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Self-Regulation of Negative Affect at 5 and 10 Months

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Abstract

One hundred six infants participated in a longitudinal study of cognition-emotion integration exploring the effects of attentional control on regulation of negative affect across infancy. At both 5 and 10 months, attentional control was measured behaviorally (looking time to neutral stimulus), physiologically (cardiac reactivity), and with temperament-based parental ratings of orienting/ regulation. Looking and cardiac measures were examined both before and after a mild stressor. At 5 months, post-distress negative affect was related only to distress-related increases in heart rate. At 10 months, however, behavioral, cardiac, and parent-report aspects of attentional control explained unique variance in post-distress negative affect. Attentional control measures at 5 months did not predict negative affect at 10 months. This pattern of results is discussed with respect to the development of frontally-mediated regulatory mechanisms from infancy into early childhood.

Keywords

Attentional Control; Self-Regulation; Infants; Heart Rate

Empirical and theoretical contributions to the developmental literature indicate that, even within the first year of life, cognition and emotion work in concert to process information and guide action during emotional experiences (Bell & Deater-Deckard, 2007; Calkins & Bell, 2010; Kopp, 2002; Rueda, Posner, & Rothbart, 2004; Ruff & Rothbart, 1996). Data from studies examining individual differences in early temperament, developmental cognitive neuroscience, and psychophysiology indicate that self-regulation of emotions may be mediated by the development of cognitive regulatory abilities, specifically, attentional control (Harman, Rothbart, & Posner, 1997; Sheese, Rothbart, Posner, White, & Fraundorf, 2010; Wolfe & Bell, 2004, 2007). Recently, researchers have begun to develop models of infant self-regulation across emotional and cognitive domains highlighting the central role of attentional control (e.g., Bell & Deater-Deckard, 2007).

The recruitment and allocation of attentional resources have been examined as a proxy for self-regulation in early development by using a variety of different methodological approaches (e.g., Calkins, Dedmon, Gill, Lomax, & Johnson, 2002; Harman et al., 1997; Sheese et al., 2010). These include direct laboratory observation of looking behavior, parental reports of temperament dimensions, and changes in psychophysiological response patterns during emotion-eliciting challenges. The purpose of this study was to examine

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relations between the regulation of negative affect and multiple expressions of attentional control as they develop across the first postnatal year.

Looking behavior has commonly been used as a metric of visual attentional control (Colombo, 2004; Colombo, Kapa, & Curtindale, 2010). As the visual system of the infant matures, along with mechanisms for disengaging, shifting, and focusing attention to visual stimuli, infants are better able to effortfully direct attention as a regulatory mechanism when faced with cognitive or emotional challenges, thus attenuating the experience of negative affect. Thus, infants may look away from a distressing object or event or may direct visual attention towards a neutral object or event to regulate affect (Harman et al., 1997; Posner & Rothbart, 2000). This strategic use of allocating visual resources to regulate behavior is thought to be supported by a developing neurophysiological network, the Executive Attention System (Posner, 2004). This system is comprised of both cortical and subcortical structures and reciprocal autonomic connections, and it undergoes a period of rapid development late within the first year of life (Posner, 2004; Rothbart, Derryberry, & Posner, 1994; Ruff & Rothbart, 1996). The development of the Executive Attention System, and subsequent improvements in attentional control, allows for age-related change in regulatory abilities and is thought to also underlie temperament-based expressions of self-regulation (Rothbart, et al., 1994).

In her model, Rothbart defined temperament as biologically-based individual differences in emotion reactivity and the regulation of this reactivity (Rothbart & Bates, 2006; Rothbart et al., 1994). Temperament-based attentional control is associated with mechanisms for resolving conflict among emotions, thoughts, and action. Therefore, infants who have more developed attentional control are better equipped to regulate emotional reactivity. This is supported by evidence from a recent psychometric meta-analysis of the Infant Behavior Questionnaire (IBQ-r), where the broad temperament factors of negative affectivity and orienting/regulation were negatively associated across infancy (Gartstein & Rothbart, 2003). Additionally, temperament-based attentional control has been associated with physiological indices of coping behavior including different patterns of cardiac reactivity, specifically changes in heart rate and heart rate variability (Rothbart & Bates, 2006).

