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Anger, Sad, and Blended Expressions to Contingency Disruption in Young Infants

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Abstract

Three studies elicited young infants' (aged 17–23 weeks) anger and sad facial expressions during brief contingency disruptions to explore their potential organization over time as a bi-phasic process. Study 1 examined partial correlations among anger, sad, blended anger/sad, and neutral expressions during extinction in three extant, independently-recruited samples. Across samples, all three negative expressions were inversely related to neutral expressions, but anger and sad expressions were not significantly correlated when anger/sad blends were controlled. Study 2 compared expressions during contingency and disruption minutes in two groups: one in which the disruption was an extinction phase (absence of the formerly contingent event), or one in which the disruption was noncontingent presentations of the stimuli. Study 3 examined expression trajectories over time in two contingency and extinction sessions. Independent trajectories of anger and sad expressions occurred over time in Studies 2 and 3. Extinction and noncontingency differed in sad expression. The relation between expressions and blends also varied over time.

Recognizable facial expressions can be observed shortly after birth (Rosenstein & Oster, 1988; Fox & Davidson, 1988). Basic human facial expressions (enjoyment, surprise, anger, sad, and disgust) can be elicited in standard laboratory contexts by 4 months of age, although individual differences are apparent. Processes governing the occurrence of anger and sad facial expressions in infancy are still poorly understood, however. Anger expressions to arm restraint occur between 4–7 months, and both anger and sad expressions occur in response to contingency disruption at 2, 4, 6, and 8 months with stability in expression level apparent over at least a two-month-interval (Lewis, Sullivan, & Alessandri, 1990; Stenberg & Campos, 1990; Sullivan, Alessandri, & Lewis, 1992). The consensus in the literature on infant expressions is that neither specific expressive movements, nor facial expressions (regularly occurring, recognizable clusters of specific expressive movements) have a one-to-one correspondence to underlying, unique emotional states (Camras & Fatani, 2008; Camras & Shutter, 2010). A related view is that negative emotions are not well-differentiated in infancy. This stands in contrast to neurophysiological findings suggesting that categorical emotion patterns are detectable in adults (Wager et al., 2015) and that even among adults, differentiation of negative emotion varies among individuals, with poor differentiation associated with greater emotional/psychological risk (Starr, Hershenberg, Li, & Shaw,

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2017). When and if differentiation of negative emotion states, as opposed to expressions, arises in infancy is an open empirical question, however, the hypothesis of poor differentiation of young infants' facial expressions rests on limited data.

The poor differentiation hypothesis is supported by two types of data: First, studies show that negative facial expressions are not contextually specific. For example, arm restraint elicited primarily anger but not sad or fear expressions; however, anger expression also occurred in negative contexts unrelated to goal blockage or restraint, as in response to a novel, growling mechanical toy (Camras & Shutter, 2010). Second, blended components of anger and sad, as well as other expressions, are commonly observed in many situations designed to elicit negative emotion (Bennett, Bendersky, & Lewis, 2002; Camras et al., 2007). This finding is cited as evidence that negative expressions are either variants of undifferentiated distress or that expressions are somehow assembled through dynamical processes rather than organized, whole-face expressions (Camras & Fatani, 2008).

Studies of expressions during extinction (the abrupt blockage of access to a previously contingent stimulus) have reported predominantly anger expressions in 2–6 month-old infants that are distinct from sad expressions (Crossman, Sullivan, Hitchcock, & Lewis, 2009; Lewis, et al, 1990; Sullivan et al., 1992; Sullivan & Lewis, 2003). In contrast, negative expressions occur infrequently during the contingency phase. Moreover, negative expressions during contingency are associated with nonlearning and less soothable temperament (Lemelin, Tarabulsy, & Provost, 2002; Sullivan, 2016). Rather than assume that anger, sad, and anger/sad blended expressions support limited differentiation of negative expressions, we hypothesized that their occurrence within extinction results from neurophysiological processes governing their trajectories over time. Specific expressions are not assumed to be emotion states, but readouts of neural processes related to emotion processes of approach and withdrawal (Sullivan, 2014). Expression trajectories, except for smiling, have been unexplored in infancy (Brackbill, 1958; Emde & Harmon, 1972). Our studies explored whether and how anger and sad expressions occurring within the same context vary over time and with variation in contingency disruption.

The methods used to study situational specificity of expression in young infants do not lend themselves readily to study of expression trajectories over time because the eliciting contexts are typically very brief. For example, both Camras' (2007) and Bennett's (2002) teams examined emotion-eliciting contexts, ranging from 20 seconds or less to one minute. The dependent measure was the number of infants showing various expressions to each context. Thus, the published data focus on the initial incidence of specific expressions in a few infants and not on whether or how expressions vary over time. In studying whether expression to specific contexts changed with development, anger expressions to arm restraint were observed to increase between 4–12 months, as did blended expressions, with individual differences showing some stability (Bennett, Bendersky, & Lewis, 2005). While the organization of expressions within context appeared to change with age, an 8-month interval between observations does not allow any conclusions about expression trajectories following initial occurrence. Trajectories of expression observed over shorter and longer time periods should be revealing of relations between expressions and might provide evidence of their

underlying organization. In Study 3, we examined a session repeated after a one week interval.

