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Emotional expression and heart rate in high-risk infants during the face-to-face/still-face

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ABSTRACT

In infants, eye constriction—the Duchenne marker—and mouth opening appear to index the intensity of both positive and negative facial expressions. We combined eye constriction and mouth opening that co-occurred with smiles and cry-faces (respectively, the prototypic expressions of infant joy and distress) to measure emotional expression intensity. Expression intensity and heart rate were measured throughout the face-to-face/still-face (FFSF) in a sample of infants with prenatal cocaine exposure who were at risk for developmental difficulties. Smiles declined and cry-faces increased in the still-face episode, but the distribution of eye constriction and mouth opening in smiles and cry-faces did not differ across episodes of the FFSF. As time elapsed in the still face episode potential indices of intensity increased, cry-faces were more likely to be accompanied by eye constriction and mouth opening. During cry-faces there were also moderately stable individual differences in the quantity of eye constriction and mouth opening. Infant heart rate was higher during cry-faces and lower during smiles, but did not vary with intensity of expression or by episode. In sum, infants express more intense negative affect as the still-face progresses, but do not show clear differences in expressive intensity between episodes of the FFSF.

1. Introduction

Smiles and cry-faces are the prototypic expressions of positive and negative affect in infants. However, both smiles and cry-faces occur at a range of intensities, which may offer a window into emotion regulation processes in at-risk infants. Indices of the intensity of both positive and negative affect in infants include eye constriction (produced by cheek raising) and mouth opening (Dinehart et al., 2005; Messinger, 2002; Messinger, Mahoor, Chow, & Cohn, 2009; Messinger, Mattson, Mahoor, & Cohn, 2012). These hypothesized indices are salient, readily observable, and associated with expressions of both positive and negative affect. In the current study, we examined how these putative intensity indices occurred with smiles and cry-faces during an age-appropriate stressor, the face-to-face/still-face (FFSF) paradigm (Tronick, Als, Adamson, Wise, & Brazelton, 1978). We also investigated whether heart rate varied with the intensity of smiles and cry-faces. Finally, we compared smile and cry-face intensity of infants with and without prenatal cocaine exposure, a risk factor for regulatory difficulties (Schuetze & Eiden, 2006; Schuetze, Eiden, & Edwards, 2009).

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1.1. Smile and cry-face intensity

Infant smiles are an index of positive affect and a social signal of readiness to begin or continue a pleasurable activity (Fogel, Nelson-Goens, Hsu, & Shapiro, 2000). Smiles with eye constriction, often referred to as Duchenne smiles (Darwin, 1877; Duchenne, 1990/1862), are exhibited in adults when they report happiness (Frank, Ekman, & Friesen, 1993). When infants experience events thought to elicit joy (e.g., the approach of a familiar caregiver), they also tend to exhibit smiles with eye constriction as well as left hemisphere activation, previously associated with positive affect in adults (Fox & Davidson, 1988). Open-mouthed smiles tend to predominate when infants are engaged in playful behavior, such as social games (Dedo, 1991). In infants, both eye constriction and mouth opening index stronger positive affect during smiles, and frequently co-occur (Messinger, Fogel, & Dickson, 1999; Messinger et al., 2012), suggesting they may both be indices of positive affect.

Infant cry-face expressions communicate distress to caregivers (Camras & Shutter, 2010; Oster, Hegley, & Nagel, 1992). While adults exhibit differentiated expressions of negative affect (e.g., anger and sadness), infants tend to express negative affect as undifferentiated distress (Camras & Shutter, 2010; Oster, 2003, 2009; Oster et al., 1992). Infant cry-faces, by definition, contain a degree of eye constriction (Izard, 1983; Oster, 2009). Oster (2009) suggested that the intensity of cry-faces vary with the degree of horizontal stretching of the lip corners and the degree of mouth opening involved.

Non-experts rate both smiles and cry-faces involving eye constriction and/or mouth opening as more affectively intense than expressions without these features (Dinehart et al., 2005; Messinger et al., 2012; Messinger et al., 2009). These findings suggest that infants' eye constriction and mouth opening both potentially index the intensity of cry-faces as well as smiles. The current study documents the distribution of these facial expression intensifiers in both smiles and cry-faces during the FFSF.

1.2. Facial expression intensifiers and the FFSF

The current study investigated eye constriction and mouth opening that occurred during both smiles and cry-faces in the FFSF. Within this protocol, the mother engages in play with her infant, the mother stops playing, and then the mother reengages in play. There is a well-documented decline in smile expressions from the face-to-face episode to the still-face episode. There is a parallel increase in infant cry-face expressions from the face-to-face episode to the still-face episode. There is also a moderate increase in smile expressions from the still-face episode to the reunion episode (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). Segal et al. (1995) found that both big smiles (strong smiling with mouth opening) and other smiles declined in the still-face episode of the FFSF. However, only big smiles increased between the still-face and reunion episodes. Based on this pattern of smiles and cry-faces in the FFSF, we expected a similar pattern of change in the occurrence of facial expression intensifiers. That is, we expected a greater number of facial expression intensifiers to occur during smiles in the face-to-face compared to smiles in the still-face and reunion episodes. We also expected a greater number of facial expression intensifiers to occur during cry-faces in the still-face compared to the face-to-face and reunion episodes.

In addition to differences at the mean level across episodes, there may be changes in the intensity of expressions within the still-face episode. Recent reports indicate that levels of smiling decline as time elapses over the course of the still-face (Ekas, Haltigan, & Messinger, 2012; Goldstein, Schwade, & Bornstein, 2009). These findings led us to anticipate a similar decline in the number of facial intensifiers during smiles in the still-face episode as infant smiling bids prove ineffective. A hypothesized increase in negative affect also led us to expect an increase in the number of facial intensifiers during cry-faces over the course of the still-face episode.