In addition to associations with temperament, autonomic functioning has been linked to both visual attentional abilities and self-regulation (Richards, 1997; Braungart-Rieker & Stifter, 1996). Richards and colleagues have demonstrated that heart rate can be an accurate and useful index in identifying visual attentional processing (Richards & Casey, 1992). Infants who exhibit longer periods of lowered heart rate (and simultaneous longer periods of look duration) during visual attention tasks might do so because of better attention regulation abilities. In addition, infants with higher resting heart rate variability have been shown to be more emotionally expressive and reactive (Calkins, et al., 2002; Porges, Doussard-Roosevelt & Maiti, 1994; Stifter, Spinrad, Braungart-Rieker, 1999). As regulatory abilities develop across the first year, the reactivity is balanced by mechanisms to suppress or balance emotional lability (Porges et al., 1994).

Across the first year, infants are better able to both strategically control attention (Rothbart & Bates, 2006), and to regulate emotions (Calkins et al., 2002). Therefore, we chose to examine the relations between these abilities both before (5 months) and during (10 months) a biobehavioral transition period for attentional control (Rothbart et al., 1994; Ruff & Rothbart, 1996) We hypothesized that infants who display more negative affect (i.e., are less able to self-regulate) following a distressing experience would simultaneously display lower levels of attentional control, noted by different patterns of visual attention (decreases in the proportion of looking time to a post-distress neutral event) and cardiac reactivity (increases in heart rate and heart rate variability) relative to the pre-distress baseline. Additionally, we hypothesized that these infants would be rated by parents as lower on a temperament-based measure of attentional control (the orienting/regulation factor of the IBQ-r). Finally, we hypothesized that these relations would be present at 10 months, but not at 5 months, due to the rapid development of the underlying neurological structures supporting both self-regulation and attentional control.

Method

Participants

One hundred six infants (50 boys, 56 girls; 5 Hispanic, 101 non-Hispanic; 93 Caucasian, 2 African-American, 1 Asian, 9 Multiracial, and 1 Other) were recruited at 5 months for participation in an ongoing longitudinal study examining the psychobiology of cognition-emotion integration across early development. Initial participation in the longitudinal study involved two identical visits to the research laboratory, first at 5 months (*M* = 5 months, 11 days; *SD* = 10 days), and again at 10 months (*M* = 10 months, 11 days; *SD* = 10 days). Eight infants did not return for the follow-up visits (4 due to relocation and 4 due to the inability to contact families after initial enrollment), resulting in a sample size of 98 infants at 10 months.

All infants were born within two weeks of their expected due dates and had no diagnosed neurological or developmental problems. All parents completed a high school education, with 71% of parents having a college degree. Average maternal age at infant's birth was 30 years (range 20-38) and average paternal age was 33 years (range 23-52). Families were given a small gift for participation in the study.

Procedure

After parental consent, infants were given an opportunity to acclimate to the research lab and the experimenter. Then ECG electrodes were applied and a 3-phase attentional control/self-regulation task began. Continuous ECG was measured from two neonatal disposable electrodes using modified lead II alignment (right collarbone and lower left rib; Stern, Ray & Quigley, 2001), grounded at the scalp near electrode site Fz. The ECG signal was amplified using a SA Instrumentation Bioamplifier and digitized at 512 samples per second. Throughout data collection the QRS complex was displayed on a computer monitor and the ECG data were stored for later processing.

The infant attentional control/self-regulation task was composed of three phases designed to examine behavior and physiology both before and after a mild stressor. Because parental behaviors have been shown to impact infant self-regulation (Braungart-Rieker & Stifter, 1996; Calkins et al., 2002), mothers were asked not to soothe or interact with their infants.

During pre-distress (phase one), infants and mothers were seated side-by-side approximately 1.5m from a television screen (45cm diagonal). Following the stabilization of the ECG recording, infants were shown the first 45s of a 90s video clip depicting a visually-dynamic musical segment from Sesame Street (Richards, 1997). A video camera located above the television recorded the infant's behavior throughout the segment. During this pre-distress video, all infants spent time looking at the video (proportion of looking time: 5-months, *M* = 0.63, *SD* = 0.25; 10-months, *M* = 0.66, *SD* = 0.18). In addition, during this emotionally-neutral video, no infant exhibited negative affect at either age.

Following two playful interaction tasks with mother (toy play; peek-a-boo; part of a larger battery assessing the development of cognition-emotion integration), infants were presented with two consecutive distress tasks designed to evoke negative affect (phase two; Braungart-Rieker & Stifter, 1996; Calkins et al., 2002). These tasks, toy removal and arm restraint, are standard manipulations in the study of infant emotional reactivity and self-regulation and provide mild and transient distress to infants. During the toy removal task, mother was asked to engage her infant in 30s of typical play with an interesting toy. Mother was then asked to hold the toy out of the infant's reach, retaining eye contact but remaining silent and displaying a still face. This task continued for either 120s or until the infant achieved the distress criterion (i.e. 10 seconds of hard crying), judged online by the lead experimenter. If this criterion was met during the toy removal procedure, the arm restraint procedure was omitted and the post-distress phase began immediately[1]. For infants who did not meet this criterion, mother was next asked to gently restrain her infant's arms against his/her sides to restrict free arm movements while maintaining a still face and silence. This segment also lasted either 120s or until the infant met the distress criterion.

