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Transgenerational associations between maternal childhood stress exposure and profiles of infant emotional reactivity

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Abstract

Childhood exposure to stress can induce prolonged negative effects on health, which in turn confer risks for the next generation, but greater specificity is needed to inform intervention. A first step is to measure individual differences in emotional reactivity to stress early in life in ways that can account for heterogeneity in child exposure. The present study tested the hypothesis that mothers' childhood exposure to stress would be differentially associated with patterns of positive and negative emotional reactivity in their offspring, suggesting transmission of stress response across generations. Participants were 268 young mothers (age 14–23 years) followed longitudinally since childhood, and their infants aged 3–9 months. Latent class analysis of infant emotions expressed before and during the still-face paradigm yielded five subgroups that varied in valence, intensity, and reactivity. After accounting for sociodemographic factors, infant temperament and postpartum depression, multinomial regression models showed that, relative to an emotionally regulated still-face response, infants showing low negative reactivity were more likely to have mothers exposed to childhood emotional abuse, and infants showing high and increasing negative reactivity were more likely to have mothers exposed to childhood emotional neglect. Mechanisms by which early maternal stress exposure influences emotional reactivity in offspring are discussed.

Keywords

Emotion dysregulation; emotional reactivity; childhood stress; transgenerational; still-face response

Dysfunctional or maladaptive patterns of emotion regulation (including excessive emotional reactivity, or an inability to modulate the intensity or duration of emotional expressions) are well-established risk factors for a wide range of childhood adjustment problems (Beauchaine, 2015; Cicchetti, Ackerman, & Izard, 1995; Cole, Hall, & Hajal, 2013; Eisenberg, Spinrad, & Eggum, 2010; Kim & Cicchetti, 2010). Individual differences in emotion regulation are measurable in infancy (Keenan, 2000), show moderate continuity across development (Brand, Engel, Canfield, & Yehuda, 2006; Lang, Gartstein, Rodgers, &

Lebeck, 2010; Tees et al., 2010) and have also been shown to signal vulnerability later in childhood (Calkins, Dedmon, Gill, Lomax, & Johnson, 2002). Whereas the ability to self-regulate (involving the management of emotional reactivity) is largely theorized to arise out of interactions with primary caregivers across the first years of life (Eisenberg et al., 2010), emotional reactivity in the context of stress more likely reflects underlying biological influences (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996). Thus, characterizing individual differences in infant emotional stress reactivity may provide important clues about the transmission of stress response and health outcomes across generations that could inform early and specific targets for prevention.

One of the most widely-used laboratory-based measures of infant emotional reactivity to stress is the Face-to-Face Still-Face paradigm (FFSF; Tronick, Als, Adamson, Wise, & Brazelton, 1978). The FFSF paradigm comprises three brief episodes in which the infant's caregiver first engages in typical play (baseline), then adopts a neutral facial expression (still-face), and finally resumes normal social interaction (reunion) (Adamson & Frick, 2003; Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009; Sravish, Tronick, Hollenstein, & Beeghly, 2013). Results from studies using the FFSF support a 'typical' still-face response (SFR) characterized by increased infant negative emotion (e.g. fussiness, protest, facial expressions of anger), and decreased positive emotion (Cole, Martin, & Dennis, 2004; Ekas, Haltigan, & Messinger, 2013; Mesman et al., 2009; Provenzi, Borgatti, Menozzi, & Montirosso, 2015; Toda & Fogel, 1993; Tronick et al., 1978; Weinberg, Tronick, Cohn, & Olson, 1999). These changes in affect are interpreted as infant distress in response to the violation in expected social reciprocity (Tronick et al., 1978; Tronick & Cohn, 1989), and physiological indicators of stress, such as changes in heart rate, skin conductance, and cortisol response lend support to this notion (Haley & Stansbury, 2003; Ham & Tronick, 2009; Lewis & Ramsay, 2005; Ramsay & Lewis, 2003). A review of research using the FFSF has shown that the typical SFR of increased negative and decreased positive emotion is robust across studies despite differences in sample characteristics and modifications to the paradigm (Provenzi, Giusti, & Montirosso, 2016). Results from longitudinal studies have shown prospective associations between the intensity of infants' emotional expressions during the FFSF and later emotion dysregulation (Braungart-Rieker, Garwood, Powers, & Wang, 2001; Cohn, Campbell, & Ross, 1991; Ekas et al., 2013; Mesman et al., 2009), as well as subsequent behavioral and emotional problems (Moore, Cohn, & Campbell, 2001; Willoughby, Waschbusch, Moore, & Propper, 2011).

There is also, however, heterogeneity in response to the FFSF. Sociodemographic (e.g. infant age, sex) and temperamental factors appear to be associated with infant reactivity to the FFSF, but not with any consistent pattern. For example, a meta-analysis revealed that some studies find higher levels of negative emotional response among male infants, others report more negative and less positive emotions among female infants, and still others find no effect of infant sex (Mesman et al., 2009). Similarly, equivocal results have been found in relation to infant fussy temperament, leading Mesman and colleagues to conclude that "temperament may be an important factor but has not been studied in relation to the still-face paradigm often enough to draw conclusions" (p. 11). Furthermore, even though postpartum depression tends to be associated with maternal behavior during the still-face paradigm (Field et al., 2007; Mantis, Mercuri, Stack, & Field, 2018; Weinberg, Olson,

Beeghly, & Tronick, 2006), it remains unclear whether infant emotional response also varies according to maternal depression severity (Field, Diego, & Hernandez-Reif, 2009; Graham, Blissett, Antoniou, Zeegers, & McCleery, 2018).