1.3. Cocaine-exposure and facial expression

There is some evidence that prenatal cocaine exposure is associated with a bias toward negative expressions of affect. Bendersky and Lewis (1998) found that a lower proportion of four-month-old infants with high levels of cocaine exposure displayed at least one smile during face-to-face interaction than nonexposed infants. A higher proportion of infants with high levels of cocaine exposure exhibited negative expressions during interaction after a period of no maternal response than did nonexposed infants. A previous report from the multi-site Maternal Lifestyle Study, found that heavily cocaine-exposed infants showed more passive and withdrawn engagement than nonexposed infants (Tronick et al., 2005). The modulated use of emotional expression is particularly important for at-risk infants, as inappropriate levels of intensity on the part of the infant may be readily misinterpreted by the caregiver (as in Eiden, Schuetze, & Coles, 2011). This is particularly important as mothers who used cocaine prenatally had lower sensitivity at 13 months. Given previous evidence of maternal sensitivity difficulties, appropriate levels of infant expression intensity may be particularly important in this population.

However, as argued by Lester (2006), and true of most cocaine studies, putative attribution of a group of infants as cocaine exposed should also be seen as an index of other kinds of exposures that typify such groups (e.g., alcohol, opiates, and other abused drugs). The current study examined whether infants with prenatal cocaine exposure showed less intense smiles and more intense cry-faces or a different profile of heart rate during these expressions, all potential indicators of deficits in emotion regulation.

Table 1
Demographics and secondary exposure variables by exposure status.

Infant characteristics		Early environment		Other prenatal exposures		
Exposure	Male	High School Completion	Hollingshead SES mean	Tobacco*	Alcohol	Marijuana*
Prenatal cocaine exposure	47.7%	15.9%	31.59 (*SD* 8.71)	45.4%	38.6%	25.0%
No prenatal cocaine exposure	63.3%	28.6%	30.49 (*SD* 11.36)	10.0%	42.9%	4.1%

Note: High School Completion indicates whether the mother completed 12 or more years of education. Other prenatal exposure indicates if these exposures occurred prenatally. An asterisk indicates significant group differences.

1.4. *Facial expression and heart rate*

Adult heart rate is generally more elevated during negative facial expressions than during smiling (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). Emde, Campos, Reich, and Gaensbauer (1978) found that infant heart rate was greater during smiles than neutral expressions, suggesting that more intense smiling might involve more rapid heart rate than less intense smiling. Haley and Stansbury (2003) found that stronger ratings of negative affect were associated with higher heart rate in the still-face and higher levels of baseline cortisol (see also Moore et al., 2009). In the FFSF, there is a consistent increase in heart rate from the face-to-face to the still-face episode; however, it is not clear whether there is a decrease in heart rate from the still-face to the reunion (Conradt & Ablow, 2010; Mesman et al., 2009; Weinberg & Tronick, 1996). Kraft and Pressman (2012), have found evidence for facial expression, particularly smiling with eye constriction, being closely tied to heart rate.

Among infants with prenatal cocaine exposure there is evidence for impaired regulatory function of heart rate at 1–2 months Schuetze and Eiden (2006), in which higher levels of exposure were associated with higher heart rate. We hypothesized that more intense positive and negative affect—as indexed by expressions involving eye constriction and mouth opening—would be associated with higher heart rate, in all episodes of the FFSF. We additionally explored the patterns of facial expression intensifiers and heart rate by FFSF episode, but did not generate specific hypotheses about their relationship.

Our first goal in this study was to investigate the occurrence of eye constriction and mouth opening—potential intensity indices—during both smiles and cry-faces. We next examined the association between the proportion of smiles and cry-faces and the episodes of the FFSF. This allowed us to then investigate differences in the proportions of the potential intensity indices during these smile and cry-faces. To address potential effects of prenatal cocaine exposure, we examined whether exposed infants showed a smaller proportion of facial expression intensifiers during smiles and a greater proportion of facial expression intensifiers during cry-faces. Finally, we examined heart rate during these potential intensity indices; we then compared these levels between infants prenatally exposed to cocaine and nonexposed infants as an indicator of deficits in emotion regulation.

2. Methods

2.1. *Participants*

Participants were enrolled in the Maternal Lifestyle Study (MLS), a multi-site, longitudinal investigation of the impact of prenatal cocaine/opiate exposure on a broad range of outcomes measured between one month and 16 years of age. The study was approved by the institutional review board and informed maternal consent was obtained. Prenatal cocaine exposure was determined via maternal admission of drug use and/or a positive enzyme multiplied immunoassay technique (EMIT) screening for drug metabolites in meconium, confirmed with gas chromatography/mass spectroscopy (GC/MS). Non-exposure was determined by denial of cocaine/opiate use during pregnancy and a negative meconium toxicology screen. Mothers were screened in the hospital for eligibility to participate in the follow-up component of the study (see Bauer et al., 2005 for more detail on participant screening and enrollment). Eligible participants for both the exposed and comparison groups were then matched on infant gestational age, race, and child gender. Of this matched sample, dyads who attended the one-month visit were enrolled in the longitudinal component of the MLS.

For the current study, participants were drawn from a single-site cohort of the MLS, which included infants that had video recordings of the FFSF protocol at their four-month visit. The initial sample consisted of 106 dyads of biological mothers and their infants. Of these dyads, 11 were excluded from analyses due to equipment malfunction or being too fussy to participate and two infants were excluded because of prenatal opiate exposure. The final sample consisted of 93 mother–infant dyads, 44 infants had prenatal cocaine exposure and 49 infants had no cocaine exposure.