The post-distress (phase three) immediately followed and was procedurally identical to the pre-distress phase except that infants were shown the next 45s of the Sesame Street video clip. This provided infants an opportunity to use attentional/self-regulatory mechanisms to regulate the negative affect elicited by the distress tasks. Continuous ECG and infant looking behaviors were again recorded for later coding of attentional control/self-regulation, as well as ratings of negative affect following distress. Following the post-distress video, ECG electrodes were gently removed.

Prior to arrival at the laboratory for each study visit, mothers completed the IBQ-R (Garstein & Rothbart, 2003) to establish a temperament-based report of general infant behavior. The orienting/regulation factor was of particular interest in these analyses. This factor was constructed from the low-intensity pleasure, cuddliness/affiliation, duration of orienting, and soothability scales and has been shown to have high internal consistency ($\alpha = 0.91$; Gartstein & Rothbart, 2003). Higher scores on the orienting/regulation factor reflect higher parental ratings of attention-mediated regulation.

Throughout data collection, event mark labels were placed on the physiological record to identify task-related epochs for artifact screening and analysis. The ECG data were artifact scored by a trained research assistant for gross motor movements and were analyzed using IBI Analysis software developed by James Long Company (Caroga Lake, NY). Measures of interest included the average heart rate (bpm) and heart rate variability (statistical variability of the heart rate measure) from the pre- and post-distress phases. At each age, difference scores (post-distress ECG phase three minus pre-distress ECG phase one) were calculated to investigate regulation-related changes in cardiac activity following the infant distress tasks.

Using Video Coding System software developed by James Long Company, shifts in gaze during the video segments from both the pre- and post-distress phases were coded by a trained assistant. Each eye shift was judged as either toward or away from the video screen, and the frequency and duration of the resulting looks were analyzed to calculate the proportion of time the infant spent looking at the video. At each age, difference scores (post-distress phase three looking minus pre-distress phase one looking) were calculated to investigate regulation-related changes in visual attentional control following the distress tasks. Inter-rater reliability was high across both ages and phases of the task (lowest $\alpha = 0.93$, 21% overlap).

Using a qualitative scale of negative affect, coders rated 10-second epochs of the post-distress video for the presence and severity of negative affect on a 6-point scale ranging

[1]At both ages, infants who met the criterion during the toy removal task, as opposed to the arm restraint task (25% of the sample at 5 months, 26% at 10 months), did not differ on any of the attentional control or self-regulation measures described in subsequent analyses (largest $t = 1.94$, $p = .06$). Fifteen percent of the sample met this criterion at both 5 and 10 months.

from 0 (neutral face and voice) to 5 (escalated crying with at least one shriek). These ratings were averaged across the 45s phase to supply a measure of infant negative affect following the distress procedures. Because the distress tasks are designed to induce negative affect, we interpret higher levels of negative affect during the post-distress video as indicative of poorer behavioral and physiological self-regulation after distress. Conversely, we interpret lower negative affect during the post-distress video as indicative of greater behavioral and physiological self-regulation after distress. Inter-rater reliability for the post-distress negative affect coding was high at both ages (lowest $\alpha = 0.97$, 20% overlap).

Results

We first report zero-order correlations among measures of task-related changes in visual attention and cardiac activity, parent ratings of orienting/regulation, and infant negative affect following distress. This is followed by regression analyses examining the amount of variance in post-distress negative affect explained by measures of attentional control/self-regulation. These analyses are threefold, first at 5 months, then 10 months, and finally predicting 10-month self-regulation from 5-month measures.[2]

Regulation of Negative Affect at 5 Months

Of the original 106 infants, 75 contributed complete data at the 5-month-visit.[3] At 5 months, higher negative affect (i.e. less self-regulation) experienced across the post-distress phase of the attentional control/self-regulation task was associated with (a) less visual attention (defined as decreases or smaller changes in the proportion of time spent looking towards the neutral video clip; $r(75) = -0.26$, $p = .03$), and (b) increased heart rate ($r(75) = 0.58$, $p < .001$) during the post-distress phase, relative to the pre-distress phase. No other associations were found among the measures.

