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The Relation of ANS and HPA Activation to Infant Anger and Sadness Response to Goal Blockage

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Abstract

This study examined the relation of anger and sadness to heart rate and cortisol in 4-month-old infants' ($N = 56$) response to a goal blockage. The blockage occurred during a contingency learning procedure where infants' response no longer produced a learned interesting event. Anger and sadness were the major emotional expressions to the blockage. The two emotional expressions were differentially related to heart rate and cortisol. Anger was related to increased heart rate, but not cortisol, whereas sadness was related to increased cortisol, but not heart rate. Along with other work, the present results support the view that infant anger in response to goal blockage involves autonomic as opposed to adrenocortical activation as a consequence of an expectation of control over the event. In contrast, sadness in response to goal blockage involves adrenocortical as opposed to autonomic activation stemming from the absence of an expectation of control.

From the first months of life, individual differences have been found in infant response to the blockage of a desired goal (e.g., Kochanska, Tjebkes, & Forman, 1998; Lemerese & Dodge, 2000; Lewis, 2000; Saarni, Mumme, & Campos, 1998; Stifter & Grant, 1993). Our past work on infant response to goal blockage has involved a contingency learning situation (Alessandri, Sullivan, & Lewis, 1990; Lewis, Alessandri, & Sullivan, 1990; Lewis, Sullivan, Ramsay, & Alessandri, 1992; Sullivan, Lewis, & Alessandri, 1992). Infants learn that arm-pulling leads to an interesting event. After the contingency is learned, different types of goal blockages are introduced. One type of blockage involves an extinction procedure where the event no longer occurs regardless of infant arm-pulling. In response to this form of blockage, infants show anger and sadness as well as arm-pulling. Increases in arm-pulling are associated with increased anger, but not increased sadness (Lewis et al., 1990). That anger, but not sadness, is related to arm-pulling suggests that an angry expression and arm-pulling reflect infants' attempt to reinstate the outcome and therefore their expectation of control over the event, while sadness may not.

The type of blockage that involves the event continuing to occur independent of infant arm-pulling has been called a noncontingent blockage. When this condition is introduced, infants show increased anger, but not increased arm-pulling (Sullivan & Lewis, 2003). That what was a response-contingent event now occurs independent of arm-pulling serves to inform infants that they are no longer in control. Thus, anger, but not arm-pulling to this form of blockage supports the idea that anger in response to a blocked goal reflects infant expectation of control.

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On the other hand, sadness in response to goal blockage appears to reflect the absence of infant expectation of control. Past work suggests that adrenocortical activation to goal blockage is most likely to occur when there is the absence of perceived control to overcome the obstacle (Dickerson & Kemeny, 2004; Henry, 1992; Levine, Coe, & Wiener, 1989; Levine & Wiener, 1989). For example, animals who do not have the control to terminate aversive stimulation show considerably enhanced adrenocortical responses relative to yoked controls who do have the control, yet receive the same aversive stimulation (Levine et al., 1989). On the basis of such evidence, Henry (1992) proposed that, in the absence of perceived control, responses to goal blockage would involve adrenocortical activation. If sadness reflects the absence of control, sadness should be related to increases in cortisol response. We examined this possibility using two goal blockage situations with young infants (Lewis & Ramsay, 2005). For both blockages sadness was, while anger was not, related to cortisol response; infants showing greater sadness showed a higher cortisol response. Taken together these results suggest that sadness to goal blockage reflects the absence of infant expectation of control.

Henry (1992) also proposed that, as a consequence of perceived control, responses to a blocked goal would be associated with autonomic activation reflecting the effort involved in attempting to overcome the obstacle. There would be no autonomic activation in absence of perceived control. Thus, in response to goal blockage, increases in anger should be related to autonomic activation, but unrelated to adrenocortical activation, whereas increases in sadness should be related to adrenocortical activation, but unrelated to autonomic activation. Henry's view suggests that in response to goal blockage the pattern of high autonomic and low adrenocortical activation may be the more optimal physiological response, whereas the pattern of low autonomic and high adrenocortical activation may be a less optimal physiological response. It would appear that the lack of adrenocortical activation when infants show anger supports the view that anger may be more adaptive than sadness. The relation of high autonomic and low adrenocortical activation to anger over a blocked goal would add further support to the view that anger rather than sadness is a more adaptive response.