At the one-month visit, mothers completed a detailed interview regarding their licit and illicit drug use during pregnancy. Maternal education (i.e., completion of 12 years of education or more) and socioeconomic status (SES) was also ascertained at this visit. SES was assessed using the adjusted version of the Hollingshead index tailored to measure SES in low-income populations (Hollingshead, 1975; LaGasse et al., 1999). Both groups were predominantly African-American and showed high levels of environmental and social risk (see Table 1). Although infants in the comparison group did not have prenatal cocaine or opiate exposure, mothers in both the exposure group and the comparison group reported alcohol, tobacco, and marijuana use during pregnancy (see Table 1). Infants in the exposure group had significantly higher prenatal tobacco, $t(74) = -4.53$,

$p < .001$, and marijuana exposure, $t(74) = -7.37$, $p < .001$, than the comparison group, but did not differ on prenatal alcohol exposure. A cumulative exposure variable was also created, as outlined by Fisher et al. (2011), a sum of dichotomous variables describing cocaine, opiates, marijuana, alcohol, and tobacco exposure (no opiate exposure was present in the current sample). In preliminary analyses, neither tobacco, marijuana, nor the cumulative exposure variable (summing dichotomous indicators of cocaine, opiate, marijuana, alcohol, and tobacco exposure) had significant effects on infant smile and cry-face expressions (e.g., $ps > .51$), although tobacco approached significance in its association with cry-face intensity, $F(1, 13) = 3.37$, $p = 09$, $\eta_p^2 = .21$.

2.2. Protocol

For the FFSF protocol, mother–infant dyads were seated facing each other and pediatric electrodes were placed on the infant to measure heart rate. Mothers were instructed to play with their infant as they would at home for 2 min (face-to-face episode). They were then asked to turn away from their infant for 15 s, and then look toward their infant for 2 min and not respond, adopting a flat or "poker face" (still-face episode). Finally, mothers turned their head away from their infant for 15 s and then re-engaged in play for 2 min (reunion episode). Examiners and coders were blind to infant cocaine exposure status.

2.3. Recording of video and physiology

Three cameras were used to record the mother–infant interaction onto a super-VHS tape deck. One camera was focused on the infant's face and two cameras were focused on the faces and upper bodies of the infant and mother respectively. Video from this first angle (the infant's face) was used in facial coding.

Pediatric electrodes recorded heart rate throughout the mother–infant interaction. The analog signal from these pediatric electrodes were converted into inter-R-wave intervals and digitized using a devoted Hewlett Packard monitor that calculated inter-beat-intervals (IBI). IBIs were converted into average heart rate in one second intervals corresponding to the SMPTE time code and were recorded in separate data files. Off-line analysis indicated minimal quantities of movement and other artifact in the heart rate data. Coding of facial expressions and co-occurring heart rate were matched at one-second intervals.

2.4. Facial expression coding

Coding of facial expressions was conducted by coders certified in the Facial Action Coding System (FACS), which decomposes a given facial expression into minimally separable and meaningful action units (Ekman & Friesen, 1978). Coders were also trained in Baby FACS, an application of this coding system to infant faces (Oster, 2009). Coders assessed the presence of facial actions in two passes. In the initial pass, coders indicated the presence of smiles (AU12), cry-faces (including AU4, and AU20), or absence of smiles/cry-faces at the frame level. Coders then reviewed these sequences and identified whether each sequence contained eye constriction (AU6), mouth opening (AU26), or both. Inter-observer agreement for the first step of identifying facial expression codes (smiles, cry-faces, and absence or smiles/cry-faces) was assessed for 10 of the sessions (10.8% of the sample). As these data consisted of presence/absence codes, Cohen's kappa was used to calculate reliability for each individual session (Cohen, 1960). The average kappa for the presence of facial expressions was 0.72 (ranging from .56 to .92), with an average agreement of 92% (ranging from 76% to 98%). Reliability was calculated separately for the second step for an additional 10 sessions (10.8% of the sample) in which the presence of eye constriction and mouth opening had also been coded. The average kappa for the presence of intensifiers was 0.61 (ranging from .49 to .72), with an average agreement of 76% (ranging from 62 to 96%). The lower values of kappa may be due, in part, to relatively low rates of occurrence of these facial expressions (eye constriction, $M = .14$, $SD = .17$; mouth opening, $M = .15$, $SD = .17$; smiles, $M = .08$, $SD = .07$; cry-faces, $M = .19$, $SD = .22$), as outlined in (Bakeman, McArthur, Quera, & Robinson, 1997), these values are fairly consistent with expected values of kappa given a 2 by 2 coder matrix, high observer accuracy, bur relatively rare behavioral events.

3. Results

3.1. Facial intensifiers and exposure

3.1.1. Co-occurrence of intensifiers

To assess whether eye constriction and mouth opening might both function as indices of emotional intensity, we examined the co-occurrence of these facial expression intensifiers during smiles and cry-faces. For smiles, co-occurrence was defined as the presence of both eye constriction and mouth opening during a smile. For cry-faces, co-occurrence was defined as the presence of both eye constriction and mouth opening during a cry-face. Both smiles and cry-faces were analyzed by calculating the relative risk of both intensifiers co-occurring compared to not co-occurring. For example, consider a fictitious subject's expressive behavior. They had 120 s of smiling total. Eye constriction was present for 55 s, 40 of which involved both eye constriction and mouth opening. Eye constriction was absent for 65 s, 5 of which involved mouth opening, and 15 of which involved just eye constriction. The relative risk (RR) of co-occurrence in this case is 9.46 ((40/55)/(5/65) = 9.46); smiling with eye constriction was 9.46 times more likely to co-occur with mouth opening than without.

In our data, smiling with eye constriction was more likely to occur with mouth opening (66.5%) than was smiling without eye constriction (45.8%), $RR = 1.45$, $CI = [1.37–1.53]$. Cry-faces with eye constriction were more likely to occur with mouth opening (72.7%) than were cry-faces without eye constriction (48.7%), $RR = 1.49$, $CI = [1.42–1.57]$. These results suggest that eye constriction and mouth opening may have similar functions as they tend to co-occur during smiling and cry-faces. One potential function is to index the intensity of the expression with which they are occurring.

Table 2
Tests of association between facial expression intensifiers during smiles in the context of prenatal cocaine exposure, FFSF episode, and gender.