Table 1 shows that changes in visual attention, task-related changes in physiology (heart rate and heart rate variability) as well as parent-reported infant orienting/regulation accounted for 35% of the variance in negative affect during the post-distress video at 5 months. At the level of the predictors, however, the only significantly contributing factor was increase in heart rate, alone accounting for 30% of the variance.

Regulation of Negative Affect at 10 Months

Of the 98 infants who returned for the 10-month visit, 84 contributed complete data.[4] At 10 months, higher negative affect (i.e. less self-regulation) experienced across the post-distress phase of the attentional control/self-regulation task was associated with (a) less visual attention to the neutral video clip ($r(83) = -0.38$, $p < .001$), (b) increased heart rate ($r(83) = 0.64$, $p < .001$), and (c) increased heart rate variability ($r(83) = 0.23$, $p = .04$) during the post-distress phase. Additionally, decreases or smaller changes in looking time were related to increases in heart rate ($r(83) = -0.39$, $p < .001$). No other associations were found among the measures.

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[2]Due to a lack of sex-related differences on the dependent measures (largest $F = 1.77$, $p = .19$), all correlation and regression analyses were collapsed across sex.

[3]Infants without complete data were excluded from the regression analyses. Of the original 5-month-old sample, one infant was missing looking data due to poor camera angles, 16 infants were missing hr/hrv data due to excessive artifact in the ECG signal during either phase of the attention/regulation task, 3 due to equipment failure, and 1 infant rejected the electrodes. Three parents did not return the IBQs, and 7 infants were excluded due to missing data on more than one of these measures. Therefore, a total of 31 infants were excluded from the analyses.

[4]Infants without complete data were excluded from the regression analyses. Of the 98 returning 10-month-old sample, 9 infants were missing hr/hrv data due to excessive artifact in the ECG signal. Three parents did not return the IBQs, and 2 infants were excluded due to missing data on more than one of these measures. Therefore, a total of 14 infants were excluded from the analyses.

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Table 2 shows that changes in visual attention, task-related changes in physiology (heart rate and heart rate variability) as well as parent-reported infant orienting/regulation accounted for 50% of the variance in negative affect during the post-distress video at 10 months. At the level of the predictors, changes in cardiac activity explained 39% of the variance (33% from changes in heart rate, 6% from changes in heart rate variability). In addition, changes in visual attention accounted for 6% of the variance in self-regulation. Finally, parent ratings of temperament-based orienting/regulation across contexts and situations explained an additional 7% of the variance in observed self-regulation.

Longitudinal Analyses

To examine age-related continuity and change among these measures, we examined associations among the variables collected at 5 and 10 months. Of the original sample, 59 infants contributed complete data at both ages. Three measures demonstrated stability between 5 and 10 months, including parent-rated orienting/regulation ($r(59)= .56$, $p<.01$), distress-related changes in heart rate ($r(59)= .32$, $p=.02$) and post-distress negative affect ($r(59)=.31$, $p=.02$). The only other significant associations between ages were that 5-month task-related increased heart rate was associated with 10-month negative affect ($r(59)= .35$, $p<.01$) and higher 5-month parent-rated orienting/regulation was related to 10-month increased heart rate ($r(59)= .34$, $p<.01$).

Finally, we conducted a longitudinal regression analysis to identify developmental trends in these relations. Together, the measures of attentional control/self-regulation at 5 months (change in visual attention, changes in heart rate and heart rate variability, and parent-rated orienting/regulation) as well as negative affect following distress at 5 months were not predictive of level of negative affect following distress at 10 months (F (5, 53) = 2.27, p = .06).

Discussion

The aim of this study was to examine how infant regulation of negative affect was affected by individual differences in attentional control across the first year. Our data demonstrate that with age, the ability of attentional control to explain variation in regulation improved and operated across several domains. Whereas observed regulation of negative affect in younger infants was almost exclusively explained by patterns of physiological reactivity and regulation, later within the first year for those same infants, other aspects of attentional control significantly contributed to the expression of regulation, including reallocation of visual resources during a neutral video and temperament-based patterns of orienting/regulation, in addition to the previously observed changes in cardiac reactivity. Specifically, continued high levels of negative affect at 5 months was marked by increased heart rate following a mild, but salient distressing experience. However, at 10 months, this continued negative affect was accompanied by increased heart rate and heart rate variability, less time spent visually engaged to the neutral video, and lower parental ratings of overall regulatory skill. Indeed, the inability of attentional control factors at 5 months to predict later negative affect at 10 months bolsters maturational arguments for a biobehavioral shift in general regulatory mechanisms late within the first year (Rothbart et al., 1994; Ruff & Rothbart, 1996).