Bauer, Quas, and Boyce (2002) reviewed work on differential patterns of autonomic and adrenocortical activation in relation to risk for behavioral problems. They suggested that the patterns of autonomic and adrenocortical activation may have important implications for psychopathology. They proposed that four groups of subjects be considered according to whether they showed (1) high autonomic and high adrenocortical activation, (2) low autonomic and low adrenocortical activation, (3) high autonomic and low adrenocortical activation, or (4) low autonomic and high adrenocortical activation. In contrast to Henry's view, Bauer et al. suggested that more pathological functioning might be associated with the pattern of high autonomic and low adrenocortical activation as well as the pattern of low autonomic and high adrenocortical activation. These they contrasted with more balanced autonomic and adrenocortical activation. Pointing out that this and other possibilities have not been tested empirically in adults or children, they called for such investigation to determine how the autonomic and adrenocortical systems are coordinated in individual differences in emotional and behavioral functioning.

To our knowledge, there has not been an examination in infants of the separate emotions of anger and sadness in response to goal blockage as they relate to both autonomic and adrenocortical activation. For example, Haley and Stansbury (2003) examined the relation of heart rate and cortisol only to a global measure of negative affect that did not distinguish the two emotions. In the present study, we examined anger and sadness to a blocked learned response in relation to heart rate and cortisol reactivity in a sample of 4-month-old infants. Consistent with Henry's view, we expected anger to be associated with increased heart rate, but not cortisol and sadness to be associated with increased cortisol, but not heart rate. Four months was chosen as the sample age since in past work it has proved a good time to examine

individual differences in infant anger and sadness responses to goal blockage (Lewis et al., 1990; Lewis & Ramsay, 2005; Sullivan & Lewis, 2003).

Method

Participants

Participants consisted of 56 4-month-old infants (M age = 4.0 months, SD = .3) (29 females, 27 males). There were 21 first-borns, 26, second-borns, and 9 latter-borns. The racial ethnicity of the sample was 91% White. Most (68%) mothers had received at least a college degree. Thirteen additional infants were excluded due to equipment problems, fussy behavior, and failure to complete the procedure. Mothers were recruited for participation during their hospital stay following the birth of their infant. All infants had been cared for in the full-term well-baby hospital nursery. Infants did not have any known developmental problem at the time of the assessment.¹

Procedure

The contingency learning situation involved pulling on a string attached to infants' wrist where each arm-pull could activate a 3-second audio-visual display that consisted of a color slide of an infant's smiling face and a recording of children's voices singing (Alessandri et al., 1990; Lewis et al., 1990). The situation had three successive phases: baseline; learning; and extinction. The baseline phase involved a 2-minute period of nonreinforcement during which arm-pulling did not activate the display. The learning phase was a 6-minute period of contingent stimulation during which arm-pulling did activate the display. The extinction phase consisted of a 2-minute period of non-reinforcement (i.e., procedurally identical to the baseline phase). During the procedure, infants were seated in a reclining infant seat in a three-sided booth facing a rear-projection screen mounted in the rear wall of the booth with an audio-cassette player positioned behind the screen. Infants' faces were video-recorded from a camera behind the rear wall through an opening below the screen. A parent sat behind the infants out of the infants' view.

