Infant emotional development adapts to distinct patterns of caregiver mental health and household dynamics

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Caregiver mental health and the home environment influence emotional development, but it is unclear whether different patterns of these variables shape infant outcomes. To capture heterogeneity of infants' proximal environments, we use latent profile analysis to examine how distinct *patterns* of caregiver psychological distress and variability in the home predict emotional regulation in 104 mother-infant dyads (M age = 6.4 months, 46% White; 31% Hispanic/Latino; 51% Male). Infants of mothers experiencing high psychological distress who were in homes with high physical stimulation (e.g., noise, activity) and temporal disorder (e.g., lack of routines) demonstrated lower negative affect and increased regulation during two stressor tasks. These findings indicate that emotional development may be adapted to the unique characteristics of infants' proximal environments.

Effective emotional regulation, or the ability to monitor, evaluate, and modify emotional responses, is a hallmark of early social and emotional development (Thompson, 1991). Emotional regulation shows considerable developmental changes over the first few years of life, as infants progress from relying on external regulation from caregivers to developing internal strategies to regulate their own emotions (Calkins & Hill, 2007). Indeed, by the end of the first year, infants already demonstrate a variety of regulatory behaviors to alleviate distress, such as self-soothing (e.g., thumb-sucking) and distraction (e.g., voluntarily shifting visual attention away from a distressing stimulus). Being able to successfully regulate emotions has important implications for children's long-term social and behavioral (Martin & Ochsner, 2016), and deficits in this ability have been associated with increased risk for psychopathology in later life (Cavicchioli et al., 2023). As such, it is important to understand the development of this fundamental skill and the experiential factors that may shape individual differences.

During early postnatal life, infants largely depend on their parents to assist in regulating their emotional responses (McLennan & Offord, 2003) which scaffolds the development of infants' emotion regulation skills (Eisenberg et al., n.d.; Feng et al., 2008; Kopp, 1989). Accordingly, disruptions to caregiver mental health and the early caregiving environment have been shown to impede children's developing self-regulation skills (Calkins & Hill, 2007; Gable & Isabella, 1992; Goodman & Gotlib, 1999).

For instance, prior findings indicate that mothers who report elevated depressive symptoms tend to be less responsive to their infants' signals for regulatory help during parent-child interactions (Feldman, 2003). Mothers who experience depression during the perinatal period also tend to endorse their infants as being more difficult and having higher negative reactivity relative to non-depressed mothers (McGrath et al., 2008). Similar findings have been observed in studies assessing infant negative reactivity via observation (Gartstein et al., 2010) and/or psychophysiological function (Brennan et al., 2008). Moreover, highly reactive infants have also been shown to elicit more negative parenting behaviors in caregivers with depression, which may further contribute to differences in emotional development in offspring (Dix & Yan, 2014). Importantly, these disruptions to the development of infant emotional regulation are predictive of subsequent risk for behavioral and emotional problems in later childhood (Gable & Isabella, 1992; Goodman & Gotlib, 1999).

In addition to parenting and caregiver mental health, the structure and dynamics of the proximal home environment also influence developing regulatory abilities. For instance, variation in the physical (e.g., noise and stimulation) and temporal (e.g., routines and structure) properties of the home environment have been linked with differences in self-regulation (Evans, 2006; Evans & Wachs, 2010). These effects may be transmitted through both behavioral and biological pathways. For instance, the presence of daily routines may help regulate children’s stress physiology

(Gunnar & Vazquez, 2001). A lack of structure or routines in the home could also impact children’s ability to predict and therefore exert control over their environment, potentially hindering the development of self-regulation skills (Coldwell et al., 2006; Evans, 2006)(Evans et al., 2005; Coldwell, Pike, & Dunn, 2006; Bowes, Maughan, Caspi, Moffitt, & Arsenault, 2010). Experiencing high levels of noise or stimulation in the home may also be emotionally and physiologically stressful for children and their caregivers (Berry et al., 2016; Coldwell et al., 2006; Evans & Wachs, 2010; Garrett-Peters et al., 2016). In turn, this may impact children’s capacity to engage in regulatory behaviors by taxing their cognitive resources (Caporaso & Marcovitch, 2021; Roos et al., 2018) or by impacting the function of neural regions relevant to emotional regulation (Burghy et al., 2012; McEwen et al., 2016).

Although characteristics of the home environment and caregiving are often studied separately, there are likely important interactions between these variables in shaping children’s emotional regulation. For instance, heightened caregiver psychological distress and variability in the physical or temporal dynamics of the home environment may act as cumulative stressors (Evans, 2003; Evans & Kim, 2007). Alternatively, variation in the physical and temporal properties of the home environment may buffer the development of emotional regulation by providing more opportunities for infants to engage in regulatory behaviors to filter environmental input or alleviate distress. For instance, noise or clutter in the home could provide sensory input that stimulates the development of attention and executive functions as an adaptive response to the increased need to filter environmental input (Werchan & Amso, 2017). Similarly, variation in household routines could provide diverse learning experiences that allow the child to practice flexibly adapting behavior to changing stimuli and environments (Gelfo, 2019; Werchan et al., 2015). However, the majority of research examining how caregiver mental health and variation in the home environment impact the development of emotional regulation use variable-centered approaches, which assume that associations among variables within a population are homogonous and linear. While these approaches provide insight into how specific aspects of the home environment and caregiver mental health may impact infants *on average,* they fail to capture the heterogeneity and nuances of infants' early experiences that may be critical for understanding variability in development.