Our results support previous work describing relations between self-regulation and attention, defined behaviorally, physiologically, and temperamentally during periods of early development. Calkins and colleagues (2002) reported that infants in the last half of the first year who were rated as having lower temperament-related regulatory abilities by parents experienced more frustration (elicited by distress procedures similar to those used in the current study), and thus had poorer observed self-regulation. They were also less attentive and more physiologically reactive than infants who exhibited less frustration following the distress procedures. This pattern of relations was present for older infants in our sample.

That this pattern of relations was present at 10 months, but not at 5 months was not surprising. Based on previous work, it is clear that age-related changes in infant-driven (rather than parent-supplied) regulation strategies begin to emerge close to the end of the first postnatal year (Braungart-Rieker & Stifter, 1996; Calkins et al., 2002; Kopp, 2002). The emergence of these skills is thought to be related to the functional maturation of frontally-mediated physiological systems which incorporate autonomic regulation (Posner & Rothbart, 2000; Rothbart, Ellis, & Posner, 2004). Thus, with this work, we support developmental models suggesting the foundations of self-regulation may be present in the last half of the first postnatal year. However, we acknowledge that because our developmental analysis closely approached significance, the possibility exists that this study may have been underpowered.

Although emerging self-regulatory processes may be evident in infancy, previous anatomical, neuropsychological, and biobehavioral work with developmental populations has implicated the delayed and protracted development of the frontal cortex in supporting individual and age-related differences in cognitive and emotion-related self-regulatory mechanisms (Bell & Fox, 1994; Chugani, 1994; Diamond, 2002; Goldman-Rakic & Leung, 2002; Luna, Carver, Urban, Lazar, & Sweeney, 2004). Several recent psychobiological studies have reported individual differences in measures of self-regulation in toddlers and preschoolers (e.g. Calkins & Dedmon, 2000; Eisenberg, Spinrad, & Smith, 2004). In addition, various cognitive and emotion-related aspects of the voluntary regulation of behavior thought to derive from attention-mediated regulation in infancy have been associated with task-related increases in frontal EEG power in toddlers (Morasch & Bell, 2011) and preschoolers (Bell & Wolfe, 2007). Thus, the regulatory processes associated with frontal functioning play a critical role in early development.

In a larger scope, we aimed to empirically examine emerging links between cognition and emotion from a psychobiological perspective. Although we did not test the directionality of the predictors included in the model of dynamic self-regulation proposed by Bell and Deater-Deckard (2007), our data lend support to previous research which highlights the co-development of attentional and regulatory mechanisms as integrated across domains of behavior, temperament, and psychophysiology during infancy. Examination of the beginnings of cognition-emotion integration is valuable for understanding the foundations of individual differences in self-regulation. Recent applied work suggests that regulatory control of behavior, including mechanisms of cognitive and emotion control, is a better predictor of successfully transitioning into the school setting than actual scholastic knowledge (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Blair, 2002; Denham, 2006). Longitudinal studies directly examining links from infant regulatory mechanisms to outcomes in school achievement and adaptive social behavior will inform the study of the development of cognition-emotion integration.

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Table 1

Summary of multiple regression analysis predicting5-month post-distress negative affect from aspects of 5-month attentional control

Predicted: Post-distress negative affect	**B**	**SE(B)**	**ß**	***t***	***p***	***sR*^{2}**
Distress-related change in visual attention	-0.01	0.01	-0.10	-0.94	0.35	0.01
Distress-related cardiac activity:						
Changes in Heart Rate	0.07	0.01	0.55	5.49	0.01	0.30
Changes in Heart Rate Variability	0.02	0.03	0.08	0.81	0.42	0.01
Parent report of orienting/regulation	-0.03	0.22	-0.01	-0.14	0.89	0.01

Note: $R^2 = 0.35$, $F\ (4, 70) = 9.40$, $p < 0.001$

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Table 2

Summary of multiple regression analysis predicting10-month post-distress negative affect from aspects of 10-month attentional control

Predicted: Post-distress negative affect	**B**	**SE(B)**	**ß**	***t***	***p***	***sR*^{2}**
Distress-related change in visual attention	-0.09	0.01	-0.19	-2.15	0.04	0.06
Distress-related cardiac activity:						
Changes in Heart Rate	0.06	0.01	0.55	6.21	0.02	0.33
Changes in Heart Rate Variability	0.07	0.03	0.21	2.49	0.03	0.07
Parent rated orienting/regulation	-0.35	0.16	-0.18	-2.23	0.01	0.06

Note: $R^2 = 0.50$, $F\ (4, 78) = 19.20$, $p < 0.001$