Emotional expressions of anger and sadness—Infant emotional expressions including anger and sadness were coded from the videotapes using AFFEX (Izard, Dougherty, & Hembree, 1983), the whole face version of the Maximally Discriminative Facial Movement Coding System (MAX) (Izard, 1983/1995). AFFEX coding was done from the videotapes in slow motion with volume off second-by-second for the duration of the procedure. Following the coding system, emotional expressions were then identified on the basis of the AFFEX formulas. For anger, the mean number of expressions per minute during the learning and the extinction phase was 1.15 (SD = 1.63) and 4.01 (SD = 3.64), respectively. For sadness, the mean number of expressions per minute during the learning and the extinction phase was .30 (SD = .63) and 1.03 (SD = 2.05), respectively. Emotional response to the goal blockage was defined as the change in the frequency of the expression from the learning to the extinction phase (extinction minus learning). For anger, mean emotional response was 2.86 (SD = 3.21), and for sadness it was .73 (SD = 1.94). Anger and sadness responses have been so defined in our past work including our most recent study (Lewis & Ramsay, 2005).

Data from our previous study suggested that cortisol response was greatest for infants with a high sadness response as opposed to the other infants. Thus, differences in both heart rate and cortisol response might well be greatest for infants showing high anger or sadness. Thus, it was of interest to identify *angry* and *not-angry* infants as well as *sad* and *not-sad* infants based

¹Data on these subjects' cortisol response were previously presented (Lewis & Ramsay, 2005, Study 1). Data on heart rate and on the interaction of both heart rate and cortisol were not previously reported.

on whether or not they showed high anger or high sadness. The proportion of infants showing a learning-to-extinction increase in anger was .73 (41/56). Angry infants were defined as those infants whose anger response was in the top half of the response distribution for cases showing an increase in anger (i.e., $n = 21$ angry infants versus 35 not-angry infants). The proportion of infants showing a learning-to-extinction increase in sadness was .34 (19/56). Sad infants were defined as those infants whose sadness response was in the top half of the response distribution for cases showing an increase in sadness (i.e., $n = 9$ sad infants versus 47 not-sad infants). Each infant was classified both as angry versus non-angry and as sad versus non-sad based on the amounts of the two emotions expressed.

Since individual infants showed varying amounts of each emotion, we obtained a measure of *differential emotional response* in order to examine the relation of this measure to heart rate and cortisol. Differential emotional response was given by the difference between the z -score for anger and the z -score for sadness (anger minus sadness). Higher differential emotional response reflected relatively more anger than sadness.

The facial expression coding was done by three experienced coders who were unaware of the heart rate and cortisol data and of the predicted relation between emotional and physiological responses. The coding of anger and sadness proved reliable ($k = .87$ and $.93$, respectively) based on the coding of the data for a random sample of nine infants done by two coders. Past work also has provided evidence for the reliability of AFFEX in other situations (e.g., Izard et al., 1987; Izard, Fantauzzo, Castle, Haynes, Rayias, & Putnam, 1995).

Heart rate—Infants' electrocardiogram was monitored during the contingency learning procedure via three infant Ag/AgCl disposable electrodes attached to the chest in a triangular fashion (one on the right shoulder, one on the left side, and the ground lead on the lower abdomen). The ECG was recorded onto FM tape for later offline artifact-editing and conversion to heart rate. To do so, the ECG was played back to digitize the signal at a rate of 1,000 Hz and to detect the peak of each R-wave. Sequential heart periods (R-R intervals) were timed to the nearest millisecond, and then the heart period (HP) data were edited for aberrant values (less than 1% of the data was edited). Mean HP values were computed for each 30-second epoch and then averaged over each minute of the procedure. The HP values were then converted to heart rate values (beats per minute).

Mean heart rate during the learning and the extinction phase was 155.09 ($SD = 8.97$) and 161.77 ($SD = 10.81$), respectively. The measure of heart rate response to the goal blockage ($Mn = 6.68$, $SD = 10.03$) was defined as the change in heart rate from the learning to the extinction phase. Physiological responses including heart rate and cortisol are subject to the Law of Initial Value (LIV; Lacey, 1956; Wilder, 1956). Here the LIV involves a negative relation between learning level and learning to extinction increase. There was a significant heart rate LIV effect ($r = -.36$, $df = 54$, $p < .008$). To remove this effect, regression analysis was used to obtain a residualized heart rate response measure that was independent of learning level such that the correlation between the residualized measure and learning level was zero. This residualized response measure ($M = 0$, $SD = 1$) was used in the data analysis.