A major strength of the FFSF paradigm is that it provides an opportunity to examine two key aspects of emotion regulation: (1) initial levels of infant negative and positive emotionality and (2) *change* in these emotions in response to a social stressor (i.e. reactivity). Despite the paradigm's potential to capture these aspects of emotionality, however, most studies employing the FFSF define infant stress reactivity by mean levels of positive and negative emotion during the still-face episode (without acknowledgement of baseline levels of emotion), or by sample mean differences in emotional expressions between the baseline and still-face episodes of the FFSF. With few exceptions, the proportion of infants showing the expected changes in negative and positive affect that reflect the still-face effect is rarely described, and other profiles of infant emotional reactivity that differ in terms of intensity (high-low) and emotional valence (e.g. predominantly negative, negative and positive, positive) have been largely ignored. Yet given that *both* heightened and blunted negative emotionality are known to confer risk for psychopathology in children (e.g. Frick & Morris, 2004; Lethbridge & Allen, 2008; Rottenberg, Kasch, Gross, & Gotlib, 2002; Willoughby et al., 2011), capturing the variability in these dimensions may lead to more valid and specific characterizations of optimal and suboptimal responses, as they relate to developmental outcomes. Thus, one goal of the current study is to parse inter-individual variability in emotional valence, intensity, and reactivity in the infant SFR using a person- rather than variable-centered analytic approach.

Transgenerational Predictors of Emotional Reactivity

Research conducted across several different developmental periods supports the notion that there is transgenerational continuity in stress reactivity between mothers and children. For example, offspring of stress- or trauma-exposed parents exhibit greater risk for a broad range of adverse neurodevelopmental outcomes in childhood including alterations in the stress response system (Leen-Feldner et al., 2013). Parallel effects have been observed in the early months of life, with infants of mothers who had been exposed to trauma expressing more intense negative emotions during the FFSF (i.e., hard-crying during the still-face episode) (Bosquet Enlow et al., 2011). These studies are consistent with growing research reporting links between childhood maltreatment (e.g. emotional and physical abuse and neglect) and a broad range of adverse outcomes in the next generation, including emotional and behavioral problems in childhood (Anda et al., 2006; Bosquet Enlow, Englund, & Egeland, 2018; Heim, Shugart, Craighead, & Nemeroff, 2010; Myhre, Dyb, Wentzel-Larsen, Grøgaard, & Thoresen, 2014; Rijlaarsdam et al., 2014; Roberts, Lyall, Rich-Edwards, Ascherio, & Weisskopf, 2013). Particularly during developmental periods of heightened neuroplasticity, severe or chronic stress can alter neurobiological and physiological systems involved in stress reactivity (e.g., HPA-axis functioning, amygdala functional connectivity) (Cicchetti & Banny, 2014; Rogosch, Oshri, & Cicchetti, 2010). These enduring changes in stress reactivity are likely transmitted to the next generation through a combination of biological factors such as placental-fetal stress physiology and epigenetics (Franklin et al., 2010; Moog et al., 2018; Sandman, Davis, Buss, & Glynn, 2011), and postnatal impairments in maternal

mental health and caregiving behaviors (Bowers & Yehuda, 2016; Noll, Trickett, Harris, & Putnam, 2009; Rouse & Goodman, 2014).

Expanding the window of maternal stress exposure to include the preconception period, including the mother's exposure to stress during childhood, has further increased the variability in transmission risk (Monk, Spicer, & Champagne, 2012). One potential contributor is the lack of specificity about the type of childhood stress exposures, which can range from emotional and physical abuse and neglect to chronic environmental adversity, such as household poverty and family conflict. Differences in operational definitions of domains of stress exposures and a tendency to combine stress domains into a single composite variable have also led to results that lack consistency and specificity (Schwartz, Bellinger, & Glass, 2011). For example, broadly defined stress exposure early in development has been associated with both blunted and heightened responsiveness of the HPA axis later in life. Some evidence suggests that different *types* of stressors may activate different aspects of an individual's stress response (Humphreys & Zeanah, 2015; McLaughlin & Sheridan, 2016). Whereas threat-based stressors (e.g., physical abuse, violence exposure) may upregulate neurobiological responses to stress (McLaughlin & Sheridan, 2016), severe deprivation (e.g., neglect) has been linked to a blunted and downregulated stress profile in some studies (McLaughlin et al., 2015) although this has not been shown consistently (e.g. Boyce & Ellis, 2005; Delahanty & Nugent, 2006; DeSantis et al., 2011). Thus, there is emerging evidence supporting the need to differentiate the impact of *types* of stressors on individuals, as well as the transgenerational impact of stressor types on emotional reactivity in young children (Ursache, Noble, & Blair, 2015), and it is plausible that infant stress reactivity may be impacted differentially by the type of maternal childhood stress exposure. Elucidating the unique effects of childhood emotional and physical abuse, emotional neglect, environmental adversity, and exposure to family conflict in the form of domestic violence on different profiles of infant emotional reactivity would inform more targeted interventions for high-risk families that could optimize infant developmental trajectories.

Present Study

Extant work suggests that maternal stress exposure experienced during childhood is associated with stress response in offspring, but specificity between the exposures and effects remain unclear. To address these limitations, the current study had three primary aims: First, we employed a person-centered approach to identify latent profiles of infant emotional reactivity informed by emotional expression during both baseline and still-face episodes of the FFSF. Next, we characterized these groups by examining potential differences in emotional reactivity as a function of sociodemographic factors (e.g. infant age, sex) and infant temperament. Finally, we examined the strength of prospective associations between various forms of maternal preconception (i.e. childhood) stress exposure and different profiles of infant emotional reactivity to stress. We hypothesized that most infants would respond to the still-face with decreasing positive affect and increasing negative affect, but that individual differences in emotional reactivity would cluster in subgroups distinguished by type of emotional valence and intensity of response. Given some evidence for sex differences in emotion regulation, we expected that male infants as well as

temperamentally fussy infants would be represented in groups characterized by higher levels of negative reactivity. Finally, we expected that subgroups of infant emotional reactivity would be associated with different types of maternal childhood stress exposure.