The bi-phasic or opponent emotion process model is a respected hypothesis addressing change in motivated states over time (Solomon & Corbit, 1974; Solomon, 1980). It may offer a plausible account of the occurrence of anger, sad, and blended expressions in context as well as prediction of expression trajectories over time. The model proposes that any given emotion process (*a*), once elicited, will decline over time. As it declines, the *a*-process will concurrently elicit an opposite-valence process (*b*). The *b*-process increases slowly, eventually masking the declining *a*-process. The *b*-process in turn decays until the net result is a return to homeostasis. Opponent processes explain many emotional and motivational phenomena including human attachment, separation and grief, addiction, and bingeing (Radke, Rothwell, & Gewirtz, 2011; Solomon, 1980). Although the opponent process model was conceived within a valence, rather than a directional (goal approach/withdrawal) framework of emotion, a bi-phasic process might also account for transitions between a high arousal emotion (anger) and a low arousal emotion (sadness/distress) during extinction in young infants. Consistent with this interpretation, anger and distress emotion in tantrums appear to be organized as a bi-phasic process in older children (Potegal & Davidson, 2003; Potegal, Kosorok, & Davidson, 2003; Potegal, 2005). Anger (the *a*-process) and distress-withdrawal (the *b*-process), were both involved in tantrum behavior of toddlers. Anger rose rapidly in response to a blocked goal or thwarted desire, but gradually declined. As it did, the sadness/distress increased, remaining in evidence until children eventually calmed. We hypothesized that infants' facial expressions may be organized this way as well. Oster's (2005) suggestion that the sad expressions of young infants may be attempts at distress regulation is also compatible with this view, although like Camras, she asserted that neither anger nor sad movements should be considered as whole face expressions, but rather as variants of unorganized distress or "cry faces".

A reasonable extension of the bi-phasic hypothesis is that blended anger/sad expressions might reflect the transition between anger (proposed *a*) and sad (proposed *b*) processes. Alternatively, even if they are not bi-phasic processes, anger and sad expression components might be more likely to be co-activated when the context is ambiguous. When access to an expected goal becomes disrupted suddenly, such as during extinction, competing action tendencies to either continue responding (approach) or to give up (withdraw) may arise until it becomes clear that regaining the goal is impossible. In either case, we propose that trajectories of anger, sad, and blends of these expressions within the same context in early infancy may be more organized than currently thought. With longer or repeated observation time, trajectories suggesting either bi-phasic processes or transitions between expressions may be evident.

Contingency learning and extinction methods offer a suitable procedure for examining expression change over time in early infancy. The developmental period between 4–6 months follows the decline in subcortical reflexes at the end of the first quarter-year and is characterized by the rise of voluntary movement (Rovee-Collier & Lipsitt, 1982). The medial and lateral aspects of the prefrontal cortex show functional activation during this period as well, earlier than previously thought (Grossman, 2013). Periods of alertness are

longer. Habituation and learning are more reliable. Affective processes are likely impacted by these changes. Thus, early expression trajectories may be reliably observed at this age during contingency learning and disruption. Extinction phases in infant learning studies at this age typically last on the order of minutes, rather than seconds. However, extinctions of this length typically do not lead to complete cessation of contingent responses in a single session. Significant declines in behavior during extinction have been reported in studies wherein extinction behavior was observed over multiple sessions (Rovee-Collier & Gekoski, 1979; Crossman et al., 2009). Although extinction elicits negative expression initially, presumably repeated extinction experiences will be accompanied by an eventual decline in anger expressions as infants learn not to respond over time. The trajectory of sad expressions in this case is unclear.

This paper presents three investigations of anger, sad and blended expressions during contingency learning and its disruption in early infancy. We explored how time affected expression trajectories and whether the observed changes in expression levels over time were consistent with bi-phasic processes within and across sessions. We also examined noncontingency as an alternate form of contingency disruption. Exposure to noncontingency following contingency has been shown to lead to increases in both anger and sad expressions (Sullivan & Lewis, 2003) and has been associated with helpless distress in animals and children (DeCasper & Carstens, 1981; Maeir & Selipman, 1976; Wortman & Brehm, 1975). Noncontingency thus afforded an opportunity to test whether introducing uncertainty about a formerly contingent event altered expression trajectories relative to extinction, where the loss of stimulation is clear, and whether sad expressions, which mark distress, would increase. The overarching hypothesis across the studies was that differentiated trajectories of anger and sad expressions would be observed over time and condition. Sad expressions were expected to increase with noncontingency extinction and experience, while anger expressions were expected to remain stable across disruption types and a repeated experience.

General Methods

The datasets in this report included infants recruited from the population pool surrounding our university. All infants were tested in the same laboratory using a standard contingency learning procedure, except as noted in Study 2. Infants were included in the studies if they individually met a minimum learning criterion, defined as sustaining an average pulling rate during the contingency phase of at least 15% above their average baseline rate (See Crossman et al., 2009; Sullivan & Lewis, 2003). Each study had a different team of facial coders, but all coders received standard training and met a minimum standard of reliability (.85).

Participants

Healthy infants born in two university-affiliated hospitals participated in each study. All studies had IRB approval to recruit mothers in the maternity unit shortly after delivery. A follow-up telephone call to those who expressed interest in participation was made when infants reached the appropriate age. The procedures were reviewed again at the lab visit

when parents signed the consent form. Participating families were offered reimbursement for transportation and received a gift pack of infant toiletries for their participation. Participating infants were free of birth complications or known sensory and neurological deficits. They were full-term, between 37–41 weeks gestational age. Exact age and diversity statistics are reported with each study.

Procedures

Learning lab.—Sessions occurred in a three-sided booth with infants situated in an infant seat. The seat was placed approximately 62 cm from a monitor screen (43 cm) mounted on the rear wall of the booth. Auditory feedback was delivered via the monitor's speakers. Sessions were scheduled at a time of day when mothers expected that their infants would be alert and playful. Pulling responses were recorded online by an elastic terrycloth band placed on each infant's right wrist. The band was connected via a ribbon to a leaf switch (Zygo Industries, CM-2) mounted behind the booth directly below the screen. With a pull of the ribbon toward the body with sufficient force, a colorful image of a happy baby appeared, accompanied by a 3-second recording of children's voices singing the *Sesame Street* theme song. Infants' pulling also controlled the delivery of the slide and music. The ribbon had sufficient slack, so that hand to mouth activity would not produce the audiovisual event. A color video camera, mounted below the screen, continuously recorded infants' facial movements during all sessions. A time record was recorded simultaneously for subsequent use in coding facial behaviors.

