The Cognitive Neuroscience of Early Socioemotional Development

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Consideration of early socioemotional development is incomplete without concomitant examination of changes in cognition. In this chapter, we propose that developing relations between cognition and emotion must be considered in any conceptualization of socioemotional development (Bell & Wolfe, 2004; Gray, 2004; Rothbart, 2004). There has been much conceptual work proposing developing interrelations between cognition and emotion during very early childhood (e.g., Fox & Calkins, 2003; Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Posner & Rothbart, 2000), as well as the suggestion that cognition and emotion are fully integrated by school age. Cognition–emotion integration in the school-age child may be demonstrated by the many self-regulatory activities that are essential for school readiness (Blair, 2002). There is, however, little empirical data on cognition–emotion, or self-regulatory, development and what research there is tends to focus on cross-sectional samples of infants (e.g., Keenan, 2002; Lewis, Koroshegyi, Douglas, & Kampe, 1997) and preschool children (e.g., Kerr & Zelazo, 2004; Rothbart, Ellis, Rueda, & Posner, 2003). There are no longitudinal studies on emerging cognition–emotion relations across very early development, despite speculations that this integration may have its foundation in infancy and may demonstrate major development shifts during the second and third years (Bell & Wolfe, 2004; Calkins & Fox, 2002).

In this chapter, we present a developmental framework for individual dif-
ifferences in the integration of cognition and emotion. Although this “integration” has been the focus of much recent speculation in the developmental literature, the manifestation of developing cognition–emotion relations can take many forms, each of which has very different implications for child outcome. For example, emotion and influences on emotion development may have an impact on cognition and, thus, cognitive outcome. Conversely, cognition and influences on cognitive development may affect the regulation of emotion and, thus, socioemotional outcome. Finally, cognition and emotion may become increasingly reciprocal over time, with interlocking developmental trajectories demonstrating the significance of both cognition and emotion as outcome measures. The focus of our research program is on individual differences in cognitive development; thus our most current work is designed to test the first and last of these models of cognition–emotion integration (see Figure 14.1).

We consider developing cognition–emotion relations within the larger context of “self-regulation,” a construct with many definitions in the psychological literature (Baumeister & Vohs, 2004). We define self-regulation as conscious efforts to control one’s inner states or responses with respect to thoughts, emotions, attention, and performance (Vohs & Baumeister, 2004). Thus, our conceptualizations of cognition and emotion might better be described as individual differences in “cognitive control” and “emotion con-

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**FIGURE 14.1.** Two models of hypothesized cognition–emotion relations. In the top model, emotion mediates the relation between temperamentally based attentional control and cognition. In the bottom model, attentional control directly influences both emotion and cognition, with emotion and cognition being correlated. We hypothesize that cognition and emotion become increasingly correlated across development.
control.” Within our self-regulation framework, we focus on “attentional control” as the mechanism for developing cognition–emotion relations and the two models we noted previously highlight how attentional control might promote developing cognition–emotion relations.

Our emphasis on attentional control comes from both the neuropsychology and temperament literatures because conceptual efforts to integrate cognitive and emotional development may be most successful within a biologically based developmental framework. We consider the most compelling biological framework to be that of temperament-based attentional control, which is associated with the executive attention system (Rothbart, 2004). Rothbart and Bates (1998) have defined temperament as biologically based individual differences in emotional reactivity and the emergence of self-regulation of that reactivity beginning later in the first year of life, around 10 months of age (Rothbart, Derryberry, &Posner, 1994). The emergence of these early regulatory capacities is facilitated by the development of attentional control and thus may have implications for early and later cognitive development as well (Blair, 2002; Bush, Luu, & Posner, 2000; Fox, 1994; Ruff & Rothbart, 1996). Thus, we propose that attentional control is crucial to any investigation of the integration of cognition and emotion during infancy and early childhood.

In this chapter, we first examine the construct of attentional control, as we propose it is the mechanism for cognition–emotion integration. We next examine the cognitive construct of working memory and the socioemotional construct of emotion regulation because we propose that these two areas of development are linked by the attentional control mechanism. In our examinations of attentional control, working memory, and emotion regulation, we focus on the neuropsychology of each construct. After examination of those three constructs, we illustrate our own attempts at integrating cognition and emotion by highlighting our current longitudinal work with children in their second year. Of course, development is a complex process. Thus, we end by briefly noting how caregiving behaviors and child language development may be linked to attentional control and, thus, are essential components in the study of cognition and emotion. Caregiving and language are included in our hypothesized models shown in Figure 14.1.

ATTENTIONAL CONTROL

Focus on attentional control as the catalyst for developing cognition–emotion relations results from current neuropsychological research. Posner recently proposed that the executive attention system, involving prefrontal cortex and components such as the anterior cingulate cortex, regulates both cognitive and emotion processing (Bush et al., 2000). In adults, this system is characterized by effortful, controlled attentional processing to either cognitive or emotion stimuli, and in particular the anterior cingulate cortex is activated during
cognitive-attention and emotion-attention processing (Fichtenholtz et al., 2004; Yamasaki, LaBar, & McCarthy, 2002).