Methods

Sample

Participants were 268 young mothers and their infants recruited from the Pittsburgh Girls Study (PGS). The PGS is a longitudinal population-based study, with the original aim of characterizing the ontogeny of conduct disorder in females. The PGS sample (N=2,450) was formed following enumeration of 103,238 City of Pittsburgh households in 1999-2000. A stratified, random household sampling method with over-sampling of households in low-income neighborhoods was used to identify girls between the ages of 5 and 8 years (see details in Hipwell et al., 2002; Keenan et al., 2010). In wave 1, approximately half of the PGS sample was African American (52%), 41% European American, and the remaining girls were described as multiracial or representing another race. A large minority (39%) of households received public assistance (e.g., food stamps, Medicaid) and 17% of caregivers had completed fewer than 12 years of education. In-home, annual face-to-face interviews were conducted with the primary caregiver (> 90% biological mother) until the girl participants were age 18 (PGS waves 10-13). Separate interviews with the girls began at age 7 and are continuing in early adulthood. Sample retention across PGS assessment waves included in the current paper ranged from 97.2% (wave 2) to 86.4% (wave 15).

The PGS interview tracked pregnancies and birth outcomes beginning when the girls were 11 years of age, and in two separate substudies recruited participants for identical lab-based observational assessments in the postpartum period. The first substudy, conducted between 2006-2013 (PGS waves 5-12), included 122 primiparous adolescent mothers (ages 12-20 years) who were assessed with their infants in the first postpartum year. The second substudy was conducted between 2011-2016 (PGS waves 10-15) and included 185 primiparous mothers aged 18 and older, and their infants. Of this combined sample of 307, observational data were missing for seven dyads for the following reasons: assessment was not conducted in the lab (n=3); assessment incomplete due to infant distress (n=2) and technical failure (n=2). To reduce heterogeneity due to infant developmental factors, dyads were only included in the current analyses if the infant was between 3 and 9 months of age at the first lab visit (32 subjects were excluded: 19 infants < 3 months and 13 infants 10 months). In addition, to ensure temporal ordering of childhood stress exposure (measured from age 8 through 13) and motherhood, four young mothers (one 12-year-old and three 13-year-olds) were excluded. The final sample therefore included 268 mothers-infant dyads (87.3% of the enrolled samples).

Procedure

Approval for all study procedures was obtained from the University of Pittsburgh Human Research Protection Office. Written informed consent from the caregiver and verbal assent from the girl were obtained through age 17. Adolescent mothers younger than 18 years

provided written consent for their infants' participation. All participants aged 18 and older provided written informed consent for themselves and for their infants.

Between 3 and 9 months postpartum, the mother visited the research suite with her infant to complete interview measures and to be filmed during mother-infant interactions. When the infant was alert and not distressed, each mother-infant dyad was filmed in face-to-face interaction for five minutes (baseline): the mother was first asked to talk to her infant in any way she wanted to without the use of toys for 2 mins and then to help her child get interested in a specific toy for 3 mins. Mothers were then prompted to adopt a neutral, motionless face (still-face), which lasted for 3 minutes unless the infant engaged in hard crying for 20 secs, in which case the episode was curtailed. Finally, mothers resumed interaction with infants for a 3-min period (reunion). Infants were seated in a high chair and the mother sat directly opposite for the duration of the filmed interaction. Families were compensated for their participation.

Measures

Demographic data—Mothers reported on their ages at birth, infant age at the time of the lab visit and infant sex (female=1, male=2). Maternal race was assessed from caregiver report in the PGS interview. Infant weight in kg was measured at the time of the lab visit using a digital medical baby scale, and weight-for-age was calculated as an indicator of infant general health.

Infant Temperament—Mothers completed the Infant Characteristics Questionnaire (ICQ; Bates, Freeland, & Lounsbury, 1979) to measure their perceptions of their infants' temperament. The 6 items of the fussy/difficult subscale were rated on 7-point scales (1 = most easy/optimal temperament to 7= most difficult temperament) and combined to create a composite score. The ICQ has demonstrated adequate convergent validity with other parent-report measures of infant temperament as well as the independent impressions of trained observers (Bates et al., 1979).

Postpartum depressed mood was assessed using the 10-item Edinburgh Postnatal Depression Scale (Cox, Holden, & Sagovsky, 1987). Mothers reported on the severity of depressed mood, anhedonia, guilt, anxiety and suicidal ideation experienced in the past week using 4-point scales (0-3). The EPDS has good psychometric properties (Cox et al., 1987; Murray & Carothers, 1990). In the current sample, 10.8% scored above 10 indicating possible clinical impairment (Cox et al., 1987). The distribution of scores was significantly positively skewed and were log10 transformed for analyses.

Maternal childhood exposure to stress was assessed prospectively in the course of PGS annual interviews based on a combination of self- and parent-report. Five types of childhood stressors were coded as present (1) or absent (0) each year when the current mothers were 8-13 years of age: parent-child aggression, parent domestic violence, emotional abuse, emotional neglect, and chronic poverty. Parent-child aggression was assessed using the Parent-Child Conflict Tactics Scale (CTS-PC; Straus, Hamby, Boney-McCoy, & Sugarman, 1996), including 1 parent-rated item and 2 self-reported items regarding the frequency that any caregivers in the home "hit or spanked" the child. Participants who were "often"