Cortisol—Two salivary cortisol samples were obtained from the infants, the first shortly after arrival at the laboratory before the start of the contingency learning procedure, and the second 20 minutes after the end of the procedure. To collect each sample, an absorbent dental cotton roll was applied to the tongue, cheeks, and gums of the infants. A syringe was then used to express the saliva into labeled test tubes. Usually the application of only one cotton roll was necessary for collection of a sufficient quantity of saliva for analysis. Each sample collection took no longer than 1 minute. Oral stimulants to increase saliva flow were not used so as to avoid any problem with the cortisol assay associated with their use (Schwartz, Granger,

Susman, Gunnar, & Laird, 1998). No infant was fed in the minutes prior to collecting the samples so that milk contamination of the assay was not an issue (Magnano, Diamond, & Gardner, 1989). Samples were immediately refrigerated and then frozen for storage until they were shipped in dry ice to our laboratory (Covance, Chantilly VA) for the cortisol assay. The assay used the Salivary Cortisol Mnemonic 6410 protocol. The assay was run in duplicate for which a minimum sample volume of 100ul was needed. The criterion for re-analysis was a coefficient of variation greater than 20%. The lower limit of quantitation of the assay is .007 µg/dl. The intra- and inter-assay coefficients of variation are both less than 10%. The cortisol data were screened for outlying values defined as any value greater than 3 *SDs* above the mean for a given time point (Gunnar, Mangelsdorf, Larson, & Hertzgaard, 1989; Magano, Gardner, & Karmel, 1992; Lewis & Ramsay, 1995). To maintain the sample size, each outlying value (a total of 5 infants had a single missing value) was replaced by a value that was proportional to the one non-outlying value relative to the mean values for the infants with both samples.

Mean pre- and post-stressor cortisol levels were .70 (*SD* = .35) and .71 (*SD* = .31) µg/dl, respectively. The measure of cortisol response to the goal blockage (*Mn* = .017, *SD* = .44) was defined as the difference (post- minus pre-stressor) between the two cortisol samples. Since there was a significant cortisol LIV effect ($r = -.72$, $df = 54$, $p < .001$), regression analysis was used to obtain a residualized cortisol response measure that was independent of pre-stressor cortisol level. This residualized response measure ($M = 0$, $SD = 1$) was used in the data analysis.

In light of Henry's (1992) and Bauer et al.'s (2002) views on differential autonomic and adrenocortical activation, four groups of infants reflecting the different patterns of high versus low heart rate and high versus low cortisol were identified based on a median split in the heart rate and cortisol response distributions: (1) high heart rate-high cortisol ($n = 17$); (2) low heart rate-low cortisol ($n = 17$); (3) high heart rate-low cortisol ($n = 11$); and (4) low heart rate-high cortisol ($n = 11$).

Time-of-day—In order to accommodate the schedules of mothers and infants, it was necessary for the testing to be done throughout the day (8:45 AM to 6:30 PM). Arrival time at the laboratory was noted in order to examine whether there were differences in heart rate, cortisol, and/or emotional response as a function of time-of-day. There was no relation of arrival time to heart rate response ($r = .17$), cortisol response ($r = -.03$), or anger and sadness response ($r = .05$ and $-.04$, respectively). Therefore, time-of-day was not considered further.

Results

The data analyses addressed the following issues: (1) the interaction of heart rate and cortisol for angry versus not-angry infants and for sad versus not-sad infants; (2) the differential prediction of heart rate and cortisol from anger and sadness, and, conversely, the differential prediction anger and sadness from heart rate and cortisol; and (3) differences in the differential emotional response for the four groups according to the different patterns of high and low heart rate and cortisol (high heart rate-high cortisol, low heart rate-low cortisol, high heart rate-low cortisol, and low heart rate-high cortisol). The data were collapsed across boys and girls because preliminary analyses indicated no sex differences in the relations of anger and sadness to heart rate and cortisol.