The functioning of the executive attention system begins to influence behavior during the later half of the first year of life (Ruff & Rothbart, 1996), a time when advances are beginning to be made in cognitive control (Diamond, Prevor, Callender, & Druin, 1997), attention control, (Rothbart et al., 1994; Ruff & Rothbart, 1996; Wilson & Gottman, 1996), and regulation of emotions (Calkins, Dedmon, Gill, Lomax, & Johnson, 2002; Ruff & Rothbart, 1996; van Bakel & Riksen-Walraven, 2004). Major advances in the development of the executive attention system continue throughout early childhood (Posner & Rothbart, 2000; Rothbart, Ellis, & Posner, 2004), a time when dramatic increases are seen in both cognitive and emotional control (Diamond et al., 1997; Kochanska, Murray, & Harlan, 2000). Because the executive attention system focuses on the emotion-attention and cognitive-attention functions of the frontal cortex, this may be the functional system that has the ability to connect cognitive and emotion development (Bell & Wolfe, 2004; Calkins & Fox, 2002; Fox et al., 2005).

As noted, the executive attention system has a long developmental period and begins to show some developmental changes in the last half of the first year of life (around 10 months of age), with major development occurring during toddlerhood (Derryberry & Rothbart, 1997; Rothbart et al., 1994; Rueda, Posner, & Rothbart, 2004). The executive attention system integrates thought and behavior and exerts control on emotional experience and expression. This has led to speculation that regulation is driven not only by positive/ negative affect but also at the cognitive level. Rothbart has hypothesized that high attentional control is associated with low negative affect (Rothbart et al., 1994). Indeed, Rothbart's model of the development of temperament describes the process by which infants regulate distress using developing attentional abilities (Posner & Rothbart, 2000; Rothbart et al., 1994). Because of the beginnings of development of the executive attention system in the first year of life, infants who react strongly to events may initially be irritable but later develop the ability for sustained attention (Ruff & Rothbart, 1996). Thus, in Rothbart's model, the development of controlled attentional abilities precedes developing cognitive control, although to our knowledge this has not been empirically tested.

Attentional control associated with executive attention system develops rapidly during the toddler and preschool years and underlies what Rothbart calls "effortful control" (Rothbart & Bates, 1998; Rothbart et al., 2003). Effortful control focuses on the voluntary deployment of executive attention and involves the ability to withhold a dominant response in order to perform a nondominant response (inhibitory control), to detect errors, and to engage in planning. Longitudinal and cross-sectional studies demonstrate beginning advancements in voluntary deployment of executive attention around 30 months of age (Gerardi-Caulton, 2000; Kochanska et al., 2000; Rothbart et al., 2003), with stability across various episodes by 4 years of age (Kochanska
Knaach, 2003). Our most current longitudinal work still in progress suggests that some children demonstrate executive attention by 24 months of age. Thus, controlled attentional abilities associated with the executive attention system demonstrate initial development at the end of the first postnatal year and progress on to rapid development during the second year.

Neuropsychology of Attentional Control

Although most of the work on the executive attention system and attentional control in infants and young children has focused on behavioral measures, heart rate (HR) has long been used to measure attention in infants and young children (e.g., Richards & Casey, 1992). During stimulus orienting, there is a large deceleration in HR associated with the orienting reflex. Following this is a period of sustained attention involving voluntary, subject-controlled information processing during which HR remains at a lower level and the variability in the HR is decreased (Richards, 2004; Richards & Casey, 1992). During sustained attention, infants and young children cannot be distracted from a central stimulus with a peripheral stimulus. Richards has speculated that the neural control of HR change associated with sustained attention originates from a cardioinhibitory center located in the frontal cortex (Richards & Hunter, 1998). Colombo suggests that processing during sustained attention might be similar to attentional processing associated with the executive attention system (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001). Thus, Colombo proposes that infants who exhibit longer periods of lowered HR (and concomitant longer periods of look duration) during visual attention tasks might do so because of better attentional control abilities. Richards has suggested that the same may be true in early childhood (Richards & Cronise, 2000).

Recent electrocortical work has indicated that the anterior cingulate cortex may indeed be associated with this HR-defined effortful, controlled attention during infancy. Using high-density electroencephalogram (EEG) recordings with infants, Richards (2004) has provided estimations of cortical sources of brain wave activity during HR-defined sustained attention. This source localization work implicates prefrontal cortex, including anterior cingulate. Recent functional magnetic resonance imaging (fMRI) work with adults also has highlighted anterior cingulate cortex in regulation of HR during effortful cognitive processing (Critchley et al., 2003; Luu & Posner, 2003). Thus, functioning of the anterior cingulate cortex may be manifested neuro-psychologically in the HR response.

Recently, Posner and colleagues (Bush et al., 2000) have proposed that the attentional skills associated with the executive attention system and anterior cingulate serve to regulate both cognitive and emotional processing. Traditionally, the anterior cingulate has been viewed as having two major subdivisions to separately process 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 emotion subdivision has interconnections with the orbitofrontal cortex, amygdala, and hippocampus, among other brain areas. This subdivision is activated by affect-related tasks, such as the emotional Stroop (Bush et al., 2000) and the classic odd-ball task using aversive photos that vary in emotional valence (Fichtenholtz et al., 2004). It appears that there is suppression of the affective subdivision during cognitive processing and likewise with 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 anterior cingulate, 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. We propose that working memory and emotion regulation tasks can be used to investigate the development of these processes during infancy and early childhood.