exposed to hitting or spanking for one or more years (according to parent or child report) were coded as positive for parent-child aggression. The CTS-PC also assessed for childhood exposure to emotional abuse, including 5 parent-reported items and 10 child-reported items about the frequency that the primary or secondary caregiver in the home engaged in five emotionally abusive behaviors (i.e., threatening to hit, shouting, swearing at the child, calling the child names, and threatening to kick the child out of the home). Participants were coded as positive for emotional abuse history if either the parent or child endorsed three or more emotionally abusive behaviors as occurring “often” in the same year consistent with the adverse childhood experiences (ACES) framework (Centers for Disease Control and Prevention, 2016). Emotional neglect was assessed by the low warmth subscale of the Parent-Child Relationship Scale (Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998), including 6 parent-rated items regarding parental warmth or engagement with the child (e.g., “How often have you enjoyed time together with your child?”). Participants were coded as positive for emotional neglect if their caregiver endorsed “almost never” to one or more items on this subscale. Parent domestic violence was assessed by the Conflict Tactics Scale-2 (Straus et al., 1996), including three self-reported and four parent-reported items about the frequency that either caregiver engaged in physical aggression towards their partner (e.g., hit, kicked, slapped). Participants were coded as positive for domestic violence exposure if any items were endorsed by parent or child as occurring “more than 5 times” in the past year. Finally, past year receipt of public assistance (e.g. WIC, Medicaid), an index of household poverty, was reported annually by caregivers when the current mother was between 8 and 13 years old. A variable was created to reflect chronic poverty (receipt of public assistance for two or fewer years = 0, public assistance for three or more years = 1).

Infant emotional reactivity—Infant behaviors during the baseline and still-face episodes of the FFSF were coded by two independent observers using time-sampled global ratings. The trained coders were unaware of all other information about the mother-infant dyads, and observations during baseline were coded independently from those during the still-face episode. The frequency and intensity of infant positive and negative emotional expressions were coded based on affective displays of smiling and laughter or distress and fussiness respectively on 4-point scales (1=none to 4=frequent/severe). Observations from the warm-up and toy play interactions were averaged to create baseline intensity scores for displays of positive and negative emotionality. The positive and negative emotion dimensions were moderately correlated in expected directions at baseline, during the still-face and across the FFSF episodes (positive and negative emotion at baseline: *Spearman’s rho* = $-.29$, $p < .01$; positive and negative emotion during the still-face: $r = -.39$, $p < .01$; positive emotion during baseline and still-face: $r = .31$, $p < .001$; and negative emotion during baseline and still-face: $r = .44$, $p < .01$). Inter-rater reliability on the emotion dimensions was determined by intra-class coefficients (ICCs) on a random sample of 28 mother–infant pairs for the baseline episode (infant positive emotion ICC=0.91, infant negative emotion =0.94) and 27 randomly selected pairs for the still-face episode (infant positive emotion ICC=0.92; infant negative emotion ICC=0.94).

Data Analytic Plan

Infant positive and negative emotion during baseline and during the still-face episodes were included as indicators in a latent class analysis (LCA, Vermunt & Magidson, 2004), conducted using Mplus, version 8 (Muthén & Muthén, 1998-2017). Model solutions were evaluated based on statistical measures of model fit (e.g. Akaike and/or Bayesian information criterion (AIC/BIC), Lo-Mendell-Rubin (LMR) adjusted likelihood ratio test), precision of assigning individuals into latent classes (e.g. entropy), and model parsimony (Collins & Lanza, 2010). Information criteria with smaller values indicate better model fit (BIC typically outperforming AIC in terms of the number of classes, (Nylund, Asparouhov, & Muthén, 2007); higher entropy values indicate greater certainty of subgroup membership. Following extraction of the latent classes, infants were assigned to the subgroup for which they had the highest posterior probability. Mean scores were plotted for each latent class to visualize and guide interpretation of qualitative differences.

To characterize the subgroups of infant emotional reactivity, the latent classes were compared on sociodemographic characteristics (i.e., age, sex) and infant fussy temperament. Group comparisons were conducted using univariate one-way ANOVAs and *post hoc* least significance difference tests for continuous variables. Chi-square tests were used to examine group differences for categorical independent variables with *post hoc* comparisons of adjusted standardized residuals to determine significant differences (z score > 1.96) among observed from estimated frequencies (Agresti, 2007). Finally, a multinomial logistic regression was conducted to test associations between mothers' experiences of childhood stress (i.e., chronic poverty, parent-child aggression, inter-parental aggression, emotional abuse, and emotional neglect) and infant membership in the latent classes. To increase specificity of predictive effects, the model controlled for maternal and infant age, infant sex, weight-for-age percentile, infant fussiness, and severity of postpartum depressed mood as covariates.

Results

Sample characteristics

Descriptive statistics are shown in Table 1. Most of the sample comprised Black or multi-racial mothers (85.8%), and the mean age at delivery was 18.93 years ($SD=1.84$, range=14.60-23.06). The infants (49% male) were aged 4.62 months ($SD=1.39$, range=3.0-9.40) at the time of the lab visit and were of average weight-for-age relative to the general population. More than half of the mothers had been exposed to multiple years of household poverty as children (60.6%), and substantial minorities experienced parent-child aggression (23.5%), inter-parental violence (29.2%), emotional abuse (44.3%) and emotional neglect (18.9%).

For the sample as a whole, infants displayed moderate levels of positive emotion and low levels of negative emotion during the baseline period ($M = 2.15$, $SD = .66$, skewness = .13, and $M=1.44$, $SD=.64$, skewness = 1.74, respectively). Conversely during the still-face episode, mean levels of positive emotion were low ($M=1.50$, $SD=.73$, skewness = 1.34), and levels of negative emotion were moderate ($M=2.30$, $SD=1.09$, skewness = .22). Overall,

infants showed less intense positive emotion (Wilcoxon signed-ranks $Z = -10.29$, $p < .001$, $d = 0.63$) and more intense negative emotion (Wilcoxon signed-ranks $Z = 11.09$, $p < .001$, $d = .68$) in the still-face, relative to the baseline episode.

