It is traditional in developmental science to use research protocols focused on narrow aspects of development, such as specific social or perceptual processes. This narrow focus allows the research team some level of control in scientific investigations of a process as richly complex as development. Recently, however, there has been growing acknowledgment that this approach results in a fractionated consideration of development (Rothbart, 2004), accompanied by a growing number of conceptual attempts to view development through a more integrative lens. Perhaps the integrative attempt that has drawn the most interest in the developmental literature is one that combines cognitive and emotion processes (e.g., Bell & Wolfe, 2004; Calkins & Fox, 2002; Sokol & Muller, 2007).
The focus of this volume is on the integration of cognition and emotion during development, and our emphasis in this chapter is on early development. Much conceptual work has suggested that the integrative process associated with cognition and emotion may have its foundations in infancy and may demonstrate major developmental shifts during the 2nd and 3rd years (Bell & Deater-Deckard, 2007; Bell & Wolfe, 2004; Calkins & Fox, 2002; Rothbart, Sheese, & Posner, 2007). Within the developmental field there is the hypothesis that cognitive and emotion processes begin as separate developmental phenomena and become increasingly linked over time, possibly fully integrated by the end of early childhood (Blair, 2002). Empirical data demonstrate this integration with respect to school-related skills (Blair & Razza, 2007).

Expanding knowledge of neuroscience and brain–behavior relations (Sokol & Mueller, 2007) has enhanced the ability to discuss potential mechanisms that may be responsible for interactions between cognitive and emotion processes throughout development (Bell & Deater-Deckard, 2007; Lewis & Todd, 2007; Posner & Rothbart, 2000). We focus on temperament-based attentional control associated with the executive attention system (Posner & Rothbart, 2000) as the psychobiological system associated with developing cognition–emotion relations. Thus, we begin with a brief overview of the early development of attentional control, followed by a discussion of the brain mechanisms associated with attentional control and the measurement of those mechanisms in the developmental literature. Then we highlight specific cognitive control and emotion control behaviors that we propose are regulated by attentional control, and we propose three models by which attentional control is associated with cognition–emotion integration. Our conceptual framework of developing cognition–emotion relations is described in more detail in our recent review (Bell & Deater-Deckard, 2007).

TEMPERAMENT-BASED ATTENTIONAL CONTROL AND THE EXECUTIVE ATTENTION SYSTEM

We consider temperament, and especially temperament-based attentional control, as critical for cognition–emotion integration (Henderson & Wachs, 2007; Posner & Rothbart, 2000; Rothbart et al., 2007). Temperament is defined by Rothbart et al. (2007) as biologically based individual differences in emotional reactivity and in the emergence of self-regulation to modulate emotion reactivity beginning late in the 1st year of life. Early regulation of temperament-based emotional distress is facilitated by the development of attentional control associated with the executive attention system (Ruff & Rothbart, 1996). Attentional control is required for resolving conflict among thoughts, feelings, and responses (Rueda, Posner, & Rothbart,
2005). Thus, attentional control is important for the developing regulation of both cognitive and emotion processes (Kopp, 2002).

The executive attention system's influence on the regulation of emotion reactivity by attentional control begins around 10 months of age (Ruff & Rothbart, 1996), when initial developmental changes in cognitive control behaviors, we believe, also begin to be influenced by the executive attention system (Bell & Wolfe, 2004; Diamond, 1985, 2002; Diamond et al, 1997). Attentional control exhibits a rapid course of development during the toddler and preschool years and is the basis of the temperament construct effortful control (Posner & Rothbart, 2000; Rothbart, 2004). Effortful control refers to the child's purposeful use of executive attention and involves inhibitory control, detection of errors, and planning. As such, effortful control reflects the influence of temperament on behavior (Posner & Rothbart, 2000). The foundations of effortful control appear around 10 months of age (Rothbart, Derryberry, & Posner, 1994), and a shift in the development of effortful control of behavior seems to occur around 27 to 30 months of age (Kochanska, Murray, & Harlan, 2000). There is great improvement in effortful control at 3 and 4 years of age (Kochanska & Knaack, 2003), with continued development of effortful control through age 7 (Rueda, Posner, & Rothbart, 2004).