WORKING MEMORY

The construct of working memory (Baddeley, 1986, 2000) has been the focus of a great deal of attention in the adult cognitive literature, and with good reason. Working memory is an essential component for everyday adult cognition because it underlies higher-order cognitive processes such as reasoning, planning, cognitive control, problem solving, and decision making (Logie, 1993). Working memory is needed when relating multiple pieces of information held in one's mind to each other or when inhibiting an interfering response while keeping information in one's mind (Diamond et al., 1997). Importantly, individual difference measures of working memory in adulthood are predictive of language comprehension, learning, and fluid intelligence (see Kane & Engle, 2002, for a review). Much less attention has been given to the development of working memory. Knowledge of the development of working memory is crucial, however. In a recent study of 7-year-old children, working memory was associated with English and mathematics achievement in school. Likewise, children with poor working memory performance at age 5 scored poorly on reading assessments at age 8 (Gathercole, Tiffany, Brisco, & Thorn, 2005). Clearly, there is a need to examine the development of this cognitive construct from its earliest origins and include in this examination possible contributors to individual differences in the development of working memory.

Our current research includes a longitudinal study that is unique in that it is the first to examine the development of working memory, and individual differences associated with that development, across the developmental time periods of infancy and early childhood. The only infancy-to-childhood study
of the development of working memory of which we know is reported by Diamond and colleagues (1997). That project, however, had three groups of research participants—infants, toddlers, preschoolers—with short-term longitudinal methodology within each age grouping. Age-appropriate working memory tasks were used with each group. Thus, infants (6–12 months of age) performed the A-not-B task; toddlers (15–30 months of age) did A-not-B with invisible displacement; preschoolers (3½–7 years of age) did the day-night Stroop-like task. Within each age grouping, increases in performance were noted across age. That is, striking age-related performance with each developmental period was reported, but no across-development period assessments were made. We have argued that within-subjects studies are essential for the examination of individual differences in working memory performance because individual differences in the efficiency of brain functioning affect cognitive outcome (Bell & Adams, 1999). Our current longitudinal work provides that within-subjects data across infancy and early childhood. We highlight our protocol for the toddler assessment in a later section of this chapter.

Neuropsychology of Working Memory

Within the last decade there has been increasing focus on frontal lobe processing associated with working memory during infancy and childhood (e.g., Bell, 2001; Casey et al., 1995; Diamond et al., 1997; Roberts & Pennington, 1996). Developmental neuroscience research has demonstrated that individual differences in EEG activity recorded from frontal scalp locations are associated with performance on working memory tasks during both infancy and early childhood. We have reported that at 8 months of age, only infants with high performance on an infant working memory task (looking A-not-B) exhibit changes in frontal EEG power values from baseline to task; infants with low performance show no change in EEG from baseline to task (Bell, 2001, 2002, 2006). Changes in EEG activity from baseline to task are assumed to be indicative of changes in cortical functioning associated with task performance (Pivik et al., 1993). We have reported similar findings with 4½-year-old children; that is, children with high performance on a preschool working memory task (day–night Stroop) exhibit higher overall (baseline and task) EEG power values at the frontal regions than children with low performance on the same task (Wolfe & Bell, 2004). This focus on frontal activity is in agreement with Engle's model of working memory that has attentional control as the source of individual differences in working memory performance.

Working Memory and Attentional Control

In our research program, we focus on the construct of working memory as developed by Engle and colleagues (Engle, Kane, & Tuholski, 1999; Kane & Engle, 2002). Engle defines working memory as a system consisting of those highly activated long-term memory traces that are active above threshold as
short-term memory representational components in the prefrontal cortex. Included in this characterization of working memory are the procedures and skills necessary to achieve and maintain that activation, as well as a limited-capacity, domain-free controlled attention component. This executive attention component is perhaps the most intriguing part of Engle's conceptualization of working memory because it is noted by Engle to be comparable to the construct of executive attention described by Posner's executive attention system (Engle et al., 1999).

The attentional capacity highlighted by Engle and colleagues is the capability of maintaining short-term memory representations in the presence of interference or response competition. Without this interference, information, goals, and response plans are easily retrieved from long-term memory. In the face of interference, however, it is likely that incorrect information and inaccurate responses are retrieved (Kane & Engle, 2002). Thus, this executive attention component is not needed for all cognitive processing but is called into action in circumstances that require inhibition of prepotent responses, error monitoring and correction, and decision making and planning (Engle et al., 1999). As would be expected, this domain-free executive attention ability can be used to predict performance on tasks requiring cognitive control, such as working memory and inhibitory control tasks (Kane & Engle, 2002).

It is precisely the predictive ability of attention that is the focus of Engle's research. Individual differences in executive attention, called "working memory capacity" by Engle and colleagues (Engle et al., 1999; Kane & Engle, 2002), are associated with a wide variety of cognitive abilities, including general fluid intelligence (Engle et al., 1999). We should emphasize that individual differences in executive attention are revealed only in situations that encourage or require controlled attention. Thus, the individual differences perspective in Engle's model reflects the ability of the individual to apply activation to short-term memory representations, to bring these representations into focus and to maintain them, and to do so in the face of interference or distraction (Engle et al., 1999; Kane & Engle, 2002). This suggests that individuals high in this controlled attention ability are more effective at blocking distracting, task-irrelevant information and maintaining a focus on pertinent information than individuals low in attention. Indeed, individuals ranked low on this attentional ability are more likely to break focus and orient to an irrelevant, attention-capturing external cue (Unsworth, Schrock, & Engle, 2004).