Zero-order correlations among the study variables are depicted in Table 2. Older maternal age was associated with having a younger infant at the time of the lab visit ($r = -.12$, $p < .05$), as well as higher reported infant fussiness on the ICQ ($r = .32$, $p < .01$) and lower rates of exposure to household poverty during childhood ($r = -.18$, $p < .01$). Reported levels of infant fussiness were higher among younger infants ($r = -.18$, $p < .01$) and among infants at a lower weight-for-age percentile ($r = -.17$, $p < .01$). Maternal exposure to parent-child aggression and emotional abuse in childhood were moderately correlated ($r = .33$, $p < .01$) but otherwise there was little overlap between the childhood exposure variables.

Extraction of Latent Classes

Latent class models were estimated by iteratively specifying two to six classes (see Table 3). Consideration of model fit, precision and parsimony determined selection of a five-class model. Although BIC and entropy statistics were similar for the five- and six-class models respectively, the LMR adjusted likelihood ratio test revealed no significant improvement in fit from five to six latent classes, and the six-class solution also generated a group corresponding to approximately 5.60% of the sample (15 individuals). The average posterior probabilities of the five classes comprised: 0.93, 1.0, 1.0, 0.92 and 0.98 for classes one to five respectively indicating a high certainty of the classification. The five-class solution was also compared on conceptual grounds to alternative solutions and appeared parsimonious and defensible.

Figure 1 shows a profile plot of mean scores for observed infant emotions in the baseline and still-face episodes of the FFSF in the five latent classes. Class 1 is characterized by moderate levels of positive emotion at baseline that are absent in the still-face episode, combined with low negative emotion across baseline and still-face; labeled 'low negative reactivity', $n=75$). Class 2 is characterized by high levels of baseline positive emotion that *increase* in the still-face episode, combined with minimal expressions of negative emotion across baseline and still-face ('positive reactivity', $n=29$). Class 3 comprised infants displaying moderate-to-high levels of baseline positive emotion that show a modest decrease in the still-face episode, combined with low levels of negative emotion at baseline that increase moderately during the still face ('moderate still-face response', $n=71$); a combination of behaviors that were most closely aligned with a typical SFR. Like Class 1, Class 4 is characterized by moderate levels of baseline positive emotion that are absent in the still-face episode, but these infants also display a large increase in negative emotion from baseline to still-face ('strong still-face response', $n=67$). Class 5 is characterized by low levels of baseline positive emotion that are absent in the still-face episode, combined with high levels of baseline negative emotion that further increase in the still-face ('high-increasing negative reactivity', $n=26$). Thus, two classes reflected the 'typical' SFR of reduced positive and increased negative emotion: one manifesting a moderate intensity SFR and the other a strong, more intense SFR. Together, the 'moderate still-face' and 'strong still-face' classes represented 51.5% of the sample, whereas the other three classes exhibited

patterns of emotional reactivity that deviated in terms of intensity and valence from the typical SFR.

Characterizing the Latent Classes

The results of the univariate comparisons of study variables by latent class are shown in Table 4. The proportion of male infants varied across the subgroups ($X^2_{[4]} = 9.54, p < .05$). *Post hoc* comparisons of observed and estimated frequencies revealed adjusted standardized residuals of -2.43 for the low negative reactivity class indicating that male infants were under-represented in this group (i.e. the percentage of 37.3% male infants is statistically lower than the null hypothesis rate of 50%). In contrast, a significantly higher rate of male infants was represented in the strong SFR group (59.7%, adjusted standardized residual = 1.98). None of the remaining latent classes differed on proportion of male sex. The results also revealed a group difference in terms of infant age ($F_{[4,263]} = 2.88, p < .05$). *Post hoc* comparisons demonstrated that infants in the moderate SFR group were significantly older than infants classed as low negative reactivity, strong SFR and high-increasing negative reactivity). ANOVAs revealed no group differences in terms of maternal report of fussy infant temperament, or for the covariates of maternal age at delivery, infant weight-for-age percentile or maternal postpartum depressed mood.

Association between maternal stress exposure and infant response groups

Based on conceptual grounds, group size and univariate comparisons, Class 3 (moderate SFR) was selected as the reference group in the multinomial logistic regression analyses. The multinomial logistic regression model fit the data well ($-2 \log \text{likelihood} = 726.11, X^2_{[44]} = 69.84, p < .01$). After controlling for all covariates, maternal childhood emotional abuse exhibited a unique effect on odds of membership in the low negative reactivity class compared to the reference group (Table 5). Specifically, exposure to maternal childhood emotional abuse was associated with a 2.4-fold increase in the odds of infants showing low negative reactivity to the FFSF ($AOR = 2.44; 95\% CI = 1.15-5.16$). In addition, maternal childhood emotional neglect was associated with a more than 4-fold increase in the odds of infants responding with high, increasing negative emotions to the still-face (Class 5) compared to the regulated still-face response ($AOR = 4.65; 95\% CI = 1.45-14.91$). Maternal history of chronic poverty, parent-child aggression, and inter-parental aggression did not predict offspring membership in the emotional reactivity classes.

Discussion

The current study advances knowledge on transgenerational effects of childhood stress exposure. Although a wealth of extant research supports a link between maternal stress exposure, broadly defined, and adverse offspring neurodevelopmental outcomes such as vulnerability to stress, the lack of specificity in both exposure and outcome has led to inconsistent results, which have likely hampered prevention and intervention efforts. We sought to increase specificity in *exposure* with a focus on five established domains of childhood stress (i.e. chronic poverty, emotional abuse, emotional neglect, parent-child aggression, and exposure to domestic violence) that were relatively independent of each other. Using a person-centered analytic approach, we also sought to increase specificity in

offspring *outcome*, by parsing inter-individual variability in infant emotion regulation in the context of a potent stressor. We hypothesized that infants' responses to the FFSF could be empirically clustered in subgroups in terms of emotional valence and intensity of response. Furthermore, we expected that these subgroups would be associated with different types of maternal exposure to childhood stress. The results of the analyses supported both sets of hypotheses.