The interaction of Heart Rate and Cortisol Response by Anger and Sadness Response

Figure 1a shows mean heart rate and cortisol response for anger. Heart rate was higher for the angry than not-angry infants ($M = .38$ versus $-.23$, $SD = .67$ versus 1.09 , $N = 21$ versus 35 , $F(1, 54) = 5.20$, $p < .03$), while there was no change in cortisol. Figure 1b shows mean heart rate and cortisol response for sadness. Cortisol was higher for the sad than not-sad infants ($M = .62$ versus $-.12$, $SD = 1.26$ versus $.90$, $N = 9$ versus 47 , $F(1, 54) = 4.47$, $p < .04$), while there

was no change in heart rate. The two significant effects follow up on a repeated measures (heart rate, cortisol) ANOVA with two between-subjects factors (angry/not-angry, sad/not-sad) that yielded a significant three-way interaction, ($F(1, 52) = 3.85, p = .055$). Thus, these results indicate that anger was associated with increased heart rate, but not cortisol and that sadness was associated with increased cortisol, but not heart rate.

Heart Rate and Cortisol Response Predicted from Anger and Sadness Response

The preceding analyses compared heart rate and cortisol for infants showing versus not showing anger or sadness. Looking at continuous measures of anger and sadness as they relate to heart rate and cortisol is another way to explore the relation between the emotional and physiological responses. Table 1 shows the results of regression analyses predicting heart rate and cortisol response from anger and sadness response. There were two different regression analyses. One regression predicted heart rate from anger, sadness, and cortisol. The other regression predicted cortisol from anger, sadness, and heart rate. The overall model predicting heart rate from anger, sadness, and cortisol yielded a significant R^2 of .15 ($F(3, 52) = 3.05, p < .04$). Heart rate was predicted by anger ($\beta = .43, p < .008$), but not sadness ($\beta = -.11$). The overall modeling predicting cortisol from anger, sadness, and heart rate also yielded a significant R^2 of .17 ($F(3, 52) = 3.53, p < .03$). Cortisol was predicted by sadness ($\beta = .48, p < .003$), but not anger ($\beta = -.22$).

Anger and Sadness Response Predicted from Heart Rate and Cortisol Response

Similarly, Table 2 shows the results of regression analyses predicting emotional response. There were three different regression analyses. One regression predicted anger from heart rate, cortisol, and sadness. A second regression predicted sadness from heart rate, cortisol, and anger. The final regression predicted the differential emotional response (difference between anger and sadness) from heart rate and cortisol. The overall model predicting anger from heart rate, cortisol, and sadness yielded a significant R^2 of .39 ($F(3, 52) = 10.85, p < .001$). Anger was predicted by heart rate ($\beta = .31, p < .008$), but not cortisol ($\beta = -.17$). The overall model predicting sadness from heart rate, cortisol, and anger also yielded a significant R^2 of .39 ($F(3, 52) = 11.17, p < .001$). Sadness was predicted by cortisol ($\beta = .35, p < .003$), but not heart rate ($\beta = -.08$). The overall model predicting differential emotional response by heart rate and cortisol yielded a significant R^2 of .18 ($F(2, 53) = 5.61, p < .007$). Relatively greater anger than sadness was predicted by both increased heart rate ($\beta = .26, p < .05$) and decreased cortisol ($\beta = -.34, p < .01$).

Thus, the results for the regression analyses predicting physiological from emotional responses (see Table 1) and the regression analyses predicting emotional from physiological responses (see Table 2) are consistent in showing differential relations of anger to increased heart rate, but not cortisol and of sadness to increased cortisol, but not heart rate. The zero-order relations (Pearson r) between the physiological and emotional responses also show the same differential relations of anger to heart rate and sadness to cortisol (see Table 3).