Based on human and nonhuman primate literatures, Engle has hypothesized that individual differences in attentional control (i.e., working memory capacity) are associated with individual differences in the functioning of the prefrontal cortex (Engle et al., 1999; Kane & Engle, 2002). Engle asserts that his model is appropriate for research with children (Engle et al., 1999). Indeed, we use Engle's model of working memory because it includes the processes associated with controlled attention, such as inhibitory control of prepotent responses, specifies the role of the prefrontal cortex in the process of working memory, and allows for individual differences in working memory.
based on both the capacity for controlled attention and differences in prefrontal functioning. Researchers have begun to demonstrate some associations between attentional control characteristics and cognitive tasks involving working memory and inhibitory control in preschool children (Davis, Bruce, & Gunnar, 2002; Gerardi-Caulton, 2000; Wolfe & Bell, 2004). Researchers also have begun to demonstrate associations among these frontal lobe, executive function tasks and emotion-related aspects of self-regulation (Davis et al., 2002; Wolfe & Bell, 2004). It is the emotion-related aspects of self-regulation to which we now turn.

EMOTION REGULATION

Just as attentional control and working memory display dramatic developments during infancy and early childhood, so does emotion regulation (Calkins, 2004; Eisenberg, Smith, Sadovsky, & Spinrad, 2004; Kopp & Neufeld, 2003). Developmental changes in emotion regulation are demonstrated as the infant progresses from almost total dependence on caregivers for regulation of emotion state to independent self-regulation of emotions (Calkins, 2004). According to Kopp (1982, 1989; Kopp & Neufeld, 2003), early emotion regulation is influenced mainly by innate physiological mechanisms. Beginning around 3 months of age, some voluntary control of arousal is evident, with more purposeful control evident by 12 months, when developing motor skills and communication behaviors allow for interactions with caregivers. During the second year, infants begin to utilize language skills and increasing impulse control (Kopp, 1982, 1989), thus making the transition from passive to active methods of emotion regulation (Calkins, 2004). Kopp (1989) considers this emotion self-control to fully emerge between ages 3 and 4 years of age. Rothbart has suggested that the changes in self-control occurring between ages 3 and 4 years are related to executive attention system (Rothbart et al., 2004).

Part of executive attention is the dimension of temperament known as effortful control, which Rothbart has defined as the ability to inhibit a dominant response in order to perform a subdominant response (Rothbart & Bates, 1998). Regulatory aspects of temperament typically are viewed as driven by individual differences in arousal and emotional reactivity (Rothbart et al., 2004). Effortful control, however, represents a behavioral system emerging in the second year that allows for voluntary control of arousal and emotion. Rothbart and colleagues (1994) have posited that the development of executive attention might underlie the effortful control of emotion. The developmental literature supports that association (Kochanska et al., 2000; Kochanska & Knaach, 2003).

Eisenberg's concept of emotion-related regulation (Eisenberg, Spinrad, & Smith, 2004) is similar to Rothbart's temperament construct of effortful control in its focus on voluntary control of emotion. Emotion-related regulation
appears to also be strongly associated with attentional control and this type of regulation can occur prior, during, or after the elicitation of emotion.

Although there appears to be convergence among the emotion regulatory constructs highlighted by Rothbart, Eisenberg, Kopp, and Calkins in the preceding paragraphs, this appears not to be the case throughout the developmental literature. Recently, Cole, Martin, and Dennis (2004) discussed the lack of specificity in the developmental literature regarding the construct of emotion regulation. Such varied behaviors have been labeled as emotion regulation that many researchers have questioned the utility of the construct. In a paper that argued for the scientific utility of this developmental process, Cole and colleagues proposed a very specific definition of emotion regulation. To be specific, the term emotion regulation refers to two types of regulatory processes (Cole et al., 2004). Emotions can organize a child’s thinking, learning, and action; in other words, outcomes related to activation of an emotion can be affected (“emotions as regulating”). Likewise, thinking, learning, and action can modify emotions; in other words, these factors can cause changes in an emotion (“emotions as regulated”). Thus, from Cole’s point of view, emotion regulation can only be examined during an emotion experience, unlike Eisenberg’s notion of emotion-related regulation which also can be examined prior and after emotion elicitation. Although the Cole definition of emotion regulation incorporates cognition–emotion interactions, there is less emphasis on self-conscious, voluntary regulation of emotion.

Neuropsychology of Emotion Regulation

Similar to research on individual differences in working memory task performance, work focusing on emotions and emotional regulation has demonstrated individual differences in frontal EEG activity. Developmental evidence seems to suggest that electrophysiological differences in emotion regulation 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 EEG activation during rest (Bell & Fox, 1994; Davidson & Fox, 1989; Fox, Calkins, & Bell, 1994; Fox & Davidson, 1987). 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 emotional regulation and EEG activation persist throughout the preschool years (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001) and into middle childhood and beyond (Schmidt, Fox, Schulkin, & Gold, 1999). 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 emotion regulation. Fox (1994) proposes both cortical and subcortical influences on these brain electrical patterns. Thus, different levels of regulatory ability may be associated with frontal lobe activation asymmetries.
Measures of heart rate variability (HRV) and its variations of respiratory sinus arrhythmia and vagal tone have been linked to emotional reactivity and regulation. Infants with higher HRV are more emotionally expressive and reactive (Calkins et al., 2002; Porges, Doussard-Roosevelt, & Maiti, 1994; Stifter & Fox, 1990; Stifter, Spinrad, & Braungart-Ricker, 1999). This reactivity produces distress and irritability. As regulatory abilities develop, due to development of the executive attention system, the reactivity can lead to concentration when interest is paramount or to more expressive reactivity when other situations take precedence (Porges et al., 1994; Ruff & Rothbart, 1996). The suppression of HRV may be associated with coping behaviors involving attentional control during both infancy and early childhood (Bar-Haim, Fox, VanMeenen, & Marshall, 2004; Rothbart, Posner, & Boylan, 1990). Thus, individual differences in attention and the regulation of emotion may be mediated by autonomic activity (Ruff & Rothbart, 1996).