Coefficients	*error df, df*	*F*	*p*	η_p^2
Smiles (face-to-face, still-face, reunion)				
Episode	2, 66	1.00	.37	.03
Exposure	1, 33	1.64	.21	.05
Gender	1, 33	0.17	.68	.01
Episode by Exposure	2, 66	2.23	.12	.06
Episode by Gender	2, 66	0.71	.50	.02
Exposure by Gender	1, 33	0.02	.90	.01
Episode by Exposure by Gender	2, 66	2.46	.09	.07
Smiles (face-to-face vs. reunion)				
Episode	1, 58	0.07	.79	.01
Exposure	1, 58	0.82	.37	.01
Gender	1, 58	4.12	.05	.07
Episode by Exposure	1, 58	2.27	.14	.04
Episode by Gender	1, 58	0.06	.80	.01
Exposure by Gender	1, 58	0.06	.82	.01
Episode by Exposure by Gender	1, 58	0.95	.33	.02

Note: An asterisk indicates a *p*-value of less than .05.

3.1.2. *Weighted proportion criterion*

To assess episode and exposure effects we first conducted a series of repeated measures ANOVAs on the proportion of time spent in each episode involving smiles, and the proportion involving cry-faces. Proportions were defined as the number of seconds of occurrence (e.g., of smiles) in a given FFSF episode divided by the total number of seconds in that episode. In preliminary analyses, the effects of maternal education and SES, tobacco exposure, marijuana exposure, and a cumulative exposure summary variable on these proportions were examined. These variables had no significant effects, and were excluded from subsequent analyses. To prepare for analyses involving intensifiers, we calculated the proportion of smiles with eye constriction and the proportion of smiles with mouth opening. The dependent variable, the weighted intensifier proportion, was the sum of these two proportions, such that the presence of two intensifiers received twice the weight of one intensifier. The same metric was applied to cry-faces for intensifier analyses.

3.1.3. *Smiles*

Initial analyses compared the effect of episode on the proportion of time in each episode involving smiles using a 3 (Episode) repeated measures ANOVA. There was a significant episode effect on the proportion of smiles, $F(2, 92) = 21.51$, $p < .001$, $\eta_p^2 = .32$. Post-hoc tests revealed that there was a significantly greater proportion of smiles in the face-to-face ($M = .13$, $SE = .02$) episode than the reunion ($M = .09$, $SE = .01$), and a greater proportion of smiles in the reunion ($M = .09$, $SE = .01$) than the still-face ($M = .03$, $SE = .01$).

Intensifier analyses for smiles were run using a 3 (Episode) by 2 (Exposure) by 2 (Gender) repeated measures ANOVA model predicting the weighted intensifier proportion (see Table 2). A subset of subjects ($n = 37$) smiled during all three episodes and were included in these analyses. The weighted intensifier proportion during smiles did not vary by episode, gender, or exposure. Interaction terms were also non-significant. A larger subset of subjects ($n = 66$) smiled during the face-to-face and reunion episodes, and were included in a second model focusing on the contrast between these episodes. In this 2 (Face-to-Face vs. Reunion Episode) by 2 (Exposure) by 2 (Gender) repeated measures ANOVA model, the weighted intensifier proportion during smiles did not vary by episode, gender, or exposure. Interaction terms were also non-significant.

3.1.4. *Cry-faces*

Initial analyses compared the effect of episode on the proportion of time in each episode involving cry-faces using a 3 (Episode) repeated measures ANOVA. There was a significant episode effect on the proportion of cry-faces, $F(2, 92) = 13.53$, $p < .001$, $\eta_p^2 = .23$. Post-hoc tests revealed that there was a significantly greater proportion of cry-faces in the still-face ($M = .17$, $SE = .03$) and reunion ($M = .16$, $SE = .03$) episodes than in the face-to-face ($M = .07$, $SE = .02$) episode.

Table 3
Tests of association between facial expression intensifiers during cry-faces in the context of prenatal cocaine exposure, FFSF episode, and gender.

Coefficients	*error df, df*	*F*	*p*	η_p^2
Cry-faces (face-to-face, still-face, reunion)				
Episode	38, 2	1.90	.16	.09
Exposure	19, 1	0.17	.68	.01
Gender	19, 1	0.96	.34	.05
Episode by Exposure	38, 2	0.48	.62	.03
Episode by Gender	38, 2	0.66	.52	.03
Exposure by Gender	19, 1	0.07	.79	.01
Episode by Exposure by Gender	38, 2	0.65	.53	.03
Cry-faces (still-face vs. reunion)				
Episode	34, 1	0.52	.48	.02
Exposure	34, 1	0.03	.86	.01
Gender	34, 1	0.16	.69	.01
Episode by Exposure	34, 1	0.74	.40	.02
Episode by Gender	34, 1	0.74	.40	.02
Exposure by Gender	34, 1	0.27	.61	.01
Episode by Exposure by Gender	34, 1	0.78	.38	.02

Note: An asterisk indicates a *p*-value of less than .05.

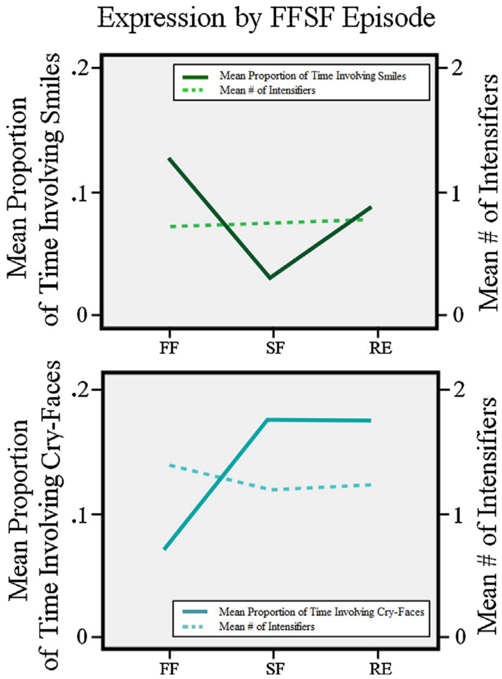

Fig. 1. Mean proportion of time involving smiles and cry-faces against mean number of facial expression intensifiers by FFSF episode. *Note*: FF represents the face-to-face play, SF the adopting of a flat, poker face, and RE the re-engagement of the parent in face-to-face play.