NEUROLOGICAL MECHANISMS OF COGNITION-EMOTION INTEGRATION

Our psychobiological framework for the integration of cognition and emotion is dependent on psychophysiology and neuropsychology work on the brain mechanisms of the executive attention system. These mechanisms have been studied using brain imaging measures of the central nervous system and cardiac measures of the autonomic nervous system that have implications for central processes.

Central Nervous System Measures

Bush, Luu, and Posner (2000) proposed that the attentional control skills associated with the executive attention system (encompassing the anterior cingulate cortex [ACC] and other areas of the frontal cortex) regulate both cognitive and emotional processing. The ACC has sections that process cognitive and emotional information separately and that also modulate autonomic nervous system activity (Hajcak, McDonald, & Simons, 2003). The cognitive section is connected with the prefrontal cortex, parietal cortex, and premotor and supplementary motor areas and is activated by tasks that involve choice selection from conflicting information, which may include many working memory tasks (Engle, 2002). The emotion section is
connected with the orbitofrontal cortex, amygdala, and hippocampus, among
other brain areas, and is activated by tasks with emotion content (Fichtenholtz
et al., 2004). It was previously thought that there is always suppression of the
affective section during cognitive processing and suppression of the cogni-
tive subdivision during affective processing. However, studies of adults have
indicated some level of interaction between the cognition and affective sec-
tions of the ACC on emotion conflict tasks (e.g., Bush et al., 2000). It was
this particular finding that has focused so much recent attention on the ACC
and the executive attention system in the study of cognition–emotion rela-
tions.

In research with infants and young children, ACC and other frontal
lobe activity usually is inferred using brain electrical activity, such as event-
related potentials (ERP) or the ongoing electroencephalogram (EEG). The
ERP signal is time-locked to specific repeated stimuli. The EEG is the spontane-
ous background signal from which ERPs are extracted. The EEG signal
has temporal resolution on the order of milliseconds. Thus, postsynaptic
changes are reflected immediately in the EEG, making this methodology
outstanding for tracking rapid shifts in brain functioning. Furthermore, these
brain electrical signals are robust, and the techniques by which they are ob-
tained are relatively simple, noninvasive, and comparatively inexpensive.
These characteristics make the EEG one of the more favorable methodolo-
gies for studying brain development in infants and children and for relating
brain development to changes in behavior (Bell & Wolfe, 2007; Taylor &
Baldeweg, 2002).

Because we will be noting some of our EEG findings later in this chap-
ter, we briefly discuss how the ongoing EEG signal is quantified. EEG data
typically are analyzed with a Fourier transform, and this analysis results in at
least three measures used by EEG researchers: power, coherence, and asym-
metry. (We note findings related to EEG power and coherence later in the
chapter.) Theoretically, the EEG signal is composed of multiple sine waves
cycling at different frequencies. The Fourier transform decomposes the EEG
into these different sine waves and estimates the spectral EEG power (in
mean square microvolts) at each frequency. The Fourier transform results in
information regarding the contribution of each individual frequency to the
entire EEG spectrum at a particular electrode site. Increasing power values
across age are considered indicative of brain development (Bell, 1998).

EEG power values are usually totaled across frequency bins to form
measures of absolute power in a specific frequency band, with power consid-
ered a reflection of the excitability of groups of neurons. For adults, alpha
activity (8–13 Hz) is the predominant frequency band for adults and “activa-
tion” of brain areas underlying specific scalp electrodes is assumed when al-
pha power values at those electrode sites are lower during cognitive process-
ing than they were during resting baseline. Thus, alpha power and EEG
activation are inversely related. EEG power in the adult theta band (4–8 Hz)
shows the opposite pattern. That is, activation of brain areas underlying specific scalp electrodes is assumed when theta power values at those electrode sites are higher during cognitive processing than they were during resting baseline.