**Emotion Regulation and Attentional Control**

As previously noted, much of the neuropsychological work examining emotion regulation has conceptually linked developing regulatory abilities with development of the executive attention system. Ruff and Rothbart (1996) consider attention part of the larger construct of self-regulation, with individual differences in attention impacting the degree of success in the development of self-regulation. Developmentalists have followed suit by examining emotion regulation as a correlate of effortful control (e.g., Calkins & Fox, 2002), a special class of voluntary regulatory processes that develop with maturation of attentional mechanisms (Posner & Rothbart, 2000; Rothbart & Bates, 1998). Thus, in the developmental literature, regulation and attentional control are intricately linked.

**RESEARCH ON CONNECTIONS BETWEEN COGNITION AND EMOTION**

Our most current research is based on the general hypothesis that attentional control is critical in defining the developmental trajectories of both working memory and emotion regulation during infancy and early childhood. Specifically, we are testing the two models noted at the beginning of this chapter. Thus, one hypothesis is that emotion regulation mediates the relation between temperamentally-based attentional control and working memory (see Figure 14.1 top). The alternate hypothesis is that attentional control directly influences both emotion regulation and working memory and that emotion regulation and working memory become increasingly correlated with development (see Figure 14.1 bottom). We are testing these hypotheses with a longitudinal protocol that has assessments at 5 months, 10 months and 2, 3, and 4 years of age. Our previous longitudinal work incorporated assessments at 8 months.
and 4⅓ years (Wolfe & Bell, in press) and did not allow us to track the many changes that occur in working memory, emotion regulation, and attentional control with early development (e.g., Diamond et al., 1997). We are currently focusing on the 2-year data collection point for a cohort of 106 infants and parents who were recruited from nearby communities. All of the children were healthy, full-term newborns. The average age of the parents at the child’s birth was 30 for the mothers and 33 for the fathers, with no teenage parents in the sample. All parents have at least a high school diploma, and 78% of the mothers and 74% of the fathers have a college degree. Matching census data for the local geographic area, 89% of the children are Caucasian.

One of the greatest challenges in incorporating a 2-year assessment into our longitudinal protocol—aside from skillfully negotiating the application of the EEG and HR electrodes—involves administering tasks that are comparable to the infant tasks already experienced in the longitudinal investigation (i.e., tap the same cognitive, attention, and emotion skills of interest) and that the children understand and attempt. Because our longitudinal study will continue on to the preschool years, it also is crucial that these tasks likewise provide a smooth transition from our infant tasks to our preschool tasks. This section of the chapter highlights some of the ways in which we are measuring working memory, emotion regulation, and attentional control in our toddler sample at age 2 years. We are still in the midst of data collection, but we report some very preliminary behavioral findings on the 83 children we have seen thus far at the age two assessment. Although we do not report any EEG and HR data here, we do record EEG and HR during the working memory and attentional control tasks. We utilize emotion regulation tasks that allow the child the freedom to move about the room; thus, electrophysiological recordings are not available for emotion regulation.

**Working Memory**

As previously mentioned, our research focuses on the construct of working memory that includes controlled attention (Diamond, 2002; Engle et al., 1999; Kane & Engle, 2002). In all our infant work, we (Bell, 2001, 2002, 2005; Bell & Adams, 1999) have examined this working memory process with the A-not-B task (Diamond et al., 1997). Likewise, we have examined these cognitive skills in our previous preschool samples (ages 3½–4½ years) with age-appropriate working memory tasks (Wolfe & Bell, 2004), such as the Stroop-like day–night task (Diamond et al., 1997; Gerstadt, Hong, & Diamond, 1994), the tapping task (Diamond et al., 1997; Diamond & Taylor, 1996), the yes–no task (Wolfe & Bell, 2004), and the dimensional change card sort task (DCCS; Zelazo, Muller, Frye, & Marcovitch, 2003). All these tasks, however, are inappropriate for use with toddlers in their standard forms because they require language skills that are too advanced for most 2-year-old children. Thus, according to the developmental literature, the A-not-B task for infants is considered too easy for toddlers (although see Espy, Kaufmann,
McDiarmid, & Glisky, 1999), and the day–night types of tasks are too difficult for the 2- and 3-year-old age groups (see Diamond & Taylor, 1996; Gerstadt et al., 1994).