Parents (usually the mother) were instructed to place their infants in the infant seat in front of the screen and place the terrycloth band on the infant's right wrist. They sat out of camera view behind their infant throughout the sessions. They were instructed to speak to reassure their infant if the baby fussed. They were told they could terminate the session at any time if they felt the infant was too upset by just saying so, and that some fussing and crying was likely at the end of the procedure, when the "slideshow" would be turned off (or disrupted as in Study 2). No parent exercised this option.

Sessions consisted of three phases: baseline, contingency learning, and contingency disruption. A 2-minute non-reinforcement phase, *baseline*, assessed the operant level of pulling responses without additional stimulation. This was followed by a 6-min *contingency* phase, during which each response activated the 3-s audiovisual display. This time interval is sufficient to observe learning in the pulling task, but is brief enough to minimize boredom or crying (Crossman, et al., 2009; Lewis & Sullivan, 1989; Sullivan & Lewis, 2003). Following this, infants experienced another 2-min phase in which pulls were no longer reinforced; i.e., the *disruption* phase. In Studies 1 and 3, this was 2 minutes of extinction. In Study 2, it was 2 minutes of either extinction or of noncontingency (See Study 2 for additional detail). If infants cried continuously for more than 60 seconds during any part of the procedure, the session was terminated for that day. Regardless of performance in the first session, all participants in Study 3 were invited to return to the lab for a second session, approximately one week later ($M = 1.39$ w, $SD = .61$).

Facial expression coding.—Different, trained teams of two coders evaluated expressions during selected minutes of the contingency and disruption phases in each study. Expressions during the contingency phase were coded during the middle minutes of contingency session. These minutes were selected because previous studies identified this time as a period of accelerated responding on average, accompanied by generally positive expressions and little negative expression (Sullivan & Lewis, 1989; Sullivan, et al., 1992): Thus, it offered a contrast to the final disruption phase.

Expressions were coded only when the infant's head was within 45° of forward facing. Recordings were advanced to the selected minute and each 1-min segment was scored second-by-second without sound. Using the Maximally Discriminative Facial Movement Coding System—MAX (Izard, 1995), anger and sad expression components, or neutral were scored in the upper and lower facial regions in independent passes through the recording. Neutral expressions were included in Study 1 as measure of the infants' continued interest in the contingency event. It was coded when there was no visible movement in a facial region while the infant was looking at the stimulus source, giving the infant a sober, but not sad, angry, or distressed appearance. The regional codes were tallied across each minute using a macro which compiled expressions according to MAX formulae. Appendix A lists the MAX movement codes used to compile expressions and provides a verbal description. Expressions were then tallied as neutral/sober, full or partial MAX-anger, full or partial MAX-sad, or blended anger/sad expressions. Inclusion of partial face expressions insured that expressions of at least moderate intensity were scored. Expressions which included MAX-anger codes in the upper face and MAX-sad codes in the lower face were categorized and tallied as anger/sad blends. Expressions which included MAX-sad codes in the upper face and MAX-anger codes in the lower face occurred rarely and so were not examined further. Single movement codes were not counted.

All coders were trained on a previously scored set of videos as well as pre-coded stills of infants from earlier learning studies. Coders first established reliability on each facial region (85% inter-rater agreement). Reliability of coding was subsequently checked in each study by having coders independently code 15–25% of randomly selected recordings, ensuring that coding was reliable and significantly above chance in all studies. Coders were unaware of the hypothesized relations between expressions or the hypotheses of the particular study.

Study 1

This study is a secondary data analysis of previously published data examining correlations between anger, sad expressions, and a specific anger/sad blend during extinction across three independent samples. Mean ages and standard deviation of each sample are reported in Table 1. The samples were predominantly White/European ancestry (60–95%). The ethnicity of minority participants varies by sample as the studies were conducted over a 10-year period. Sample A (Extinction Group, Study 2, Sullivan & Lewis, 2003) included 40% minority participants (primarily Black and Hispanic) and 48% female infants. Sample B (a subset of participants from Sullivan, 2016 for whom expressions were coded) included 35% minority participants, primarily Black and Asian, and 55% female infants. Sample C (Lewis, Hitchcock & Sullivan, 2003) included 5% Asian-American and 52% female infants. The aim

of this analysis was to assess the stability of the relations between anger, sad, anger/sad blend, and neutral expressions across datasets. If blended expressions represent transitional expressions between anger and sad, as opposed to random occurrences, we hypothesized that the observed relations of blended expressions to the other expressions would be similar across studies, and that controlling for blended expressions would reduce the correlation between anger and sad expressions.

Data Analysis Plan.

The total level of each expression was computed over the two minutes of extinction in each study. Correlational analyses assessed the relations between MAX-anger, MAX-sad, and anger/sad blended expressions. Neutral expressions (sober attention to the screen) were examined to observe their relations with the negative expressions. Partial correlations assessed whether controlling for anger/sad blends affected the relation between expressions. Differences between the observed correlations in each sample were tested to assess their reliability across the samples.

Results and Discussion

Table 1 shows the bivariate and partial correlations between the four MAX-coded expressions during extinction and *N*'s for each of the three samples. Across all three samples, there was a modest positive correlation between anger and sad expressions when anger/sad blends were uncontrolled (r 's = .21 to .24). Anger/sad blends were related to each MAX expression. MAX-anger expressions and blends were negative and consistently significant (r 's = -.45, -.51, and -.46, all p 's < .01). In contrast, correlations with MAX-sad expression tended to be of lesser magnitude and were inconsistently significant (r 's = -.25, -.26, both p 's $\leq$.05, and -.21, p > .06). When the shared relation among expressions was controlled by partialling out anger/sad blends, the relation between anger and sad expression was reduced to nonsignificance in each dataset (r 's = .17, .18, and .12 all p 's > .06). Although the decrease in correlation was not significant in any dataset, this pattern was consistent across all three samples, with no significant difference in the magnitude of the correlations between the studies.