Patterns of Infant Stress Reactivity

As far as we are aware, the current study is the first to employ latent class analysis of observed infant positive and negative emotional expressions during the baseline and still-face episodes of the widely used FFSF to identify distinct clusters of infants in terms of emotional reactivity to stress. This was possible with the use of a large combined sample of young mothers drawn from the same parent sample and participating in one of two identical lab-based observational assessments in the postpartum period. The validity of the paradigm and observational coding scheme and comparability with prior work was supported by the finding that mean levels of infant positive emotion decreased, and mean levels of negative emotion increased from the baseline to the still-face episode. In terms of individual differences, the focus of the current analyses, the results lent some support to the notion of a 'typical still-face response' given that four out of five of the latent classes were characterized by at least some increase in negative emotion and decrease in positive emotion from the baseline to the still-face episodes. However, the person-centered approach also revealed substantial variability in infant baseline emotional valence and intensity of response to the still face, highlighting the importance of taking these multiple factors into account when considering infant SFR.

Of the four groups displaying the expected changes in emotional valence from baseline to still-face, three groups were distinguished largely by the *intensity* of emotional change. Thus, the 'moderate SFR' was characterized by modest to moderate levels of positive and negative emotion change in the expected directions, whereas change in the 'strong SFR' group was characterized by a pronounced decrease in positive emotion (from average levels at baseline to none in the still-face episode), and by a large increase in negative emotion (more than 1 SD) in response to the still-face. The largest group ($n=75$) comprised infants who showed the same pronounced decrease in positive affect from baseline to still-face but were relatively unresponsive to the still-face in terms of the expression of negative emotions ('low negative reactivity'). Thus, although the direction of change in emotional valence was similar, reactivity intensity varied across these three profiles. In contrast, the 'high increasing negativity' group appeared similar to the 'moderate SFR' group in terms of intensity of change in emotional valence from baseline to still-face but was distinguished from all other groups by markedly low levels of positive affect and high levels of negative affect during the baseline interaction period. Infants in this class displayed negative emotions at levels that were > 2 SD above the mean during baseline and then responded to the mother's neutral face with further increases in negative emotions to almost maximal levels.

The final group ('positive emotional reactivity'; Class 2) was the only class not to show the typical change in affect expected from baseline to still-face. Specifically, this group was

characterized by high levels of positive affect during baseline and a yet further increase from baseline to the still-face episode, whereas displays of negative emotions were minimal and stable across the episodes. Such a pattern may indicate a high capacity for emotion regulation (e.g., engagement in self-soothing), consistent with the notion of resilience in the face of stress. The increase in positive affect from baseline to still face could reflect that infants in this group used positive strategies to attempt to re-engage and make bids to the mother during the still-face episode. An important avenue for future research will involve the collection of physiological indicators of HPA activation (e.g. changes in heart rate, skin conductance, and cortisol response) in tandem with observed emotions in order to clarify whether the FFSF was an effective stressor for these infants.

Results of univariate comparisons of the five groups based on demographic variables revealed differences in infant age and sex. Specifically, infants in the 'moderate SFR' group were older than infants in the 'strong SFR', 'low negative reactivity', and 'high-increasing negative reactivity' groups. This is consistent with previous work suggesting more pronounced still face effects at younger than at older ages (Striano, Liskowski, & Group, 2005; Toda & Fogel, 1993). Self-regulation skills increase rapidly across the first year of life, thus as infants get older, they may be less reactive to social stressors in part due to the elaboration of self-soothing and coping strategies. In addition, male infants were more likely to be classified in the 'strong SFR' group and less likely to be classified in the 'low negative reactivity' group. This finding aligns with some prior research suggesting that male infants show more negative emotional dysregulation (Davis & Emory, 1995; Weinberg et al., 1999) and tend to be more reliant on the caregiver providing an optimal level of stimulation that encourages infant positive engagement and minimizes negative engagement (Field, 1994; Stoller & Field, 1982). As noted previously, extant research examining infant sex as a correlate of the SFR has been mixed (Mesman et al., 2009); our findings suggest that sex effects may emerge if variability in the intensity of infant emotional reactivity from baseline to still-face is considered. Interestingly, maternal perception of fussy-difficult infant temperament was similar across all the latent classes, indicating that the groups could not be distinguished in terms of this dispositional characteristic as reported by the mother.

Transgenerational Associations with Maternal Preconception Stress

Regarding the final study aim, our findings support the hypothesis that different types of maternal childhood stress exposure have unique associations with infant emotional reactivity profiles. Whereas previous studies examining this association have relied on combined measures of general stressful events (e.g., Bosquet Enlow et al., 2016; Brand et al., 2010), our study differentiated between five common domains of childhood adversity, ranging from chronic stressors such as living in poverty to more acute measures of emotional abuse and family violence. After accounting for sociodemographic factors, infant temperament and postpartum depression, the multinomial regression model revealed two unique associations between types of maternal stress exposure in childhood and profiles of infant emotional reactivity. First, relative to infants displaying a moderate SFR, infants showing low negative reactivity were more likely to have mothers exposed to childhood emotional abuse. Low negative reactivity may be an indicator of a transgenerational blunting effect; high levels of maternal exposure to childhood emotional abuse contribute to the development of a blunted

physiological stress response that is subsequently transmitted to the offspring. Second, infants showing high and increasing levels of negative emotions in response to the FFSF relative to the moderate SFR group were more likely to have mothers who were exposed to emotional neglect as a child. Overall, the pattern of these two findings is somewhat inconsistent with single-generation studies of childhood adversity, which have found stronger associations between threat (vs. deprivation) and an upregulated neurobiological stress response (Gunnar & Vazquez, 2006; Heim & Nemeroff, 2001; McLaughlin & Sheridan, 2016). In contrast, maternal history of emotional neglect emerged as the best predictor of heightened infant negative reactivity in our study, whereas maternal history of emotional abuse was associated with the infant profile most closely aligned with a blunted response. However, our findings are consistent with one other study which documented an association between retrospectively reported maternal child abuse and lower baseline cortisol levels in offspring (Brand et al., 2010). Given that most studies measuring infant emotional reactivity rely on mean levels of positive and negative affect, more studies that employ a person-centered approach are needed to replicate the profiles of reactivity observed in this study.