Intensifier analyses for cry-faces were run using a 3 (Episode) by 2 (Exposure) by 2 (Gender) repeated measures ANOVA model (see Table 3 for a summary). A subset of subjects ($n = 23$) displayed cry-faces during all three episodes and were included in these analyses. The weighted intensifier proportion during cry-faces did not vary by episode, gender, or exposure. Other interaction terms were also non-significant. A larger subset of subjects ($n = 38$) displayed cry-faces during the still-face and reunion, and were included in a second model focusing on the contrast between these episodes. In this 2 (Still-Face vs. Reunion Episode) by 2 (Exposure) by 2 (Gender) repeated measures ANOVA model, the weighted intensifier proportion during cry-faces did not vary by episode, gender or exposure. Interaction terms were also non-significant (see Fig. 1 for a summary of means and intensifier levels by episode).

3.1.5. Time and intensifiers in the still-face episode

We tested for an association between the elapsed time spent in the still-face episode and the number of facial expression intensifiers exhibited. Separate models were created for smiles and cry-faces and the natural logarithm of seconds (as in Ekas et al., 2012) was used as a predictor (see Table 4). To assess changes in intensifiers over the course of the still-face episode, we used hierarchical linear modeling with Full Information Maximum Likelihood estimation (HLM; Raudenbush & Bryk, 2002). This framework was used to account for the intensively repeated measure structure of the data, and the dependency between infants and the outcome measure ($ICC = .99$). Elapsed time in the still-face was predictive of the number of facial expression intensifiers exhibited during cry-faces. Negative infant facial expression grew more intense over time during the still-face episode, $t(92) = 2.50$, $p = .01$. In a chi-square difference test, this model was a significant improvement over a model which did not include elapsed time as a predictor, $\chi^2(3, N = 93) = 1754.91$, $p < .001$. Elapsed time in the still-face was not predictive of the number of facial expression intensifiers exhibited during smiles.

3.1.6. Consistency

Smile and cry-faces analyses did not indicate variation in the number of intensifiers on the basis of episode. Follow-up analyses were conducted to assess whether the number of intensifiers were consistent across episodes within each subject. Two intra-class correlations (ICC's) were conducted using the mean number of intensifiers in each episode for each subject during smiles and during cry-faces. A two-way mixed model ICC showed relatively high consistency for smiles ($ICC = .61$), and more moderate consistency for cry-faces ($ICC = .42$). Inter-correlations between the mean number of smile intensifiers in each episode suggests consistency between the face-to-face and still-face ($r = .61$), still-face and reunion ($r = .64$), and face-to-face and reunion ($r = .58$). In cry-faces these same inter-correlations suggest that the number intensifiers is consistent between the face-to-face and still-face ($r = .55$), and moderately consistent between the reunion and the face-to-face ($r = .35$) and still-face ($r = .36$). Thus, the number of intensifiers exhibited by a given infant was stable within smiles and moderately stable for cry-faces over the course of the FFSF.

Table 4
Coefficient estimates for the association between facial expression intensifiers and elapsed seconds in the still-face episode during smiles and cry-faces.

Coefficients	β	*SE*	*t*	*p*
Smiles				
β_{00} (intercept)	0.15	0.03	4.24	<0.01*
β_{10} (log[elapsed seconds])	−0.01	0.01	−1.24	0.22
Cry-faces				
β_{00} (intercept)	0.14	0.10	1.51	0.13
β_{10} (log[elapsed seconds])	0.07	0.03	2.50	<0.05*

Note: An asterisk indicates a *p*-value of less than .05.

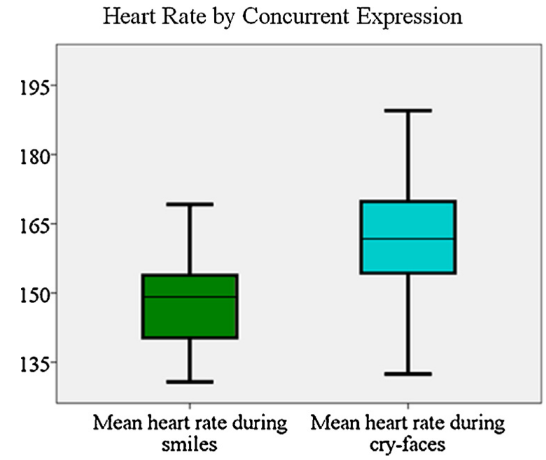

Fig. 2. Mean heart rate over the FFSF in the context of both smiles and cry-faces. The mean heart rate during cry-faces was significantly higher than the mean heart rate during smiles, $t(57) = 9.18$, $p < .001$.

3.2. Heart rate and intensifiers

Infants had a higher mean heart rate during cry-faces and a lower mean heart rate during smiles, $t(57) = 9.18$, $p < .001$ (see Fig. 2). We examined the relationship between heart rate and facial intensifiers using separate repeated measures ANOVAs. Heart rate did not vary with the intensity of smiles, $F(2, 44) = .05$, $p = .96$, $\eta_p^2 = .01$, or cry-faces, $F(2, 36) = 2.36$, $p = .11$, $\eta_p^2 = .12$. A repeated measures ANOVA also indicated that heart rate was lower in the face-to-face ($M = 151.47$, $SE = 1.26$) than the still-face ($M = 157.78$, $SE = 1.41$) and reunion ($M = 158.07$, $SE = 1.79$), $F(2, 82) = 23.99$, $p < .001$, $\eta_p^2 = .37$.

4. Discussion

During smiling, eye constriction and mouth opening are associated with ratings of positive affect (Messinger et al., 2009) and these same facial actions are associated with ratings of negative affect during cry-faces (Dinehart et al., 2005; Messinger, 2002; Messinger et al., 2012). This commonality led us to ask whether eye constriction and mouth opening functioned as indices of intensity in a sample of high-risk infants during the FFSF. Eye constriction and mouth opening tended to co-occur during smiling and cry-faces, suggesting that eye constriction and mouth opening both may index facial expression intensity. Further, increasing proportions of eye-constriction and mouth opening during cry-faces over time suggests that infants became more affectively negative as their mothers continued to be unresponsive in the still-face.