Neutral/sober expressions showed consistent, modest negative relations with anger/sad blends (r 's = -.40, -.35, both p 's < .01, and -.15, p = .20) and significant positive relations with MAX-sad expression (r 's = .32, .37, .28, all p 's < .05). Controlling for the blended expression, neutral/sober expression was negatively related to both MAX negative expressions, with its relation to MAX-anger being significant across the three samples (see Table 1). Consistently negative, but inconsistently significant relations were observed between MAX-sad and neutral/sober expressions after controlling for blends. The reversal of correlation when blends were controlled is likely a function of the negative correlations of blends with MAX-sad and MAX-anger in the uncontrolled data and suggests that the amount of neutral/sober looking decreases with increasing negative expression, especially MAX-anger. Given that controlling blends resulted reduction of significant relations between anger and sad facial expressions, subsequent studies of expression over time included blends as a covariate. In this way, the independent trajectories of anger and sad expressions over time could be examined.

Study 2

This study of 172 infants ($M = 23.07$ w, $SD = 2.04$; 50% female; 62% were of White/European descent; 7% Black; 8% Hispanic; 13% Asian; and 10% Other/Unknown) sampled negative expressions during the mid-point of contingency acquisition (when arousal was likely to be high, but not negative in tone) and two minutes of contingency disruption. Disruption was defined as either brief exposure either to extinction or to noncontingency, an event previously reported to lead to increased sad as well as anger expression (Sullivan & Lewis, 2003). The randomized groups did not differ significantly in either age or gender; Age: $F_{1, 171} = 0.01$, $p = .94$; Gender: $\chi^2 = 1.19$, $p = .14$. We hypothesized that the sad trajectory would differ by disruption condition, but the anger trajectory would not, suggesting the potential for the differentiation of these expressions.

Facial data from Contingency Minutes 4 and 5, and 2 minutes of its disruption (Disruption 1 and 2) were examined. Half of the infants were randomly assigned to receive either extinction (see General Methods) or noncontingency after the contingency phase ($N = 86$ per group). Following Sullivan and Lewis (2003), infants in the noncontingency group received slides and music independent of their pulling. The number of presentations was equal to each infant's pulling rate in the final 2 minutes of the contingency phase. They were distributed in a random pattern throughout each minute, with the exception that presentation was delayed for three seconds if a pulling response had just occurred. This delay represents the limit of contingency memory at this age (Watson, 1979). Anger, sad, and blended anger/sad facial expressions were coded blind to the condition of assignment.

Data Analysis Plan.

To maintain randomization and sample size, pulling and expressions of infants who cried to criterion short of 2 minutes of disruption (3 in the extinction group and 5 in the noncontingent group) were prorated based on the immediately prior 30 seconds of data. Analyses were conducted with and without the missing data to ensure this data treatment did not affect the pattern of results of the pulling or expression data. Mean pulling data over all session minutes were inspected and subjected to preliminary repeated measures analysis. We also calculated a disruption score to reflect the degree to which pulling was sustained above baseline in each group (average pulling during extinction/average baseline). This score was used subsequently to rule out whether changes in pulling influenced expressions during extinction.

The main analysis focused on facial expressions. A repeated measures MANOVA was conducted over four minutes (2 contingency, 2 disruption). MAX-coded anger and MAX-coded sad expressions were the repeated measures over minutes and Disruption Group (extinction versus noncontingency) was the between factor. Anger/sad blended expression was the repeated covariate. The multivariate effects were evaluated using Wilk's Lambda. Alpha levels were set at .05 for all univariate analyses. Within subject effects are reported using Greenhouse Geisser-adjusted values as sphericity assumptions were violated for both anger and sad expressions. Bonferroni correction was used for multiple planned, pairwise comparisons to determine whether negative expressions during disruption minutes differed from those observed during contingency minutes, overall and within each group.

Results and Discussion

Learning.—Summary learning metrics are presented in Table 2. Full learning curves are presented in Supplemental Figure 1. Average baseline response, learning ratio (average contingency response/baseline), and disruption ratio (average disruption response/ baseline) are shown for each group. The learning ratio confirmed that both groups were performing well above the minimum criterion of 1.15 and that, as expected, both groups were above baseline during the disruption phase. The disruption ratio indicated the Extinction Group pulled at more than twice their baseline during this phase. In contrast, the Noncontingency Group pulled at a lower rate. Minute by minute analyses confirmed that there was a strong increase in pulling across the contingency minutes; $F_{8, 897.38} = 5.42$, $p < .001$, $partial\ Eta^2 = .03$. Groups did not differ during baseline or learning (both p 's $\geq .92$).

There were no group differences in disruption ratio. The percentage of infants increasing or decreasing pulling during this phase did not differ significantly by *Chi* square; 63% of the Extinction and 57% of the Noncontingency Groups decreased pulling, *Fisher's exact* $p = .43$. Collapsing the two groups, correlations between expressions and the disruption ratio were not significant: r 's = .03, $p = .73$ and .05, $p = .52$ for MAX-anger and MAX-sad, respectively. Controlling for blended expressions did not alter these relations. Thus, changes in the pulling response during the disruption phase were unrelated to expression level.