In the developmental psychophysiology literature there is no standardization of EEG rhythms as found in adult EEG work (Pivik et al., 1993). As a result, little is known regarding the associations of specific frequencies with behaviors during infancy and early childhood. In longitudinal studies examining EEG activity during infancy (Bell & Fox, 1992) or from infancy through early childhood (Marshall et al., 2002), spectral plots revealed a dominant frequency in all scalp leads at all ages at 6 to 9 Hz. Focusing on this particular frequency band during infancy and early childhood is of value only if it can be correlated with behavior, as we discuss later in the chapter.

EEG coherence is the frequency-dependent squared cross-correlation between two scalp electrode sites that reflects the degree of phase synchrony between them (Thatcher, 1994). Coherence values range from 0 to 1, may be related to the strength and number of synaptic connections (Thatcher, 1994), and thus may reflect the level of connectivity between two EEG recording sites. Greater connectivity, however, does not indicate greater brain maturation. Higher coherence values mean that two specific brain regions are working together, which may, or may not, be the most effective use of the cortex at any given age. EEG coherence, unlike EEG power, is not affected by arousal, opening or closing of the eyes, or by state changes. Other than Thatcher’s work, little is known about the development of EEG coherence.

During cognitive processing, differences in EEG activity between quiet rest and presentation of stimuli or tasks are assumed to be an indication of cortical functioning at underlying cortical areas. EEG researchers typically are not more specific than to identify global cortical locations when interpreting this form of brain electrical activity. However, it has been shown, using high-density EEG recordings with infants, that attentional control is associated with activity in the ACC (Reynolds & Richards, 2005).

EEG asymmetry has been widely used in research on emotion reactivity and emotion regulation. Typically, asymmetry scores are computed by subtracting left hemisphere power from right hemisphere power in a specific frequency band. The resulting score may be either positive or negative. Based on the adult model that EEG alpha power and activation are inversely related, a positive asymmetry score reflects greater relative right hemisphere power and thus left hemisphere activation (or left asymmetry). A negative asymmetry score reflects greater relative left hemisphere power and thus right hemisphere activation (or right asymmetry). Greater relative left frontal EEG activation has been shown to be associated with approach-related behaviors and emotions. Greater relative right frontal EEG activation has been associated with withdrawal-related behaviors and emotions. Greater relative right frontal activation also is associated with difficulty in regulating negative
arousal. Frontal EEG asymmetries are thought to reflect forebrain and limbic sensitivity that is specific to the amygdala (Fox, Henderson, Marshall, Nichols, & Ghera, 2005). The amygdala sends projections to the emotion portion of the ACC and thus is part of the emotion network of the executive attention system.

**Autonomic Nervous System Measures**

Cardiac measures allow assessment of attentional control via the parasympathetic and sympathetic branches of the autonomic nervous system. The parasympathetic branch is critical to attention regulation (Porjesz, 1991) via two distinct patterns of cardiac activity. Changes in heart rate (HR) are associated with attention to stimuli, and changes in the variability of the HR are associated with sustained attention.

According to Porjesz’s (1991) polyvagal theory, cardiac vagal tone is a part of parasympathetic control and can be used as an index of physiological self-regulation associated with attention. Vagal tone can be quantified in at least three ways: as HR variability, as the amplitude of respiratory sinus arrhythmia, or as Porjesz’s specific measure of vagal efferents from nucleus ambiguus in the medulla. The vagus nerve to the heart from the nucleus ambiguus serves an inhibitory function of slowing HR and modulating the effects on the heart of the sympathetic branch of the autonomic nervous system. When the environment provides an external demand on the information processing system, the vagal efferents quickly withdraw or suppress vagal tone (termed *withdrawal of the vagal brake* by Porjesz, 1995) and allow the sympathetic nervous system to increase HR, which is essential for cognitive or emotional responding (Bornstein & Suess, 2000). Thus, cardiac vagal tone can be conceptualized as a measure of the efficiency of central and autonomic neural feedback mechanisms (Thayer & Lane, 2000). Thus, baseline measures are indicative of response potential, and indeed, higher resting baseline measures of vagal tone are associated with more efficient attentional processing (Suess, Porjesz, & Plude, 1994) and with more reactive emotional responding (Calkins, 1997).