4.1. Facial intensifiers and exposure

4.1.1. Co-occurrence of intensifiers

Smiles that involved eye constriction also tended to involve mouth opening (see Messinger, Fogel, & Dickson, 1999). Cry-faces that involved eye constriction also tended to involve mouth opening, which closely paralleled the relationship of co-occurrence found in smiles. The temporal association between eye constriction and mouth opening suggests that these facial actions may index a common intensity construct in both smiles and cry-faces. Similar associations have been seen for other expressive behaviors, including facial expressions, gestures, and vocalization (Weinberg & Tronick, 1994). This suggests a robust coherence in the ways infants express emotions.

4.1.2. Prenatal cocaine exposure

Bendersky and Lewis (1998) found subtle decreases in positive affect during face-to-face interaction, and increases in negative affect during the FFSF within similar samples of infants with prenatal cocaine exposure. Tronick et al. (2005) found that infants with high levels of cocaine exposure were more passive and withdrawn from interaction, which can also include cry-face expressions, than infants with no cocaine exposure. However, both of these previous studies only detected differences between non-exposed infants and those with high exposure levels. Heavy cocaine exposure could not be examined in the current sample due to its low occurrence ($n = 8$). However, prenatal cocaine exposure was not associated with the proportion of smiles or cry-faces exhibited by infants. These findings suggest no atypical profile in subtle intensity changes, altered profile of reactivity to or recovery from the SF, or differences in the amount of smiles and cry-faces displayed by cocaine-exposed infants in this subset of Tronick et al.'s (2005) population.

4.1.3. Episode effects

Consistent with the standard still-face effect (Adamson & Frick, 2003), smiles declined during the still-face and returned to intermediate levels during the reunion (Bendersky & Lewis, 1998; Mesman et al., 2009). Cry-faces increased during the still-face and remained at a high level during the reunion. We expected that the proportion of intensifiers during smiles would decline from the face-to-face to the still-face and reunion and that the proportion of intensifiers during cry-faces would increase from the face-to-face to the still-face and decline again in the reunion. The proportion of facial expression intensifiers involved in smiles did not change significantly between the face-to-face, still-face, and reunion. The proportion of facial expression intensifiers involved in cry-faces also did not change significantly between the face-to-face, still-face, and reunion. There was no evidence, then, that infants use different numbers of facial expression intensifiers during smiles and cry-faces across the episodes of the FFSF.

4.1.4. Time and intensifiers in the still-face episode

The number of facial expression intensifiers during cry-faces increased over time in the still-face. Ekas et al. (2012) found a similar pattern in which infants engaged in more cry-faces over the course of the still-face. The current study, however, is the first to investigate dynamic changes in facial intensifiers over the still-face. The results suggest that infants became increasingly distressed over the course of mother's non-engagement during the still-face. However, there was no decline in facial intensifiers in the still-face for smiles. This suggests that detailed metrics of facial expression intensity have promise for elucidating failures to regulate negative affect during the still-face and similar assessments (Messinger et al., 2009).

4.1.5. Consistency

The number of intensifiers present during smiles was consistent within individuals across FFSF episodes. The number of intensifiers present during cry-faces showed more moderate consistency. In particular, the number of intensifiers present during cry-faces was least consistent within individuals when comparing the reunion episode to the face-to-face and still-face episodes. This pattern suggests that in the reunion episode there may be variation in intensifiers during cry-faces. This in turn might yield differences for intensifiers if finer gradations of measurement are used.

There are several potential interpretations of the unexpected lack of episode differences in the proportion of facial intensifiers. It is possible that the hypothesized facial expression intensifiers are not functioning to intensify facial expression. However, this seems unlikely given that smiles with eye constriction and mouth opening occur during periods thought to elicit positive affect (Fox & Davidson, 1988; Messinger, Fogel, & Dickson, 2001). Further, non-experts rate infant smiles with eye constriction and mouth opening more positively than smiles without eye constriction or mouth opening (Messinger et al., 2009), and rate cry-faces with eye constriction and mouth opening more negatively than cry-faces without eye constriction and mouth opening (Dinehart et al., 2005; Messinger, 2002).

An alternative explanation for the lack of significant differences in the intensity of smiles and cry-faces between episodes of the FFSF is that the valence of positive affect and of negative affect does not change in the FFSF despite the SF stressor. However, this explanation does not account for why cry-face expressions grew more negative as time elapsed during the still-face, as well as suggesting that eye constriction and mouth opening should not be dismissed as facial intensifiers. Participants also showed less consistency in the number of facial intensifiers during cry-faces, in particular when comparing the reunion episode to the face-to-face and still-face episodes. Segal et al.'s (1995) findings also suggest that strong smiles with mouth opening were less frequent than other smiles in the reunion episode.

Another explanation, which could account for the lack of episode differences in intensifiers during smiles and cry-faces, involves the coding of eye constriction and mouth opening. In this study, eye constriction and mouth opening were coded as present or absent. It may be that between episode differences in eye constriction and mouth opening involve subtler differences in the degree to which these actions occur. Accordingly, future investigations might employ more fine-grained coding of the strength of eye constriction and mouth opening, and utilize other metrics of emotional expressivity (e.g., non-expert ratings of affect), to help clarify these issues.

4.2. Heart rate and intensifiers

Smiles and cry-faces were associated with increased heart rate in infants. Specifically, heart rate was higher during cry-faces than smiling and increased from the face-to-face to still-face and reunion episodes. Our findings corroborate previous reports of associations between heart rate and negative facial expressions in the FFSF (Conradt & Ablow, 2010; Haley & Stansbury, 2003; Moore et al., 2009). Similar to findings by Conradt and Ablow (2010), infants in our study displayed increased heart rate from the face-to-face to still-face episodes, with heart rate remaining elevated from the still-face to the reunion episodes. For infants, a cry-face is indicative of distress (Oster et al., 1992) and the current results suggest that these are states when high arousal occurs. Our observations also indicate that positive facial expression in the FFSF might have a similar association with higher heart rate, though less pronounced. Accordingly, these findings provide additional evidence of the connection between facial expression and indices of physiological arousal during the FFSF, an important step in bridging the gap between facial expression and internal states.