Anger and sad expressions.—Figure 1 shows the trajectory of each of the two MAX-coded expressions over minutes for the two Disruption Groups adjusted for the level of anger/sad blends. MAX-anger varied significantly over minute; $F_{3, 329.19} = 14.18$, $p < .001$, $partial\ Eta^2 = .08$, power = .99. MAX-sad did not; $F_{3, 329.19} = 1.73$, $p = .17$. The main effect of Group was not significant ($F_{1, 165} = 0.95$, $p = .39$) but there was a significant Minute by Group interaction for MAX-sad expressions; $F_{1, 376.52} = 3.12$, $p = .04$; $partial\ Eta^2 = .02$, power = .65.

The increase in MAX-anger from learning to disruption minutes (Figure 1a) was linear with significantly less MAX-anger during contingency, than disruption minutes; $F_{1, 33.48} = 26.83$, $p < .001$, $partial\ Eta^2 = .17$. Planned, pairwise comparisons indicated there were significant *M* differences between contingency and disruption minutes ranging from -0.22 ($SE = 0.52$) to -3.84 ($SE = 0.58$), all p 's $< .001$. Disruption minutes 1 and 2 also differed significantly, with a mean increase in MAX-anger expression of 1.14 across minutes, $p = .04$.

MAX-sad did not show a linear change, $F_{1, 104} = 3.07$, $p = .08$, but varied by Group as noted above. MAX-sad expressions (Figure 1b) occurred at low levels during the contingency minutes, increasing only when the disruption was due to noncontingent stimulation. Planned pairwise comparisons of MAX-sad expressions during noncontingency indicated only that Disruption Minutes 1 and 2 each had significantly more MAX-sad expressions than Contingency Minute 5; the increases in each minute respectively were 0.42 ($SE = .13$) and 0.26 ($SE = .10$), p 's = .01 and .05. When the disruption was due to extinction, MAX-sad expression level did not differ significantly from that observed during the two contingency minutes; the changes relative to Contingency Minute 5 in this condition were .07 ($SE = .19$, $p = .07$) and .11 ($SE = .15$, $p = .38$), respectively.

Blended expressions.—Anger/Sad Blend was a significant covariate of MAX-anger, but not MAX-sad, only in minute 5; $F_{3, 33.48} = 2.99$, $p = .03$, $\text{partial } \eta^2 = .08$. Conversely, during both disruption minutes, anger/sad blends were a significant covariate of MAX-sad: Disruption Minute 1, $F_{3, 33.48} = 6.85$, $p < .001$, $\text{partial } \eta^2 = .04$, power = .93; Disruption minute 2, $F_{3, 33.48} = 4.92$, $p = .01$, $\text{partial } \eta^2 = .03$, power = .85. Blends were not a significant covariate of MAX-anger during either disruption minute, p 's = .65 and .10, respectively.

The significant increase in anger expressions to contingency disruption and the significant increase of sad expression to noncontingency (See Figure 1) replicated the findings of Sullivan and Lewis (2003), although in that study, anger/sad blend expressions were uncontrolled. The anger/sad blend expression, with its differing relations dependent on phase and minute, suggested that blended anger/sad expression might mark a transition from anger to sad expressions only during disruption. While lower levels of anger were associated with blended expressions during the contingency (minute 5 only), its correlation with sad expression, but not anger, during both disruption minutes (1 and 2), supported the hypothesis that anger/sad blends may be related to the occurrence of sad expressions. However, noncontingency may represent a unique context for eliciting sadness, so we sought to replicate this finding in a study that examined expressions with a repeated extinction experience. Presumably an additional extinction experience would provide more opportunity to observe sad expressions relative to anger and allow more time to observe changes in the hypothesized *a*- and *b*-processes.

Study 3

We observed MAX-anger and MAX-sad expressions during extinction in a second contingency session. Anger, the hypothesized *a*-process, was expected to rise significantly during extinction minutes replicating previous studies, while sad expression, the hypothesized slower *b*-process was expected to show an increase only in the second session.

The 97 infants (M age = 22.8 weeks $SD = 1.93$, 50% female; ethnicities: 55% were of White/European ancestry, 8% Black, 17% Hispanic; 3% Asian; 17% Other/Unreported) were part of a larger study examining the impact of early maternal interaction on approach and withdrawal emotions (Lewis, Sullivan, & Kim, 2015). Those included in this analysis ($N = 86$, 43% female) completed two identical six-min learning sessions with a 2-min extinction conducted one week apart ($M = 1.39$, $SD = 0.55$). Of the final sample, sixty met the learning criterion in Session 1; 26 met it in both sessions. Infants who cried to criterion during Session 2 (11) were excluded from the analysis. Infants who met the learning criterion only in Session 2 (15) also were excluded to insure equivalent contingency experience in Session 1 consistent with the prior studies. Additional excluded infants were those with parent-identified sensory concerns or suspected developmental issues ($N=5$).

Data Analysis Plan.

Preliminary analyses examined pulling and summary learning metrics were calculated for each Session (See Table 2), followed by minute by minute analysis to determine whether sessions differed in contingency response. Following this, the main analyses focused on

facial expression. A repeated measures MANOVA was conducted over 6 minutes, three in each session (Session 1 Contingency Minute 5, Extinction Minutes 1 and 2, and Session 2: Contingency Minute 5, Extinction Minutes 1 and 2). Contingency Minute 4 was not included in this study because none of the negative expressions were observed in this sample during this minute. MAX-anger and MAX-sad expressions were the repeated measures over minutes and anger/sad blend was again the repeated covariate. Gender was entered as a between subject factor, but is not discussed further as there were neither a significant main effect nor gender by minute interaction; $F_{18, 150} = 1.29, p = .19$ and $F_{36, 275.30} = 1.99, p = .11$, respectively. As before, the multivariate effects were evaluated using Wilk's Lambda. Alpha levels were set at .05 for all univariate analyses, and within-subjects effects are reported using Greenhouse Geisser-adjusted values as sphericity assumptions were violated. Bonferroni correction was employed for the planned, pairwise contrasts of contingency and disruption minutes.