Cardiac measures of autonomic nervous system activity during cognitive processing are widely used in developmental studies. Infants who exhibit decreases in vagal tone during stimulus presentation will habituate more quickly than infants who do not decrease vagal tone during information processing (Bornstein & Suess, 2000). Changes in HR from baseline to task are associated with better performance on working memory tasks in both infants and young children (Bell, 2009). Studies of working memory in adults also show associations among HR, HR variability, and working memory performance (Hansen, Johnsen, & Thayer, 2003). Thus, there may be a link between autonomic nervous system functioning and prefrontal cortical activity.
Measures of vagal tone also have been linked to emotional reactivity and regulation. Infants with higher vagal tone are more emotionally expressive and reactive (Stifter & Corey, 2001). As emotion regulation abilities develop, the reactivity can lead to concentration when attention is critical to the situation or to more expressive reactivity when other circumstances take precedent (Porges, Doussard-Roosevelt, & Maiti, 1994). Vagal tone may be associated with coping behaviors involving attentional control during both infancy and early childhood (Bar-Haim, Fox, van Meenen, & Marshall, 2004).

In sum, current developmental work tends to focus on either brain imaging or cardiac measures of the psychobiology of attentional control and, thus, cognition–emotion integration. A more integrative brain systems approach is essential for appreciating the intricate interconnections between cognitive and emotion processes associated with attentional control. Thayer and Lane (2000) highlighted initial attempts at an integrative brain approach; these researchers proposed a model incorporating these central and autonomic mechanisms into a neurovisceral model of self-regulation. We have detailed the Thayer and Lane model as essential for a psychobiological approach to developing attentional control and consequent self-regulation (Bell & Deater-Deckard, 2007).

Next we discuss the development of cognitive control and then emotion control and focus on constructs that we consider particularly pertinent to the discussion of cognition–emotion integration. We illustrate our discussion with findings from one of our longitudinal studies (Bell, 2009; Wolfe & Bell, 2004, 2007).

COGNITIVE CONTROL PROCESSES: WORKING MEMORY AND INHIBITORY CONTROL

We conceptualize working memory and inhibitory control as the cognitive control constructs most associated with attentional control (Bell & Deater-Deckard, 2007; Bell & Wolfe, 2004). Working memory and inhibitory control demonstrate great changes during infancy and early childhood (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2002; Diamond, Prevor, Callender, & Druin, 1997). Stable individual differences in cognitive regulation measured via working memory and inhibitory control emerge during the preschool years (Bell, Wolfe & Adkins, 2007).

Cognitive control tasks used in developmental research have demonstrated associations with frontal lobe maturation and functioning (Diamond, 2002). The prefrontal cortex has multiple subdivisions, and working memory is a cognitive skill that appears to underlie functioning across all of these prefrontal areas (Levy & Goldman-Rakic, 2000). Of course, like other brain areas, the prefrontal cortex does not work in isolation. This area of the brain serves to moderate the activity of other brain areas, such as superior temporal
cortex, posterior parietal cortex, anterior cingulate, and others. Prefrontal cortex also receives information from these other areas and, thus, is modulated by this information (Diamond, 2002). Therefore, although it is widely accepted that prefrontal cortex plays a vital role in working memory, other brain areas are involved as well (Levy & Goldman-Rakic, 2000).

A current conceptualization of working memory highlights a limited-capacity, domain-free controlled attention component that is comparable to the construct of executive attention as defined in Posner's executive attention system (Engle, Kane, & Tuholski, 1999; Posner & Rothbart, 2000). The attentional component is able to maintain short-term memory representations online in the presence of interference or response competition. 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 refers to individual differences in executive attention as working memory capacity (Engle et al, 1999). Researchers have demonstrated relations between attentional control characteristics associated with error monitoring and cognitive regulatory tasks involving working memory and inhibitory control in infancy and early childhood (Bell, 2001; Bell & Adams, 1999; Davis, Bruce, & Gunnar, 2002; Wolfe & Bell, 2004). Thus, from early development, components of attentional control and working memory appear to be coupled.