Differential Emotional Response by Pattern of Heart Rate and Cortisol Response

Henry's (1992) and Bauer et al.'s (2002) views suggested examining differential emotional response for the four groups of infants according to pattern of high versus low heart rate and cortisol. Henry's view led to the prediction that particular patterns of high versus low heart rate and cortisol would be related differentially to anger and sadness. Specifically, his view predicts that the asymmetrical pattern of high heart rate-low cortisol would be related to anger and that the asymmetrical pattern of low heart rate-high cortisol would be related to sadness. Figure 2 shows mean differential emotional response for the four groups of infants. Differential emotional response differed between the two groups with asymmetrical autonomic and cortisol activation. There was relatively greater anger than sadness in the high heart rate-low cortisol

group as opposed to relatively greater sadness than anger in the low heart rate-high cortisol group ($M = .60$ versus $-.35$, $SD = .67$ versus 1.27 , $N = 11$ versus 11 , $F(1, 20) = 4.84$, $p < .05$). Differential emotional response was comparable for the two groups with balanced autonomic and cortisol activation ($M = -.06$ versus $-.10$, $SD = 1.05$ versus $.77$, $N = 17$ versus 17 for the high heart rate-high cortisol group and the low heart rate-low cortisol group, respectively). Thus, asymmetrical as opposed to balanced autonomic and cortisol activation was associated with the expression of differential amounts of the two emotions.

Discussion

The present results indicate that anger and sadness in 4-month-old infants' response to goal blockage show differential relations to heart rate and cortisol. Anger was associated with increased heart rate, but not cortisol, whereas sadness was associated with increased cortisol, but not heart rate. The present results as well as previous findings (e.g., Lewis et al, 1990; Lewis & Ramsay, 2005) support the view that infant anger in response to goal blockage involves autonomic as opposed to adrenocortical activation as a consequence of an expectation of control over the event (Henry, 1992). In contrast, sadness in response to goal blockage involves adrenocortical as opposed to autonomic activation stemming from the absence of an expectation of control. Stated differently, the expectation of control leads to anger and autonomic activation, whereas the absence of an expectation of control leads to sadness and adrenocortical activation.

Darwin (1872/1965) proposed that emotions were action patterns of both face and body which were adaptations to particular contexts. Thus, anger and instrumental activity constitute an adaption that may have evolved as part of the action pattern designed to overcome a blockage of a desired goal. In classifying emotions as "exciting" (e.g., anger) or "depressing" (e.g., sadness) that had motivational characteristics, Darwin anticipated recent characterizations of emotions as involving individual differences in the two emotional/motivational tendencies of approach and withdrawal (cf. Davidson, 1995; Harmon-Jones, 2004; Hood, Greenberg, & Tobach, 1995; Schneirla, 1959). In response to goal blockage, approach and withdrawal involve different patterns of facial expression (anger versus sadness), instrumental activity (active versus passive), and physiological responding (leading to energy versus stress) in addition to the presence versus absence of an expectation of control. Following Darwin, we have argued that anger/approach is a more optimal response to goal blockage than sadness/withdrawal. In support of this view, we have found: (a) anger is associated with perceived control and increased instrumental activity to overcome the obstacle, whereas sadness is not (Lewis et al., 1990; Lewis & Ramsay, 2005; Sullivan & Lewis, 2003); (b) anger is associated with increased positive emotion once the obstacle has been removed, whereas sadness is not (Lewis et al., 1992); and (c) anger is not associated with increases in stress (as indicated by increases in cortisol), whereas sadness is associated with stress (Lewis & Ramsay, 2005). If we are correct, then the present results suggest that the pattern associated with anger, high heart rate-low cortisol, is the more optimal physiological response to blockage of a goal, whereas the pattern associated with sadness, low heart rate-high cortisol, is a less optimal physiological response to goal blockage.

Despite Darwin's view and our findings, one could take a more neutral view that both the two emotional tendencies of approach withdrawal are viable responses to goal blockage, with one being no more or less adaptive than the other. Ultimately, evidence that approach is associated with more optimal outcomes than withdrawal would be required to support the claim that the former is the more adaptive response to goal blockage than the latter. With respect to the outcome, we have predicted that approach rather than withdrawal in response to a blocked goal will be related to subsequent differences in goal-directed behavior or determination to complete a task (cf. Lewis & Ramsay, 2005).