Results and Discussion

Learning.—Pulling data and the disruption ratio for Study 3 are presented in Table 2. Infants were well above the minimum learning criterion in both sessions. The disruption ratio in Session 2 did not differ significantly from Session 1. Repeated measures analyses over all minutes and sessions confirmed that pulling showed a significant quadratic trajectory overall with an increase in pulling across all contingency minutes, followed by a decline in extinction; $F_{quadratic} = 13.13, p = .001, partial\ Eta^2 = .24, power = .99$. There was no main effect of session ($F_{1,84} = 0.90, p = .34$), gender ($F_{1,84} = 0.22, p = .64$), or an interaction ($F_{1,84} = 1.56, p = .22$).

To rule out that the amount of pulling contributed directly to any observed changes in expression, we used backward stepwise regression. Because we had no specific hypothesis about which pulling metric might be associated with expression change, this method allowed us to evaluate a series of models, successively reducing to smallest set of metrics that provided the best overall fit to expression change. Change in each facial expression was calculated as the difference between the final Extinction Minute 2, Session 2 and Session 1 Contingency Minute 5. The MAX-anger and MAX-sad change scores were tested as outcome variables in separate regressions. Each regression modeled the relations of gender, Session 1 Learning ratio, Session 2 Learning ratio, Session 1 disruption ratio, and Session 2 disruption ratio on the change in each MAX-coded expression. Each backward regression began with a full or saturated model and the learning and expression variables were eliminated in an iterative process with the fit of the model tested after each step. The analysis was complete when no more variables were eliminated. When MAX-anger expression was the outcome, none of the models were significant at any of the five steps (Final model: $F_{1, 85} = 1.31, p = .26$). When MAX-sad expression was the outcome, none of the models was significant at any of the five steps (Final model, $F_{1, 85} = 1.26, p = .27$). Thus, any observed changes in MAX-expressions from contingency to final extinction were not explained by changes in pulling response, consistent with Study 2.

Anger and sad expressions.—Figure 2 shows the change in MAX-anger and MAX-sad expressions over Contingency Minute 5 and the two Extinction minutes during each session,

controlling for anger/sad blended expressions. Note that sad expressions are plotted on a separate axis as anger expression was the more prevalent expression. The overall effect of Minute was significant for MAX-anger, $F_{3,56,370} = 5.69$, $p < .001$, $partial\ Eta^2 = .07$, power = .99 but not for MAX-sad expressions, $F_{2,45,370} = 1.74$, $p = .08$.

MAX-anger expression showed linear change over minutes: $F_{1,83,23} = 19.61$, $p < .001$, $partial\ Eta^2 = .21$, power = .99. Session 1 Contingency Minute 5 was lower in anger than all subsequent disruption minutes. Pairwise comparisons indicated significant mean differences ranging from -3.85 ($SE = .94$), $p = .01$ in Session 1, Disruption Minute 1 to -6.28 ($SE = .99$), $p < .001$ in Session 2 Disruption Minute 2; $p = .001$. There was no significant difference in MAX-anger by Disruption Minute in Session 1, but MAX-anger increased during Session 2, from Disruption Minutes 1 to 2 ($M = 2.38$, $SE = 1.08$), $p = .05$.

MAX-sad expression did not vary by Minute in Session 1 ($F_{1,83,23} = 1.90$, $p = .16$). In contrast, significantly more MAX-sad expressions occurred in each extinction minute during Session 2 compared to Session 1 Contingency Minute 5. The mean differences were: Session 2 Extinction Minute 1, $M = 1.23$, $SE = .36$, $p = .01$ and Session 2 Extinction Minute 2, $M = 1.36$, $SE = .51$, $p = .03$. MAX-sad expression increased within Session 2. It was greater in Session 2 Extinction minutes compared to Contingency Minute 5: $M = 1.42$, $SE = .35$, $p = .04$ and $M = 1.55$, $SE = .48$, $p = .03$, respectively. However, the two Extinction minutes did not differ, $p = .99$.

Anger/Sad blends.—The level of the anger/sad blend in Session 1 ranged from $M = 0.10$ ($SE = .06$) in Contingency Minute 5 to 3.32 ($SE = 0.90$) and 4.1 ($SE = 1.11$) for Extinction Minutes 1 and 2, respectively. In Session 2, it ranged from $M = 0.05$ ($SE = .04$) in Contingency Minute 5 to 2.61 ($SE = 0.88$) and 3.26 ($SE = .90$) for Extinction Minutes 1 and 2, respectively. Overall, anger/sad blend was not a significant covariate of MAX-anger or MAX-sad during Contingency minute 5 in either session; Session 1: $F_{1,83,23} = .28$, $p = .74$ and Session 2: $F_{1,83,230} = 1.70$, $p = .19$. However, the Minute by Blend interaction was significant for the Extinction minutes; $F_{10,65} = 18.92$, $p < .001$, and $F_{10,65} = 18.92$, $p < .001$, respectively, $partial\ Eta^2 = .70$; power $> .99$. During Session 1 Extinction minutes, blends were a significant covariate of MAX-anger; $partial\ Eta^2 = .04$ and $.09$; power $.70$ and $.95$, respectively. Blends were not a significant covariate of MAX-anger in the two Extinction minutes of Session 2, however (p 's = $.26$ and $.41$). In contrast, anger/sad blends were a significant covariate of MAX-sad during both Session 1 extinction minutes, both p 's $< .001$, $partial\ Eta^2 = .21$ and $.10$; power = $.98$ to $.79$, respectively. Likewise in Session 2, significant co-variation was observed during extinction, both p 's $< .001$. Effect sizes ($partial\ Eta^2$) were $.04$ and $.26$, power = $.99$ to $.97$, respectively.