**EMOTION CONTROL PROCESSES: EMOTION REGULATION**

The developments in emotion regulation during infancy and early childhood are as remarkable as those in attentional control and working memory. Developmental changes in emotion regulation are demonstrated in the progression from total dependence on caregivers for regulation of emotion state to independent self-regulation of emotions (Calkins, 2004). According to Kopp (1989), early emotion regulation is influenced mainly by innate physiological mechanisms. Around 3 months of age, some voluntary control of arousal becomes evident, with more purposeful control evident by 12 months. This is when developing motor skills and communication behaviors allow for intentional interactions with caregivers. During the 2nd year, infants begin to use language skills and better impulse control and a 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.

Emotion regulation can occur prior, during, or after the elicitation of emotion (Eisenberg & Spinrad, 2004). Like working memory, emotion regulation appears to also be strongly associated with attentional control. Regulatory aspects of temperament are driven by individual differences in arousal and reactivity. The construct of effortful control, noted earlier, represents a
behavioral system that emerges in the 2nd year and allocates resources for the voluntary control of arousal and emotion. Rothbart suggested that the development of executive attention might underlie the effortful control of emotion, evidenced in the finding that children who show more effortful control also tend to show less anger, fear, and discomfort (Rothbart et al., 2007).

ASSOCIATIONS BETWEEN COGNITIVE CONTROL AND EMOTION CONTROL

The impact of attentional control can be manifest in many different ways with respect to developing cognition–emotion relations. We consider two of those models here that are found in the developmental literature and propose a third model at the end of the chapter. We also provide some data to illustrate the initial model.

In the first model, attention control influences on the regulation of emotion may have an impact on cognitive control and, thus, on cognitive outcome. Working under this model, researchers may manipulate emotion in the experimental situation and inspect the effect on cognitive performance (Gray, 2001; Richards & Gross, 2000). With infants or very young children, researchers may examine normal variations in emotion reactivity and emotion regulation (i.e., temperament) among research participants to study impact of emotion on cognitive outcomes. Our initial longitudinal study used this model, and we report on some of those data below.

In the second model, attentional control influences on cognition may affect the regulation of emotion and, thus, socioemotional outcome (Lewis & Stieben, 2004). Researchers using this model may examine the effect of prefrontal cognitive inhibitory responses on emotion regulation. This is a model that we have not employed in our work, but it is one that has major implications for self-regulation associated with school functioning and performance.

Next we turn to findings from our longitudinal study focused on cognitive outcomes. In this initial work exploring cognition–emotion integration, we used temperament as a measure for both attentional control and emotion control. Children participated in our study during infancy, preschool, and early childhood.

Individual Differences in Cognitive Control at 8 Months

Diamond (2002) noted the dramatic improvements in cognitive control abilities across infancy and has speculated about the development of certain brain systems associated with frontal lobe functioning. Yet, all infants and young children do not improve in their cognitive control abilities.
at the same rate (Bell & Fox, 1992; Diamond et al., 1997). Our research program with infants included an investigation of three measures that have been theoretically and empirically linked with cognitive control (i.e., working memory and inhibitory control): the EEG, HR, and temperament.

Our infant cognitive control measure was a looking version of the classic A-not-B task. We have explained elsewhere that this task involves the cognitive skills of working memory and inhibitory control (Bell & Adams, 1999). The infant must constantly update memory as to the location of a hidden toy (working memory), while refraining from searching in a previously rewarded hiding location (inhibitory control). We focused on changes in EEG values from the pretask baseline recording to the task-related recording, because they would indicate cortical involvement in the task. When we divided infants into high and low performing groups (based on our working memory, inhibitory control task), only infants with high performance exhibited changes in EEG coherence from baseline to task; the low performers showed no change in EEG from baseline to task (Bell, 2009). These task-related changes were evident at frontal and posterior scalp locations (Bell, 2009). These data confirmed our previous cognitive neuroscience work associating frontal and posterior functioning with cognitive performance levels during infancy (Bell, 2001, 2002).