In our current research with 2-year-old children, we are utilizing a version of the A-not-B task that is appropriate for toddlers. As the child sits in a high chair and watches, we administer a version of this classic hiding task that incorporates elements of the invisible displacement strategy demonstrated by Diamond with toddlers (Diamond et al., 1997) and the A-not-B procedure used by Espy with preschoolers (Espy et al., 1999). First, we hide a ball under a colorful cup and move the cup to one side of the table. Next, we use a white screen to occlude the toddler’s sight of the table while placing an empty cup of the same color as the hiding cup on the other side of the table. During the placement of the screen we count a 5-second delay period out loud. We do this to increase the working memory time load requirement (Pelphrey et al., 2004) and add an inference component. After the delay is counted, the screen is lifted, revealing the two cups, and the child is asked to look or point to the ball’s location. Each child receives an initial trial with only the cup covering the ball in order to ensure that the gist of the task is understood and then the child receives a series of test trials with both cups where the ball is hidden twice on the same side before being hidden on the reverse side. As can be seen in Table 14.1, we are seeing a wide range of individual differences in performance on the A-not-B working memory task. This gives us confidence that this version of the task is age appropriate. For the preliminary analyses re-

<table>
<thead>
<tr>
<th>Task</th>
<th>Behavior (“best performance”)</th>
<th>% of children</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-not-B</td>
<td>1. No success on same-side trials with 4-second delay</td>
<td>7%</td>
</tr>
<tr>
<td>working memory</td>
<td>2. Success on one same-side trial with 4-second delay</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>3. Success on two same-side trials with 4-second delay</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>4. Success on same-side and reversal trials with 4-second delay</td>
<td>28%</td>
</tr>
<tr>
<td>Mommy/me</td>
<td>1. Refusal to participate</td>
<td>23%</td>
</tr>
<tr>
<td>working memory</td>
<td>2. Success on naming control trials only</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>3. Success on teaching trials only</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>4. Success on test trials 1 and 2 (but not 3 and 4)</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>5. Success on test trials 1 through 4</td>
<td>1%</td>
</tr>
<tr>
<td>Crayon delay</td>
<td>1. Colored on paper</td>
<td>42%</td>
</tr>
<tr>
<td>regulation</td>
<td>2. Dumped out crayons</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>3. Picked up crayon box</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>4. Touched crayon box</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>5. Touched paper only</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>6. Did not touch crayons or paper</td>
<td>21%</td>
</tr>
</tbody>
</table>
ported below, performance on the A-not-B task is scored as percentage of correct responses.

We also utilize the Mommy/me task, a working memory task that is comparable to the preschool day–night task (Diamond et al., 1997; Gerstadt et al., 1994) and yes–no task (Wolfe & Bell, 2004). This is a task we created to use with 2-year-old children. Diamond and colleagues have stated that the day–night Stroop-like task is too difficult for 3-year-olds (Gerstadt et al., 1994). We reasoned that photos of mother and self might be more interesting for younger children than drawings of a sun and a moon, as used in the day–night task. This increased interest might allow us to assess working memory performance in the day–night Stroop-like manner. Specifically, in the Mommy/me task, a child is instructed to say “Mommy” to a Polaroid picture of herself and to say her own name to a Polaroid picture of her mother. Thus, like the day–night and yes–no tasks, the child is required to remember two rules and to inhibit a dominant response. As the child sits in a high chair, the experimenter first asks the child to name the individuals in the photos as a check to determine what name the child uses for her mother and for herself (naming control trials). Then the experimenter explains the rules of the “silly backwards game” and assesses the child’s understanding by prompting her to say “Mommy” to her own photo and her name to the picture of her mother (teaching trials). Then the experimenter administers four trials without prompts (test trials). Again, as can be seen in Table 14.1, we are seeing a wide range of individual differences in performance on the Mommy/me working memory task, including of course many 2-year-old children who refuse to participate. This allows us to use the Mommy/me task as a “baseline” working memory assessment to examine trajectories of development in working memory performance at ages 3 and 4 years.

**Emotion Regulation**

During the infant portion of our longitudinal study, we employed the toy removal and arm restraint (Calkins et al., 2002) procedures to elicit distress/frustration and subsequent emotion regulation behaviors in the infants. To measure frustration and regulation in toddlers, we are using the difficult puzzle task (Smith, Calkins, Kean, Anastopoulos, & Shelton, 2004). Mothers are asked to work with their children on a set of three puzzles of increasing difficulty with respect to number of pieces (8 pieces, 12 pieces, 26 pieces). After mother and child work together on the first two easier puzzles, the experimenter requests that the child complete the final puzzle in her own while mother reads a magazine. Attached to the magazine is a note instructing mother to ignore her child’s bids for help on the puzzle. Although we have not yet begun to code the behaviors on this task, anecdotally we have seen a wide range of frustration and regulation on this task. This has ranged from quiet determination to complete the puzzle by oneself to yelling and shoving the puzzle off the table.
We also are using the crayon delay task to measure regulation with our 2-year-old children. Typically used as an assessment of self-regulation or inhibitory control (e.g., the phone task in Vaughn, Kopp, & Krakow, 1984), rather than of emotion regulation, delay tasks offer an opportunity to capture regulatory abilities in a relatively low-stress situation. In this task, the experimenter places a newly opened box of crayons on the table along with a blank sheet of paper. As the experimenter places these items in front of the child, she tells the child that the child is going to draw a picture with the new crayons. However, before the child touches the crayons the experimenter tells the child that she has to leave the room to gather the things for the last game they will play together. The experimenter instructs the child to not touch the crayons until she returns to the room. The child's behavior is coded for level of regulation (i.e., no touch, touches paper, touches box, touches crayons, picks up crayon, and colors) during this taxing task, along with latency to touch the crayons. The experimenter returns after 60 seconds. As shown in Table 14.1, there is a wide range of behaviors on this delay task, as 21% of the children thus far have waited and not touched the crayons and 42% have colored on the paper. The remaining children touched only the paper, touched the crayons, picked up the crayon box, or dumped out the crayons. In the preliminary analyses reported below, the crayon delay latency is the time in seconds at which the child touched the crayons, with no touching scored as 60 seconds.