Although the mechanisms involved are unclear, transmission from the preconception period to offspring may occur via stress-induced alterations in the mothers' neural, neuroendocrine and immune systems (Heim & Binder, 2012), which have been shown to be especially susceptible to early life environments (Danese & Lewis, 2017; Zhang, Labonté, Wen, Turecki, & Meaney, 2013). For example, victims of childhood maltreatment commonly exhibit structural and functional changes in a network of brain regions implicated in vigilance and emotional regulation (Graham et al., 2015), which may impact later caregiving quality. Chronic exposure to maternal emotion dysregulation or suboptimal caregiving may, in turn, prompt persistent activation of the infants' stress response systems and a reduction in the capacity for emotion regulation across development (Moore, 2009). Transgenerational transmission may also occur along genetic or epigenetic pathways. For example, exposure to stress in childhood may directly impact the offspring via changes in the health of gametes (Dias & Ressler, 2014; Franklin et al., 2010; Gapp et al., 2014) or may result in epigenetic changes in DNA leading to alterations in the HPA axis consistent with fetal 'programming' (Glover, O'Connor, & O'Donnell, 2010; Sandman et al., 2011). An important avenue for future research will be to probe mechanisms of transmission including altered HPA, epigenetics and behavioral indices such as emotional dysregulation emerging in childhood and influencing the caregiving environment.

Despite these intriguing findings, maternal childhood emotional abuse and neglect did not distinguish other infant groups from moderate SFR. In addition, the results of the multinomial regression revealed no unique effects of chronic poverty, parent-child aggression, or inter-parental aggression on next generation infant emotional reactivity profiles after accounting for emotional abuse and neglect. Thus, on balance, these results suggest that the relatively high prevalence of these five domains of childhood stress exposures and the challenges of parenting that are often faced by young mothers living in low-income environments (Parkes, Sweeting, & Wight, 2015; Rafferty, Griffin, & Lodise, 2011), do not necessarily translate into heightened or blunted infant emotional reactivity to stress, and some infants may be resilient or adapt positively in the context of adversity

(Luthar, 2003). Achieving greater rigor in characterizing heterogeneity in infant emotional reactivity to stress and the influence of specific stress exposure types on different developmental outcomes, will provide opportunities for probing mechanisms that can be more usefully and accurately translated into prevention and early intervention.

Limitations

The current findings should be interpreted in the context of several study limitations. First, although our sample size was larger than many studies that employ the observational FFSF paradigm to measure infant emotional stress reactivity, two of the latent classes were relatively small ($n < 30$), potentially limiting our power to detect differences between the groups. We selected moderate SFR as the reference group on conceptual grounds, but it is possible that the strong SFR profile represented infants for whom the FFSF was an especially potent stressor and against which other groups should have been compared. Our interpretations of the SFR groups were also somewhat limited by our macro approach of measuring emotional reactivity, which did not allow us to examine sequential behaviors. For example, infants in the moderate SFR group may have been using different strategies to regulate emotion and cope with the stressor than other groups. It is also important to note that Latent Class Analysis is an exploratory method that may be prone to over-extraction of classes, especially if input variables are skewed. In our data, infant negative affect was skewed in the baseline period whereas positive affect was skewed in the still-face episode. This non-normality may have increased the identification of spurious groups (Bauer & Curran, 2003) such as a group characterized by negative affect at baseline (a defining feature of the high increasing negative group), and a group characterized by positive affect during the still-face episode (i.e. the positive reactivity group). Although several precautions were taken to avoid the over-extraction of classes (use of BIC and LMR, Nylund et al., 2007), replication and characterization of these latent classes in other large and diverse samples is clearly warranted.

Finally, although the study participants were oversampled from low-income neighborhoods and included relatively high rates of adversity compared to the general population, our findings were based on a community sample rather than a selected clinical sample of mothers with documented history of maltreatment or other forms of extreme stress. Thus, the strength of the association between patterns of stress reactivity in offspring and maternal childhood stress exposures delineated here may not be as strong as associations with more severe maltreatment. In the current analyses, frequent spanking and extreme forms of physical abuse were combined, which may have masked important variability in the experience and implications of parent-child aggression. Nevertheless, the ubiquity of moderately severe exposures does not diminish the importance of specifying types of stressors in order to determine early markers of stress vulnerability within the general population.

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Figure 1.
Mean scores for infant positive and negative affect during baseline and still-face episodes for the five latent classes.

Table 1.

Descriptive statistics (N=268)

Variable	<i>n</i> (%)			
Maternal race: White	38 (14.2)			
Black	221 (82.5)			
Multi-racial	9 (3.4)			
Infant sex: male	132 (49.3)			
Childhood exposures (8-13 years)				
Household poverty	160 (60.6)			
Parent-child aggression	62 (23.5)			
Exposure to inter-parental violence	77 (29.2)			
Emotional abuse	117 (44.3)			
Emotional neglect	50 (18.9)			
	<i>Mean (SD)</i>	<i>Range</i>		
Maternal age at delivery	18.93 (1.84)	14.60-23.06		
Infant age (months)	4.62 (1.39)	3.0-9.40		
Infant weight-for-age percentile	47.68 (27.72)	0.1-99.6		
Infant fussy temperament	21.82 (6.84)	8-42		
Postpartum depressed mood [†]	4.29 (4.68)	0-23		
Observational ratings	Baseline Mean (SD)	Still-face Mean (SD)	<i>Z</i>	
Infant positive affect	2.15 (.66)	1.50 (.73)	10.29 ***	
Infant negative affect	1.44 (.64)	2.30 (1.09)	11.09 ***	

Note:

[†] Untransformed EPDS scores are displayed for ease of interpretation. *Z* = standardized test statistic from Wilcoxon signed-ranks test***
p < .001

Table 2.

