at baseline) and just as this attention system is beginning to show some developmental changes in the last half of the first year of life. Both behavioral and electrophysiological (EEG, ECG) data are being gathered throughout the protocol, which consists of multiple measures of infant cognition, emotion activation, emotion regulation, sustained attention, and maternal regulatory abilities. This work takes advantage of three of the four methodological tools highlighted by Cole et al. to confirm the distinction between emotion regulation and emotion.

First, there is independent assessment of activated emotion and purported emotion-regulation strategies. Under laboratory conditions, we induce distress in the infants under two conditions, first by having the mothers remove a desirable toy from reach and then by having mothers restrain their infants' arms. During the experience of these restraints, infants also experience nonresponsive, blank-face mothers. We code self-regulatory strategies (e.g., self-comforting, distraction) in the infants during each restraint task and immediately afterward during a sustained attention task (e.g., duration of looking) when distress levels are optimal.

Second, we take advantage of the temporal relations between emotion activation and emotion regulation by attempting to observe the process of regulation. We look for any differences in sustained attention before the distress-inducing restraint tasks

and immediately afterward. Changes in these measures (or the lack of changes) may yield valuable information about infants' regulatory capacities. The short-term longitudinal design of the study affords examination of developmental change with respect to initiation of regulatory behaviors aided by the contributions of neurological maturation of the Anterior Attention System.

Finally, the protocol consists of multiple converging measures. For example, there is maternal report of emotion activation as well as laboratory inducement of emotion. Emotion regulation is assessed behaviorally, as well as via electrophysiological means, during different controlled conditions. Overall, we use multiple brief cognitive measures, sustained attention and self-regulation tasks, maternal regulation measures, and restraint and distress tasks. Thus, with these multiple measures that take advantage of the temporal relations between emotions and regulatory phenomena, we propose to be able to examine the processes by which emotions may be regulated by constitutional (i.e., temperament) and maternal influences. Furthermore, we propose to be able to examine the processes by which emotions may be regulating with respect to cognition.

Conclusions

The significance of our infant project, and the complementary child project we will undertake as these participants grow and mature, lies in the new information the data will provide about the development of the foundations of working memory, a skill essential for higher order cognitive functioning. Emotion regulation research usually focuses on socio-emotional development; however, we have proposed that the neural mechanisms underlying regulatory processes may be the same as those underlying higher order cognitive processes. Cole et al. (this issue) noted that there are complex processes by which emotions relate to cognition, behavior, and ultimately developmental outcome, and that these processes need to be conceptualized and studied. We go one step further and propose that emotion-regulation research must necessarily include cognitive counterparts. To consider emotion regulation without simultaneously considering cognition gives a less than dynamic view of child development.

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