Perhaps our best measure of emotion regulation with this 2-year protocol is taken during the EEG and HR electrode application. Simply, we code whether or not the child accepts or rejects the electrodes. Other psychophysiological researchers who work with children have noted this procedure (Stifter et al., 1999). This measure of emotion regulation is particularly valuable in that it takes place in a stressful situation for the child—the EEG cap is a novel experience and arguably a stressful one for most 2-year-olds. Rodriguez and colleagues (2003) suggest that behaviors in a high-stress situation are more reflective of the child's regulatory abilities compared to a low stress situation. Very preliminary analyses of our current work, dividing the toddlers into two groups based on their willingness to wear the EEG and HR electrodes (approximately 73% of the children are accepting the EEG cap for the recording session), is indicating that accepting the electrodes is associated with inhibitory control abilities as measured by our warmup task pig–bull, modeled after the classic Simon-says task (Carlson, 2005). We will compare inhibitory or regulatory behaviors on the crayon delay and electrode acceptance tasks to behaviors on our third emotion regulation procedure which involves the difficult puzzle. This puzzle procedure also allows for possible coding of maternal interactive style during a task that is frustrating for the child (Calkins et al., 2002).

As a final indicator of regulatory abilities, mothers are completing the Early Childhood Behavior Questionnaire (ECBQ; Putnam, Garstein, & Rothbart, 2006) at home prior to the lab visit. In the preliminary analyses we report next, we focus on the Inhibitory Control and Impulsivity scales of this temper-
ament measure. Children who score high in Inhibitory Control are rated by their mothers as having the capacity to stop, moderate, or refrain from a behavior under instruction. Children who score high on Impulsivity are rated by their mothers as quickly initiating responses.

**Attentional Control**

Finally, we used a brief video to assess attentional control when the children in our sample were infants, but we quickly discovered that we need to employ a video to assist us during EEG and HR electrode application with the 2-year-old children. Thus, we are using a moving, novel toy for our attentional control assessment and we are coding for voluntary sustained attention to the toy. The experimenter hands the child the toy and instructs the child to hold and look at the toy without talking. The child has the toy for a maximum of 120 seconds and we code how long the child attends to the toy before discarding it or attending to other things in the room. We have just begun the coding of this task and are noting that all children will comply to the “sit and look without talking” instructions for a period of time, which appears to range from about 30 seconds to 120 seconds. After that, children typically will talk to mother about the toy, shove the toy off the table, or continue to physically orient to the toy but shift eye gaze to a nearby location. The children who shift eye gaze are especially intriguing, as it is our initial interpretation that they are attempting to comply with the experimenter’s instructions but simply lose interest in the toy. Thus, we are coding not only the length attentional control but also behavior when attention to the novel toy ends. It may be that children who attempt to comply by shifting eye gaze may also be the children who exhibit more efficient strategies on our on our emotion regulation tasks.

We are utilizing two attentional scales from the ECBQ. Children who score high in attentional focus are rated by their mothers as being capable of sustained duration of orienting on an object of attention and as being capable of resisting distraction. Children who score high in attentional shifting are rated by their mothers as having the ability to transfer attentional focus from one activity or task to another.

**Preliminary Findings**

We are unable to test our hypotheses until all visits are complete and all coding is finalized, but we can examine relations among some of the variables of interest. Initial correlations among the A-not-B working memory task, the crayon delay regulatory task, and four ECBQ scales are shown in Table 14.2. We examined one-tailed correlations because we hypothesized the direction of the relations between the variables of interest. As expected, the crayon delay task is related to the ECBQ Inhibitory Control scale. Children with better compliance on the task (i.e., longer latency to touch) are rated by their mothers as higher on inhibitory control.
TABLE 14.2. Correlations between Cognitive and Emotion Regulatory-Type Measures

<table>
<thead>
<tr>
<th></th>
<th>A-not-B % correct</th>
<th>Crayon delay latency to touch</th>
<th>ECBQ attention focusing</th>
<th>ECBQ attention shifting</th>
<th>ECBQ impulsivity</th>
<th>ECBQ inhibitory control</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-not-B % correct</td>
<td>—</td>
<td>.16*</td>
<td>—</td>
<td>-26*</td>
<td>.24*</td>
<td></td>
</tr>
<tr>
<td>Crayon delay latency to touch</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td>.27**</td>
<td></td>
</tr>
<tr>
<td>ECBQ attention focusing</td>
<td>—</td>
<td>.37***</td>
<td>-18*</td>
<td></td>
<td>.29**</td>
<td></td>
</tr>
<tr>
<td>ECBQ attention shifting</td>
<td>—</td>
<td></td>
<td></td>
<td>.46***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECBQ impulsivity</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td>-25*</td>
<td></td>
</tr>
<tr>
<td>ECBQ inhibitory control</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. One-tailed tests.

*p < .10; *p < .05; **p < .01; ***p < .001.

Performance on the A-not-B working memory task is related to performance on crayon delay and to ECBQ scales. Higher performance on A-not-B is associated with better compliance on crayon delay (i.e., longer latency to touch). The association between working memory and regulation is also seen with respect to the ECBQ scales. Higher performance on A-not-B is associated with lower impulsivity and high inhibitory control as rated by mother (see also Lee, Vaughn, & Kopp, 1983, for similar findings).