Zero-order correlations among study variables.

	1	2	3	4	5	6	7	8	9	10
1. Maternal age										
2. Infant male sex	-.11									
3. Infant age	-.12*	.07								
4. Weight-for-age	-.06	-.04	-.02							
5. Fussy temperament	.32**	.10	-.18**	-.17**						
6. Postpartum depressed mood	-.12	.07	.08	-.08	.01					
7. Household poverty	-.18**	.04	-.05	.01	-.05	-.04				
8. Parent-child aggression	.01	-.05	.01	-.04	.03	.07	.06			
9. Inter-parental violence	-.07	-.01	.03	.13*	-.07	.11	.07	.04		
10. Emotional abuse	.06	.01	-.04	.04	.03	.06	-.01	.33**	.05	
11. Emotional neglect	.01	.06	.15*	.05	.01	.09	-.07	.01	.01	-.10

Note.

* $p < .05$

** $p < .01$.

Table 3.

Results of the Latent Class Analysis.

Class solution	AIC	BIC	Adjusted BIC	Entropy	LMR adjusted LRT test
2	2272.25	2318.93	2277.71	.922	196.38**
3	1870.36	1934.99	1877.92	1.00	397.67
4	1716.54	1799.14	1726.21	.972	4 > 3 classes: 159.73***
5	1675.93	1776.47	1687.69	.922	5 > 4 classes: 49.51**
6	1655.84	1774.35	1669.72	.938	6 > 5 classes: 29.49

Note: AIC = Akaike information criterion; BIC = Bayesian information criterion; LMR adjusted LRT test = Lo-Mendell-Rubin adjusted likelihood ratio test.

**
 $p < .01$

 $p < .001$.

Table 4.

Univariate comparisons between the latent classes.

Variable	Class 1 Low negative reactivity (<i>n</i> = 75)	Class 2 Positive reactivity (<i>n</i> = 29)	Class 3 Moderate SFR (<i>n</i> = 71)	Class 4 Strong SFR (<i>n</i> = 67)	Class 5 High-increasing negative reactivity (<i>n</i> = 26)	<i>F</i> (4,263)	<i>X</i> ² (4)
Maternal age (<i>M, SD</i>)	19.17 (1.96)	19.03 (1.77)	18.69 (1.86)	19.08 (1.61)	18.42 (2.03)	1.25	
Infant male sex (<i>n, %</i>)	28 (37.3)	12 (41.4)	36 (50.7)	40 (59.7)	16 (61.5)		9.54*
Infant age (<i>M, SD</i>)	4.49 (1.18) ^a	4.63 (1.29)	5.07 (1.65) ^b	4.43 (1.36) ^a	4.23 (1.08) ^a	2.88*	
Weight-for-age (<i>M, SD</i>)	49.01 (25.55)	43.06 (27.58)	50.76 (29.14)	46.45 (28.40)	43.78 (28.96)	.62	
Fussy temperament (<i>M, SD</i>)	22.31 (7.51)	21.76 (5.99)	21.66 (6.80)	21.55 (6.90)	21.58 (6.09)	.138	
Postpartum mood [†] (<i>M, SD</i>)	3.76 (4.28)	4.59 (4.50)	4.82 (5.21)	3.96 (4.59)	4.96 (4.76)	.71	

Note: Different superscripts indicate that the mean scores were significantly different at $p < .01$. [†]Untransformed EPDS scores are displayed for ease of interpretation.

* $p < .05$.

Multinomial regression predicting infant still-face classes from maternal childhood stress domains.

Table 5.

	(3) Moderate SFR (Ref, <i>n</i> = 71)			(1) Low negative reactivity (<i>n</i> = 75)			(2) Positive reactivity (<i>n</i> = 29)			(4) Strong SFR (<i>n</i> = 67)			(5) High-increasing negative reactivity (<i>n</i> = 26)		
	AOR	95% CI	<i>p</i> value	AOR	95% CI	<i>p</i> value	AOR	95% CI	<i>p</i> value	AOR	95% CI	<i>p</i> value	AOR	95% CI	<i>p</i> value
Household poverty	.53	.26-1.09	.086	1.56	.55-4.40	.399	.62	.29-1.30	.206	.98	.35-2.74	.965			
Parent-child aggression	1.17	.49-2.78	.726	1.23	.38-4.01	.735	2.19	.88-5.47	.093	.57	.15-2.15	.403			
Inter-parental violence	1.16	.54-2.49	.697	1.08	.40-2.95	.882	1.38	.63-3.01	.417	.28	.07-1.11	.071			
Emotional abuse	2.44*	1.15-5.16	.020	.79	.28-2.21	.646	.61	.27-1.36	.226	2.24	.81-6.20	.122			
Emotional neglect	1.63	.62-4.28	.321	1.86	.57-6.02	.302	1.22	.46-3.29	.689	4.65**	1.45-14.91	.010			

Note: SFR = still-face response; AOR = adjusted odds ratio; 95% CI = 95% Confidence Interval. Model controls for maternal age, infant sex, infant age, weight-for-age percentile, infant fussiness, and postpartum depressed mood.

* $p < .05$

** $p < .01$.