In this sample, the high performance group exhibited an increase in HR from baseline to task indicative of attentional processes. The low performance group did not show this effect. Thus, both brain imaging and cardiac measures of cognitive control distinguished between the high and low performance groups.

Our temperament findings were not as expected. We used Rothbart’s maternal-report temperament measure (Infant Behavior Questionnaire, or IBQ) and predicted that the duration of orienting scale would correlate with cognitive control performance, but it did not. Instead, we found that infants rated by their parents as high on activity level or high on distress to limitations had better performance on the task. This counterintuitive finding, since replicated with a second longitudinal study currently in progress in our lab, has been difficult to comprehend. It may mean that these highly active or easily distressed infants require more parental support—a result that may lead to the enhanced development of their attention skills and cognitive control as they get older, if that support from the parent is appropriate and sensitive (Colombo & Saxon, 2002).

Individual Differences in Cognitive Control at 4 Years

We continued our investigation of individual differences when these same children were 4 years old with an age-appropriate working memory and inhibitory control task. Our preschool cognitive control measures were the day–night and the yes–no, similar to the Stroop test. For the day–night task
(Diamond et al., 1997), the child is shown a white card with a sun and instructed to say “night”; then she is shown a black card with a moon and instructed to say “day.” Similarly, for the yes–no task, the child is instructed to say “no” when the experimenter nods her head yes, and to say “yes” when the experimenter shakes her head no (Wolfe & Bell, 2004). We averaged the scores on these two cognitive control tasks.

Again, we divided the children into high and low performance groups based on their day–night and yes–no task performance. Children in the high cognitive control performance group had higher EEG power values at both baseline and during the cognitive task than those children in the low cognitive control performance group for the frontal and temporal scalp locations. All children exhibited increases in HR from baseline to task, indicative of the cognitive stress associated with performing the task.

With respect to maternal report of temperament using Rothbart’s Child Behavior Questionnaire (CBQ), we noted positive associations between performance on the cognitive control tasks and the two scales of the effortful control factor: attention focusing and inhibitory control scales. We also noted a negative relation between cognitive control performance and the anger/frustration scale, suggesting that children who perform better on the cognitive control tasks also have a greater ability to regulate their emotions of anger and frustration. We also found an unexpected, but rather robust, negative relation between cognitive control performance and parental ratings of approach/anticipation—a scale that is included in the surgency factor of the CBQ. A consideration of the CBQ items included in the approach/anticipation scale provides some insight into this negative association (e.g., gets very enthusiastic about the things he or she does, shows great excitement about opening a present, gets so excited about things he or she has trouble sitting still). Although these findings are contrary to some work comparing temperament and cognition that reports outgoing, sociable, and active children score higher on mental tasks, they are consistent with the findings of Davis et al. (2002), who reported a strong, but also unexpected, negative correlation between the Surgency factor of the CBQ and performance on inhibitory control tasks.

**Individual Differences in Cognitive Control at 8 Years**

Cognitive control may be especially critical to investigations of cognition–emotion relations during middle childhood because working memory and inhibitory control may be interdependent, relative to other executive function tasks (Luna, Garver, Urban, Lazar, & Sweeney, 2004; Roberts & Pennington, 1996). During the children’s visits to the research lab at age 8, the cognitive control tasks were the classic Wisconsin Card Sorting Task (WCST). The children also performed the Attention Networks Task (ANT) designed to examine Posner’s attentional constructs of alerting, ori-
enting, and conflict. It is the conflict aspect of attention that is associated with the executive attention network.

We are still analyzing the data from the children's visits at age 8, but we can provide some preliminary findings. Successful performance on the WCST, as indexed by either number of categories completed or total correct, was associated with EEG power values at frontal scalp locations but not at posterior scalp locations (Bell, Wolfe, & Adkins, 2007). We have not yet prepared the cardiac data for HR analysis.