FUTURE DIRECTIONS

Many other factors in the developmental literature have been linked to individual differences in early outcome. Two factors in particular have major implications for the constructs of interest in our longitudinal research: maternal interactive style and child language. We briefly note how each factor may be associated with working memory, emotional regulation, and attentional control. Thus, the inclusion of maternal interactive style and child language would be of great benefit in the study of developing cognition–emotion relations in early development.
Maternal Interactive Style

Maternal interactive style has been shown to be related to emotion regulatory behaviors in infants and young children (Calkins, 2004; Calkins, Hungerford, & Dedmon, 2004; Calkins & Johnson, 1998; Diener, Mangelsdorf, McHale, & Frosch, 2002; Rodriguez et al., 2005), as well as to cognitive behaviors in early development (Landry, Smith, & Swank, 2003; Stams, Juffer, & van Ijzendoorn, 2002). The view that nurturing and supportive maternal responses is vital for healthy psychosocial growth is incorporated into classic psychological theories. Although the environment, and specifically the caregiving environment, has been given such an essential role in early social development (Fox et al., 2005), not much attention has been given to the role of that same caregiving environment to the development of complex cognition. In the work that has been done, the focus has been on the effects of maternal behaviors on recognition memory (Miceli, Whiteman, Borkowski, Braungart-Rieker, & Mitchell, 1998). No work has examined the effect of caregiving on the development of attentional control or on working memory.

Colombo and Saxon (2002) have proposed, however, that infant cognitive status (e.g., length of attention or ability to remember over a length of time) interacts with some aspect of caregiver interaction across development. Over time, these interactive processes influence the child’s cognitive outcome. Similarly, it may be that by supporting infants in the development of attentional skill, in part to relieve early infant distress (Ruff & Rothbart, 1996), caregivers are contributing to the attentional skills associated with later cognitive processing dependent on attentional control, such as working memory. This parent–child interaction may manifest itself differently in early childhood, when the relief of child frustration is paramount to a parent’s interactions with young children (Calkins et al., 2002, 2004; Kopp, 1989, 1992). These parent–child interactions may likewise be associated with later cognitive processing in that they allow the child to develop self-regulatory skills essential before cognitions requiring cognitive control can occur. Thus, maternal behavior may also be essential for cognition, although how this is manifested across the infancy to early childhood time periods has not been investigated.

Child Language

It has been suggested that the development of language, along with the continued development of the frontal cortex, may underlie early childhood advances in voluntary control of behavior and action (Ruff & Rothbart, 1996). An association between language and self-regulatory aspects of development, especially those that involve attentional control, has been reported (Kaler & Kopp, 1990). It is this capacity of language to assist with regulatory aspects of development, especially those involving attentional control (Kopp, 1989), that
make language a likely correlate of not only emotion development but cognitive development as well.

Developmental research indicates that there is an association between memory and language. Recognition memory scores during infancy are correlated with language comprehension and expression at ages 2½, 3, and 4 years (Rose, Feldman, Wallace, & Cohen, 1991). In children at 3 and 4 years of age, those with high working memory abilities produce more complex spoken language than children with low working memory abilities (Wolfe & Bell, 2004). Thus, language skills appear to contribute to the developmental trajectories of both cognition and emotion.

We did ask the mothers of our 2-year-olds to complete the MacArthur-Bates Communicative Development Inventory. This checklist is used to document the child's production of spoken words and analyze early phases of grammar, specifically the complexity of the child’s multiword utterances. We hypothesized that children with more total spoken words would be rated by their mothers as having less impulsivity and greater inhibitory control. We also hypothesized these children would have greater attentional focusing and attentional shifting. Thus far our hypotheses are supported, except those concerning impulsivity (see Table 14.3). We have similar hypotheses with respect to the complexity of utterances and the Mean length of the utterances (MLU), with similar results (see Table 14.3).

**FINAL REMARKS**

We have proposed that the examination of early socioemotional development is incomplete without simultaneous consideration of changes in cognition. In this chapter, we have proposed that the investigation of associations between cognition and emotion is essential to any conceptualization of development and have illustrated our supposition with the examples of working memory and emotion regulation, with attentional control as the integrative mechanism.

<table>
<thead>
<tr>
<th></th>
<th>ECBQ attention focusing</th>
<th>ECBQ attention shifting</th>
<th>ECBQ impulsivity</th>
<th>ECBQ inhibitory control</th>
</tr>
</thead>
<tbody>
<tr>
<td>McArthur–Bates complex words</td>
<td>.40***</td>
<td>.41***</td>
<td>—</td>
<td>.41***</td>
</tr>
<tr>
<td>McArthur–Bates total words</td>
<td>.33**</td>
<td>.42***</td>
<td>—</td>
<td>.45***</td>
</tr>
<tr>
<td>McArthur–Bates mean length utterance</td>
<td>.30**</td>
<td>.39***</td>
<td>—</td>
<td>.32**</td>
</tr>
</tbody>
</table>

*Note. One-tailed tests.
*<i>p < .05</i>; **<i>p < .01</i>; ***<i>p < .001</i>.
for these two constructs. We also summarized our current work with 2-year-old children and highlighted very preliminary data on cognition–emotion relations. These data represent the third wave of a five-wave longitudinal study examining the interrelations between cognition and emotion across infancy and early childhood.

The examination of working memory and emotion regulation in infants and toddlers is valuable in understanding the early developmental trajectories of these important psychological constructs. In school-age children, working memory performance is associated with school achievement, including reading and math. Emotion regulation is essential for appropriate and adaptive social behavior. Because of these critical outcomes, there is a need to track the development of these cognitive and emotion processes from their early origins and include in this examination their integration across development.

REFERENCES


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