DISCUSSION

This paper explored trajectories of anger, sad, and a blend of these two expressions, observing their incidence over minutes and with repetition of the context. We sought preliminary evidence that trajectories of infants' anger and sad expressions in the same context might suggest a bi-phasic process and that blended anger/sad expressions might reflect dampening of the anger expression (the α -process) as part of a transition to sad

expression (the *b*-process). Contingency disruption was used as the eliciting context to explore this hypothesis, given that learning and extinction procedures are one of the better documented contexts in which these expressions can be elicited reliably in early infancy. The studies in this paper were necessarily limited by the need to keep contingency disruptions (extinction and noncontingency) relatively short to avoid unnecessarily stressing infants. However, the procedures were standardized, replicable, and permitted preliminary consideration of the biphasic hypothesis.

Study 1 established that anger/sad blends were not random variation in coding, but had consistent relations with both MAX-anger and MAX-sad expressions across several independently recruited and coded samples. This study demonstrated that both MAX expressions had consistent and, in the case of anger, significant associations to neutral/sober interest, an expression of low, positive engagement, when the shared relation with blended anger/sad expressions was partialled out. When blends are controlled, sober/neutral interest is inversely related to both negative expressions. The positive relation observed in the uncontrolled data may reflect only increased arousal levels. Importantly, Study 1 demonstrated the need for controlling for these blended expressions to assess clearly the trajectories of anger and sad expressions.

In the minute by minute data, when the blended expression was covaried, the results of Study 2 and the covariation pattern of Study 3 suggested that anger/sad blended expressions during extinction were more associated with sad expressions than anger. Blended expressions were a significant covariate of sad expressions, but not anger, only during disruption minutes in both studies, supporting Study 1 findings. In Study 3, anger/sad blends were a significant covariate of anger and sad expressions during Session 1 extinction, but not in Session 2. The more consistent association of blended and sad expressions over time during extinction needs replication since so little is known about sad and blended expressions in infancy.

An unexpected finding in Study 2 was that blended expressions covaried with anger expressions during Contingency Minute 5, but this effect was not replicated in Study 3. The reasons for low levels of MAX- anger and blended expressions during mid-contingency learning are unclear. In retrospect, low levels of anger/sad blended expression, co-occurring with low levels of anger expression in the context of a positive incentive event is reasonable given the rising arousal and effort of infants during contingency learning. Blends have been hypothesized to reflect dampening of anger (Oster, 2005) and this may explain their function during the contingency phase. The inconsistency in correlation across studies may reflect individual differences in the tendency to express and/or to dampen anger as the sample sizes were the same.

Study 2 demonstrated that anger expression trajectories in response to two forms of disruption (extinction versus noncontingency) were similar. MAX-anger expressions rose across the disruption minutes regardless of the type. This supports the view that anger expressions are likely to occur to disruption generally. In contrast, increased sad expression was characteristic of noncontingency as opposed to extinction, as previously reported in Study 1 of Sullivan and Lewis (2003) and other studies which have linked sadness or

helpless distress with exposure to noncontingent events (Seligman, 1975; Wortman & Brehm, 1975). Although Sullivan and Lewis (2003) replicated pulling, but not expression differences, in response to noncontingency in their second study, this study with its larger sample size and control of blended expressions, supports the original finding and showed that sad expressions remained relatively stable across contingency and extinction minutes. Interestingly, Potegal et al. (2009) also reported that once sad/distress behaviors appeared within the tantrum-like outbursts of preschool aged, clinically referred children, they remained stable. It appears that a noncontingency experience following contingency experience may be one way to elicit and study the course of infants' sad facial expressions, as opposed to anger, in greater detail.

Another method, suggested by Study 3, is to examine repeated extinction experience. Study 3 explored trajectories over a repeated extinction experience and ruled out a contribution of pulling levels. Controlling for anger/sad blends, there was no evidence of bi-phasic processes during Session 1. As in Study 2, sad expressions remained at low, relatively stable levels while anger expressions increased during the initial extinction. With a second extinction (Session 2), however, sad expressions increased significantly relative to contingency as might be expected of a slower-rising *b-process*. Anger expressions also rose in the second session above their initial levels in Session 1. While a monotonic increase over time may parsimoniously account for the observed changes in anger expression over sessions, it does not explain the late rise in MAX-sad expressions during Session 2 extinction, nor their consistent association with blended expressions during this phase. Yet, evidence for a bi-phasic process is inconclusive. The bi-phasic model proposes that the *b-process* overtakes the *a-process* as the *a-process* declines. Since anger was still on the rise in the second extinction session, sad expression would not be expected to surpass or replace anger as the predominant expression. To rule out the hypothesized opponent process trajectories, either longer or additional extinction experience would be necessary to observe both declines in anger and increased sad expressions following that decline.

The expression trajectories observed in the two studies are complex, but demonstrate that 1) changes in expression level during contingency disruption occurred and were reliable; 2) sad expressions varied independent of anger expression, increasing with one type of contingency disruption (noncontingency) or with repeated extinction exposure; and 3) relations between blends and "whole face" expressions were time and condition dependent. While not evidence for a biphasic mechanism underlying these expressions, they do call into question the hypothesis that anger, sad, and blended expressions are all randomly occurring variants of undifferentiated "distress" or frustration. The data are sufficiently interesting to encourage additional study of expressions over time in response to extinction or other disruptions. Trajectory as well as sequential analyses of elicited expressions can be undertaken to further explore whether sad expressions ever emerge as the predominant expression as predicted by the bi-phasic model, and whether anger expressions ever habituate. Sequential analysis would likely reveal whether anger expressions are likely to transition to sad expression through blends and whether expression sequences of anger, blend, sad become more common or more variable as extinction continues. Additionally, observation of these expressions over daily extinction sessions can be examined as a function of individual differences in emotion regulation, such as self-soothing behaviors or temperament. A more

soothable temperament and vagal tone have been found to influence the performance of Session 2 learners and would seem likely to influence expression trajectories as well (Sullivan, 2016). Developmental changes in these processes should also be explored.