During the age-8 visit, we were able to assess child report of temperament using the child version of Rothbart's Early Adolescent Temperament Questionnaire. The children's self-report of activation control (i.e., capacity to perform an action when there is a strong tendency to avoid it) was positively correlated with cognitive control (WCST performance). Child-reported high-intensity pleasure (i.e., pleasure derived from activities involving high intensity or novelty) emerged from the surgent dimension of temperament as negative correlate of cognitive control functioning. The child report finding complements the data for 4-year-olds from this sample, in which the surgent dimension of temperament was negatively related to cognitive control performance (Wolfe & Bell, 2004). In addition, the surgent dimension of temperament has been negatively related to academic performance in school-age children, such that low levels of fear and shyness paired with high levels of intensity pleasure are indicative of lower grades and social problems (Rothbart & Jones, 1999). Perhaps the child misses relevant information because he or she is easily excited, distracted, and often impulsive.

Cognition–Emotion Integration From 8 Months to 4 Years

With our specific interests in cognitive control, we hypothesized that the attentional and regulatory aspects of infant temperament would predict working memory performance during early childhood. These data have been reported elsewhere (Wolfe & Bell, 2007). To summarize the findings at 8 months and at 4 years of age: Infant and child EEG, as well as infant and child temperament, were correlated, as expected. Infant and child cognitive control (i.e., working memory) performance measures were not correlated, however. It is important that infant temperament was a predictor of child cognitive control. Specifically, approach/anticipation at age 4 mediated the relation between 8-month soothability and 4-year cognitive control, with a positive correlation between soothability and approach/anticipation. In essence, an infant who is difficult to soothe at 8 months may be low on approach/anticipation behaviors at 4 years and thus more likely to perform well on cognitive control tasks involving controlled, inhibitory processing. As we hypothesized with the correlation between distress and cognitive control at 8 months, many parents in supporting infants during distress or fussiness attempt to soothe infants by distracting them with visual and other
stimuli. This may aid in the development of attentional skills that later are key in relieving distress (Ruff & Rothbart, 1996). These attentional skills may also contribute to the attentional and regulatory abilities, such as self-control during approach/anticipation, associated with the executive attention system and later complex cognition, such as that required by cognitive control tasks in preschool years.

Cognition–Emotion Integration From 4 Years to 8 Years

Unlike the infant and preschool cognitive control tasks, working memory performance at 4 and 8 years was correlated. As with the infant and preschool data, it was important that 4-year-olds' temperament was a predictor of 8-year-olds' attentional control. Specifically, effortful control tasks in the research lab at age 4 (items from Kochanska's battery; Kochanska et al., 2000) were related to the conflict and alerting scores on the ANT. Thus, these regulatory skills associated with effortful control at preschool appear to contribute to the attentional control abilities during middle childhood.

CONCLUSION

In this chapter we have focused on cognition–emotion integration in early development by emphasizing brain mechanisms of the executive attention system associated with attentional control. We outlined our psychobiological framework, which highlighted the potential impact of attentional control on the development of working memory and emotion regulation beginning in infancy and continuing throughout early childhood. We argued that these cognitive control and emotion control processes become integrated with development. We presented some longitudinal data that illustrate our initial attempts at tracking individual differences in cognitive control by examining attentional and emotion-related influences on the development of working memory.

Our overall discussion of attentional control and the executive attention system, however, lends itself to a more encompassing model of cognition–emotion integration that does not assign primacy to either cognitive or emotion processes. Thus, the third model that we present is the focus of our current longitudinal work, and it assigns both cognition and emotion as outcomes. In this model, attentional control processes exert influence on both cognition and emotion so that they may become increasingly reciprocal over time, with interlocking developmental trajectories demonstrating the significance of both cognition and emotion as outcome measures. Informed by data from our initial longitudinal model and by research linking attentional control to both cognitive and emotion processes via the executive attention system, we are examining the development of attentional control, working
memory, and emotion regulation across infancy and early childhood using both behavioral and electrophysiological measures.

Examination of the beginnings of cognition-emotion integration during infancy and early childhood is valuable for understanding the foundations of individual differences in self-regulation. In school-age children, this integration between cognitive control and emotion regulation may be essential for school achievement and for appropriate and adaptive social behavior. Thus, there is a need to investigate the development of cognitive and emotion processes and their integration across early development.

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