The current study was the first to examine the association between heart rate and facial expression intensifiers. No significant associations were found. There are several potential explanations for these results. Hypothesized intensifying facial actions may not serve to intensify expression and therefore are not associated with more rapid heart rate. However, this interpretation conflicts with past findings (Dinehart et al., 2005; Messinger, 2002; Messinger et al., 2009) which suggest that the presence of facial intensifiers make smiles appear more positive and cry-faces appear more negative. An alternative interpretation may be that the underlying emotional state associated with the presence of intensifying facial actions does not correspond with significant changes in heart rate. Instead, heart rate changes during intensifying actions might only be detectable at very strong levels of eye constriction and mouth opening, rather than just their presence or absence.

We did not find heart rate differences between infants prenatally exposed to cocaine and non-exposed infants. Given previous evidence for regulatory difficulties among exposed infants in the context of other elicitors of negative affect, such as arm restraint, it may be that the FFSF does not elicit marked enough changes in heart rate distinguish exposed from non-exposed infants. However, Weinberg and Tronick's (1996) findings of an overall increase in heart rate during the SF, and our replication of that finding, does provide support for the FFSF as an effective elicitor of heart rate changes. Alternate measures may be more sensitive to regulatory differences in exposed populations, as differences have been found in respiratory sinus arrhythmia (Schuetze et al., 2009) and hypothalamic-pituitary-adrenocortical axis response, specifically altered cortisol levels in response to stressors (Fisher, Kim, Bruce, & Pears, 2012; Lambert & Bauer, 2012). Overall, these more sensitive measures of stress and arousal show promise for examining this relationship in more depth.

4.3. *Future directions and limitations*

A few aspects of the current work limit the generalizability of findings. The use of a high-risk sample, while informative for exploration of the effects of prenatal cocaine exposure, may indicate that the findings on the relationship between facial expression intensifiers (eye constriction and mouth opening) and smiles and cry-faces may differ in other samples. However, the replication of still-face effects tends to argue for general similarity between the current sample and other samples evaluated with the FFSF. Future inquiry should take advantage of the intensity levels available in the FACS to detect differences in the distribution of expressions involving eye constriction and mouth opening in the FFSF, and to examine their associations with heart rate and other physiological indices of arousal.

Despite these limitations, the current study is innovative in the area of concordance between facial expression and physiology and the use of facial expression intensifiers in emotion-eliciting circumstances. In addition, this study provides an exploration of the effects of prenatal cocaine exposure on infant affective expression. Exploration of differences in affect based on prenatal cocaine exposure are crucial to our understanding of specific deficits within this high-risk group, which in turn can help inform best practices when working with this group. Overall, the episodes of the FFSF do not appear to have different profiles of facial expression intensifiers by episode. However, there is evidence for stable individual differences in intensifier use during cry-faces which increase over time in the still-face.

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References

Adamson, L. B., & Frick, J. E. (2003). The still-face: A history of a shared experimental paradigm. *Infancy: 4.*, (4), 451–474.

Bakeman, R., McArthur, D., Quera, V., & Robinson, B. F. (1997). Detecting sequential patterns and determining their reliability with fallible observers. *Psychological Methods: 2.*, (4), 357–370.

Bauer, C. R., Langer, J. C., Shankaran, S., Bada, H. S., Lester, B., Wright, L. L., et al. (2005). Acute neonatal effects of cocaine exposure during pregnancy. *Archives of Pediatrics and Adolescent Medicine: 159.*, 824–834.

Bendersky, M., & Lewis, M. (1998). Arousal modulation in cocaine-exposed infants. *Developmental Psychology: 34.*, (3), 555–564.

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (2000). The psychophysiology of emotion. In M. Lews, & J. M. Haviland-Jones (Eds.), *Handbook of emotions* (2nd ed., pp. 173–191). New York: Guilford.

Camras, L. A., & Shutter, J. M. (2010). Emotional facial expressions in infancy. *Emotion Review: 2.*, (2), 120–129.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and psychological measurement: 20.*, (1), 37–46.

Conradt, E., & Ablow, J. (2010). Infant physiological response to the still-face paradigm: Contributions of maternal sensitivity and infants' early regulatory behavior. *Infant Behavior & Development: 33.*, (3), 251–265.

Darwin, C. (1877). A biographical sketch of an infant. *Mind: 2.*, (7), 285–294.

Dedo, J. Y. (1991). *Smiling during later infancy: Relationships among facial expressions, contexts, and other communicative behaviors*. Purdue University.

Dinehart, L. H. B., Messinger, D. S., Acosta, S. I., Cassel, T., Ambadar, Z., & Cohn, J. F. (2005). Adult perceptions of positive and negative infant emotional expressions. *Infancy: 8.*, (3), 279–303.

Duchenne, G. B. (1990). *The mechanism of human facial expression* (R. A. Cuthbertson, Trans.). New York: Cambridge University Press.

Eiden, R. D., Schuetze, P., & Coles, C. D. (2011). Maternal cocaine use and mother–infant interactions: Direct and moderated associations. *Neurotoxicology and teratology: 33.*, (1), 120–128.

Ekas, N. V., Haltigan, J. D., & Messinger, D. S. (2012). The dynamic still-face effect: Do infants decrease bidding over time when parents are not responsive? *Developmental Psychology* (Online First).

Ekman, P., & Friesen, W. V. (1978). *Facial Action Coding System*. Palo Alto, CA: Consulting Psychologist Press.

Emde, R. N., Campos, J. J., Reich, J., & Gaensbauer, T. J. (1978). Infant smiling at five and nine months: Analysis of heart rate and movement. *Infant Behavior and Development: 1.*, 26–35.