A caveat is that conducting of daily extinction sessions may be difficult in the lab. Studies by Rovee-Collier and associates (Rovee-Collier & Gekoski, 1979) that included multiple, closely spaced (24- to 48-hr apart) contingency sessions over periods of two weeks or a month were conducted in the home. See Cuevas, Learmonth, & Rovee-Collier (2016) for a recent study of extinction conducted in the home. Fortunately, there is empirical evidence that home versus lab sessions yield comparable data (Merz et al., 2017). Control of time between sessions may be more easily accomplished if sessions are conducted at home. Weekly spaced sessions in this study were a concession to family schedules. With many mothers of young infants returning to work, maintaining appointments at this interval was more convenient for participants in these samples. Another limitation of the repeated session, encountered in Study 3, is that it was associated with subject loss. Infant crying during contingency led to incomplete second sessions and a 14% exclusion rate. It is unclear whether these infants were temperamentally different or habituation to the stimulus may have played a role. Repeated sessions with the conjugate learning procedure has not reported this problem, probably because of the dynamic, variable nature of the mobile contingency and the home setting. Post hoc inspection of retention ratios in this study did not suggest recall, but it is possible that relearning with a familiar, invariant stimulus meant that infants became bored quickly. Studies using repeated sessions should vary the stimulus or use video instead of the same still image and audio clip as in this study.

In conclusion, although correspondence between infant expression and emotion state cannot be assumed and situational specificity may be limited, facial expressions result from affective processes whose organization can be studied. Changes in expression within a given context may be lawful and if so, need to be understood as the field attempts to discover how expression, physiology, and cognition combine to influence infant behavior. Studies of facial expression over more than very brief periods have been lacking in part because fully automated detection of infant facial movements has not yet been successful. Studies over more lengthy intervals are therefore labor-intensive and costly. However, expressions, particularly negative expressions, are salient human behavior. Early infancy, due to the rapidly occurring changes in the brain during this period, is an important starting point. Once expressions are elicited, tracing their trajectory over time both within and across well-operationalized contexts may yield important information about the nature and organization of these early emotion signals.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Mean MAX-coded anger (panel A) and sad (panel B) infant facial expressions during two minutes of contingency and two minutes of disruption, either extinction (EX) or noncontingent presentation (NC). MAX-coded anger/sad blends (panel C) were controlled in these analyses. Error bars depict standard errors of the mean.

Figure 2.

Mean MAX-coded anger (solid line) and sad (dashed line) facial expressions, controlling for MAX-coded anger/sad blends during one minute of contingency learning and two minutes of extinction across two sessions, controlling for anger/sad blended expressions. Anger expressions are plotted on the secondary axis due to their greater occurrence. Error bars depict standard errors of the mean.

Table 1

Bivariate and Partial Correlations Among Infant Facial Expressions in Three Independent Samples (Study 1)

Expression	Sample, N, and M age in weeks (SD)								
	A. Sullivan & Lewis, 2003 ^a (N = 81) M = 18.2 w (2.0)			B. Sullivan, 2016 (N = 99) M = 21.4 w (.59)			C. Lewis, Hitchcock, & Sullivan (N = 54) M = 17.12 w (1.1)		
	Anger	Sad	Neutral/Sober	Anger	Sad	Neutral/Sober	Anger	Sad	Neutral/Sober
Bivariate Correlations									
Anger									
Sad	.21			.24 *			.22 *		
Neutral/Sober	.18	.32 **		.20	.37 **		.14	.28 *	
Anger/Sad Blend	-.45 **	-.26 *	-.40 **	-.51 **	-.25 *	-.35 **	-.46 **	-.21	-.15
Controlling for Anger/Sad Blends									
Sad	.17			.18			.12		
Neutral/Sober	-.43 **	-.20		-.48 **	-.17		-.52 **	-.26 *	

^aStudy 2, Extinction group

* p < .05

** p < .01

Table 2

Means, Standard Errors and Confidence Intervals of Learning Disruption Scores in Two Studies. Learning Metrics are Broken Down by Experimental Group in Study 2 or by Session in Study 3

	BASELINE	LEARNING RATIO[*]	DISRUPTION/ BASELINE RATIO^{**}
<u>STUDY 2: DISRUPTION BY EXTINCTION VERSUS NONCONTINGENCY</u>			
<u>GROUP (N)</u>			
<u>EXTINCTION (86)^a</u>			
<i>M (SE)</i>	6.47 (0.51)	4.78 (1.42)	2.18 (0.36)
<i>95% CI</i>	[5.47, 7.48]	[1.96, 7.61]	[1.46, 2.88]
<u>NONCONTINGENCY (86)</u>			
<i>M (SE)</i>	6.31 (0.51)	4.73 (1.97)	1.91 (0.36)
<i>95% CI</i>	[5.31, 7.31]	[1.79, 7.67]	[1.20, 2.62]
<u>STUDY 3: DISRUPTION BY EXTINCTION OVER TWO DAYS (N= 86)^b</u>			
<u>SESSION 1</u>			
<i>M (SE)</i>	5.23 (0.59)	2.32 (0.93)	3.90 (0.76)
<i>95% CI</i>	[4.06, 6.41]	[0.41, 4.25]	[2.41, 5.52]
<u>SESSION 2</u>			
<i>M (SE)</i>	5.80 (0.51)	2.13 (0.82)	3.16 (0.54)
<i>95% CI</i>	[4.78, 6.22]	[0.45, 3.80]	[1.08, 2.30]

* Learning ratio = Average contingency response across six minutes /Average baseline response.

** Disruption ratio = Average Disruption Response/ Average baseline response.

^a There were no significant group differences in any measure in Study 2.

^b There were no significant differences between Session on any measure.