In toddlers, determination includes both persistence in mastery situations and resistance in compliance situations (cf. Dweck, 1998; MacTurk & Morgan, 1995; Messer, 1993). In recent work, we have found that the early tendency for approach as opposed to withdrawal in response to goal blockage predicts a variety of determination outcomes at older ages, including persistence on different mastery tasks and examiner ratings of persistent task focus during assessment on the Bayley Scale of Infant Mental Development at 24 months and resistance involving continuing to play despite the mother's request for her child to come sit on her lap at 20 months of age (Ramsay, Sullivan, & Lewis, under review).

There has been disagreement in the infant emotion literature over whether the separate emotions of anger and sadness as opposed to a more generalized negative emotional state (distress, upset) are present in early infancy (Camras, Malatesta, & Izard, 1991; Camras, Sullivan, & Michel, 1993; Lemerise & Dodge, 2000; Lewis, 2000). Our past contingency learning findings suggest that anger and sadness are already distinct emotions as early as 2 months of age (e.g., Lewis et al., 1990; Sullivan et al., 1992). Consistent with our findings, other work has found evidence that anger is already present by 4 months of age (Izard, Hembree, & Huebner, 1987; Stenberg & Campos, 1990; Stenberg, Campos, & Emde, 1983). Results in the present study that anger and sadness are differentially related to heart rate and cortisol provide additional evidence that the two emotions already are distinct involving different states by 4 months of age.

Although the present study examined the relation of emotional and physiological responses to goal blockage using one goal blockage situation with infants at one age, we obtained similar results when we looked at another type of goal blockage. For example, Lewis and Ramsay (2005) compared infants' response to maternal unresponsiveness in the still-face procedure, when infant attempts to maintain interaction with mother following a period of typical interaction were no longer effective. Infant response to the still-face goal blockage was comparable to the response to the contingency learning goal blockage reported here. For both contexts, sadness, but not anger was significantly related to cortisol; the greater the sadness, the higher the cortisol response. This differential relation of cortisol to sadness versus anger is consistent with the hypothesized role of anger, as opposed to sadness, in overcoming blocked goals and validates laboratory observations of individual differences in emotional and physiological responses in a more naturalistic, social context.

Research should examine whether individual infants show the same pattern of emotional and physiological responding over time. In doing so, multiple measures of both autonomic (e.g., heart rate and vagal tone) and adrenocortical activation (e.g., cortisol and dhea) should be used (Bauer et al., 2002). Cross-situation and cross-age consistency in the response patterns would clearly indicate that specific patterns of emotional and physiological responding are characteristic of individual infants.

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Figure 1a and b.

Mean heart rate and cortisol response for angry and not-angry infants and for sad and not-sad infants.

Figure 2. Mean differential emotional response (relatively greater anger than sadness) by pattern of high versus low heart rate and cortisol response.

Table 1
Regression Analyses Predicting Heart Rate and Cortisol Response from Anger and Sadness Response

	Heart Rate	Cortisol
Anger	.43 **	-.22
Sadness	-.11	.48 **
Other Physiological Response (Cortisol or Heart Rate)	.06	.06
R ²	.15 *	.17 *

* $p < .05$,

** $p < .01$, two-tailed.

Table 2
Regression Analyses Predicting Anger and Sadness Response from Heart Rate and Cortisol Response

	Anger	Sadness	Anger - Sadness Difference
Heart Rate	.31**	-.08	.26*
Cortisol	-.17	.35**	-.34**
Other Emotional Response (Sadness or Anger)	.54***	.53***	-----
R ²	.39***	.39***	.18**

*
 $p < .05$,

**
 $p < .01$,

 $p < .001$, two-tailed.

Table 3
 Relations (Pearson r) Between the Physiological and Emotional Measures

	1	2	3	4
1. Heart Rate	----			
2. Cortisol	.05	----		
3. Anger	.38 **	.05	----	
4. Sadness	.14	.37 **	.52 ***	----
5. Anger - Sadness	.24 ⁺	-.33 *	.49 ***	-.49 ***