Fisher, P. A., Kim, H. K., Bruce, J., & Pears, K. C. (2012). Cumulative effects of prenatal substance exposure and early adversity on foster children's HPA-axis reactivity during a psychosocial stressor. *International Journal of Behavioral Development: 36.*, (1), 29–35.

Fisher, P. A., Lester, B. M., DeGarmo, D. S., Lagasse, L. L., Lin, H., Shankaran, S., et al. (2011). The combined effects of prenatal drug exposure and early adversity on neurobehavioral disinhibition in childhood and adolescence. *Development and Psychopathology: 23.*, 777–788.

Fox, N. A., & Davidson, R. J. (1988). Patterns of brain electrical activity during facial signs of emotion in 10-month-old infants. *Developmental Psychology: 24.*, (2), 230–236.

Fogel, A., Nelson-Goens, G. C., Hsu, H., & Shapiro, A. F. (2000). Do different infant smiles reflect different positive emotions? *Social Development: 9.*, (4), 497–520.

Frank, M. G., Ekman, P., & Friesen, W. V. (1993). Behavioral markers and recognizability of the smile of enjoyment. *Journal of Personality and Social Psychology: 64.*, (1), 89–93.
Goldstein, M. H., Schwade, J. A., & Bornstein, M. H. (2009). The value of vocalizing: Five-month-old infants associate their own noncry vocalizations with responses from caregivers. *Child Development: 80.*, 636–644.
Haley, D. W., & Stansbury, K. (2003). Infant stress and parent responsiveness: Regulation of physiology and behavior during still-face and reunion. *Child Development: 74.*, (5), 1534–1546.
Hollingshead, A. B. (1975). *Four factor index of social status*. (unpublished manuscript).
Izard, C. E. (1983). *The maximally discriminative facial coding system*. Newark, DE: University of Delaware. Rev. ed. ed.
Kraft, T. L., & Pressman, S. D. (2012). Grin and bear it the influence of manipulated facial expression on the stress response. *Psychological science: 23.*, (11), 1372–1378.
LaGasse, L. L., Seifer, R., Wright, L. L., Lester, B. M., Tronick, E. Z., Bauer, C. R., et al. (1999). The Maternal Lifestyle Study (MLS): The caretaking environment of infants exposed to cocaine/opiates. *Pediatric Research: 45.*, (2), 247A.
Lambert, B. L., & Bauer, C. R. (2012). Developmental and behavioral consequences of prenatal cocaine exposure: A review. *Journal of Perinatology: 32.*, (11), 819–828.
Lester, B. M. (2006). The Maternal Lifestyles Study. *Annals of the New York Academy of Sciences: 846.*, (1), 296–305.
Mesman, J., van IJzendoorn, M. H., & Bakermans-Kranenburg, M. J. (2009). The many faces of the Still-Face Paradigm: A review and meta-analysis. *Developmental Review: 29.*, (2), 120–162.
Messinger, D. S. (2002). Positive and negative: Infant facial expressions and emotions? *Current Directions in Psychological Science: 11.*, (1), 1–6.
Messinger, D., Fogel, A., & Dickson, K. L. (2001). All smiles are positive, but some smiles are more positive than others. *Developmental Psychology: 37.*, (5), 642–653.
Messinger, D. S., Mahoor, M. H., Chow, S., & Cohn, J. F. (2009). Automated measurement of facial expression in infant–mother interaction: A pilot study. *Infancy: 14.*, (3), 285–305.
Messinger, D. S., Mattson, W. I., Mahoor, M. H., & Cohn, J. F. (2012). The eyes have it: Making positive expressions more positive and negative expressions more negative. *Emotion: 12.*, (3), 430–436.
Messinger, D. S., Fogel, A., & Dickson, K. L. (1999). What's in a smile? *Developmental Psychology: 35.*, (3), 701–708.
Moore, G. A., Hill-Soderlund, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother–infant vagal regulation in the face-to-face still-face paradigm is moderated by maternal sensitivity. *Child Development: 80.*, (1), 209–223.
Oster, H. (2009). *Baby FACS: Facial action coding system for infants and young children*. New York, NY: New York University (unpublished monograph and coding manual).
Oster, H. (2003). Emotion in the infant's face: Insights from the study of infants with facial anomalies. *Annals of the New York Academy of Sciences: 1000.*, 197–204.
Oster, H., Hegley, D., & Nagel, L. (1992). Adult judgments and fine-grained analysis of infant facial expressions: Testing the validity of a priori coding formulas. *Developmental Psychology: 28.*, (6), 1115–1131.
Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park. CA: Sage.
Schuetze, P., Eiden, R. D., & Edwards, E. P. (2009). A longitudinal examination of physiological regulation in cocaine-exposed infants across the first 7 months of life. *Infancy: 14.*, (1), 19–43.
Schuetze, P., & Eiden, R. D. (2006). The association between maternal cocaine use during pregnancy and physiological regulation in 4- to 8-week-old infants: An examination of possible mediators and moderators. *Journal of Pediatric Psychology: 31.*, (1), 15–26.
Segal, L. B., Oster, H., Cohen, M., Caspi, B., Myers, M., & Brown, D. (1995). Smiling and fussing in seven-month-old preterm and full-term black infants in the still-face situation. *Child Development: 66.*, (6), 1829–1843.
Tronick, E. Z., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face to face interaction. *American Academy of Child Psychiatry: 17.*, 1–13.
Tronick, E. Z., Messinger, D. S., Weinberg, K., Lester, B. M., Lagasse, L., Seifer, R., et al. (2005). Cocaine exposure is associated with subtle compromises of infants' and mothers' social emotional behavior and dyadic features of their interaction in the face-to-face still-face paradigm. *Developmental Psychology: 41.*, (5), 711–722.
Weinberg, K. M., & Tronick, E. Z. (1994). Beyond the face: An empirical study of infant affective configurations of facial, vocal, gestural, and regulatory behaviors. *Child Development: 65.*, 1495–1507.
Weinberg, K. M., & Tronick, E. Z. (1996). Infant affective reactions to the resumption of maternal interaction after the Still-Face. *Child Development: 67.*, (3), 905–914.