In the current study, we apply a person-centered approach to examine how distinct *patterns* of maternal psychological distress (e.g., symptoms of anxiety, depression, and perceived stress) and variability in the physical and temporal properties of the home environment (e.g., physical stimulation and temporal disorder) may differentially predict emotional regulation in 6-month-old infants. There are rapid changes in emotion regulation behaviors at this age, providing ample opportunity to examine individual differences in infant development. We hypothesize that infants of mothers experiencing heightened psychological distress will show higher reactivity and fewer regulatory behaviors, consistent with prior findings (Calkins & Hill, 2007; Gable & Isabella, 1992; Goodman & Gotlib, 1999). Importantly, however, we hypothesize that associations between maternal psychological distress and infant emotional regulation will differ in profiles distinguished by different household dynamics. To evaluate these hypotheses, we first apply latent profile analysis to identify distinct groups of infants based on similar patterns of maternal mental health and physical and temporal properties of the home environment. We then test whether infant emotional regulation differs by profile membership. We examine this by measuring infants' reactivity and regulation strategies during two canonical infant stressor paradigms – the Still-Face task (Tronick et al., 1978) and the Arm-Restraint task (Calkins et al., 2002; Stifter & Braungart, 1995).

Methods

Participants

Mothers were recruited from BLINDED FOR REVIEW medical records as part of an ongoing, prospective longitudinal study. Mothers who completed surveys of the home environment were eligible for the current study, resulting in data from 104 mothers and their six-month-old infants (*n* = 51 females, *n* = 53 males; *M* age = 6.4 months, *SD* = .70 months) enrolled between April 2020 and February 2023. Full sociodemographic characteristics of the sample are reported in Table 1. The Institutional Review Board at BLINDED FOR REVIEW approved all study protocols, and informed written consent was obtained electronically prior to testing.

Table 1. Sample demographics.

	N	Mean/SD (or %)
Maternal Education[a]	103	7.3 (1.4)
Annual Household Income[b]	103	10 (4.5)
Maternal Race		
White	63	61%
Asian	8	8%
Black/African American	6	6%
Other	18	17%
More than one race	8	8%
Decline to Answer	1	1%
Maternal Ethnicity		
Hispanic or Latino	24	23%
Not Hispanic or Latino	77	74%
Declined to Answer	3	3%
Infant Race		
White	15	45.5%
Asian	8	24.2%
Black / African American	7	6.7%
American Indian / Alaskan Native	3	2.9%
Other	2	1.9%
More than one race	17	16.3%
Declined to Answer	2	1.9%
Infant Ethnicity		
Hispanic or Latino	32	31%
Not Hispanic or Latino	72	69%

[a]Education was coded as 1= <10th grade, 2=10–12th grade, 3=high school/ GED, 4=apprenticeship/trade school, 5=partial college, 6=2-year college, 7=4-year college, 8=graduate degree.

[b]Income was coded as 1= <10 k, 2=10–20 k, 3=20–30 k, 4=30–40 k, 5=40–50 k, 6=50–60 k, 7=60–80 k, 8=80–100 k, 9=100–120 k, 10=120–140 k, 11=140–160 k, 12=160–180 k, 13=180–200 k, 14=200–220 k, 15=220–250 k, 16=250k+.

Measures

Maternal perceived stress. The Perceived Stress Scale (PSS; Cohen et al., 1983) was used to assess self-reported maternal stress. The PSS includes 14-questions that assess the degree to which the respondent has perceived situations as stressful within the last month. Items are rated on a five-point Likert scale ranging from 0 (never) to 4 (very often). A total score is the sum of scores from all items (after four items are reverse scored). Scores can range from 0 to 40. This scale had a Cronbach's alpha of .87, indicating good internal consistency.

Maternal depression and anxiety. Symptoms of maternal depression and anxiety were measured at 6 months postpartum using the Edinburgh Postnatal Depression Scale (EPDS). The EPDS is a self-report scale assessing common symptoms of depression and anxiety during the perinatal period (Brouwers et al., n.d.; Cox et al., 1987; Matthey, 2008; Matthey et al., 2013). The EPDS includes 10 items, 7 of which measure depression symptoms, and 3 of which measure anxiety symptoms (Brouwers et al., 2001; Matthey, 2008; Matthey et al., 2013). Items are rated on a five-point Likert scale ranging from 0 to 4. A combined maternal depression/anxiety score is calculated by summing all items (after two are reverse scored). This scale had a Cronbach's alpha of .82, indicating good internal consistency.

Home environmental variability. Variability in the physical (e.g., noise, clutter) and temporal (e.g., routines, structure) properties of the home environment were assessed at 9 months postpartum using the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al., 1995). This scale has shown concurrent validity with objective codes of the home environment by trained observers and high stability over time, with a test–retest reliability of .74 across a period of 12 months (Matheny et al., 1995). Caregivers were asked to indicate the degree to which they agreed with various statements describing different aspects of their home on a 4-point likert scale (1—*not at all like your own home*, 2—*a little bit like your own home*, 3—*somewhat like your own home*, 4—*Very much like your own home*). Physical stimulation in the home (general noise, upheaval, and activity within the home) was defined by averaging scores across the following survey items: 1, 6, 7, 8, 10, 11, 12, 14. Temporal disorder in the home (a lack of consistent plans, routines, and structure within the home) was defined by averaging scores across the following survey items: 2, 3, 4, 5, 9, 15. Positively worded items were reverse-coded prior to averaging. Chronbach's alpha was used to evaluate reliability, which was good for physical stimulation (alpha = .83) and acceptable for temporal disorder (alpha = .71), as expected for scales with fewer items (Cortina, 1993).

Infant Behavioral Assessment

Infant emotional reactivity and regulation were assessed using the Still Face and Arm Restraint tasks, which were administered remotely using Zoom. Parents were instructed to complete the study in a quiet area relatively free from distractions, and parents were instructed to hide both their own and the experimenter's video through the duration of the study.

During the Arm Restraint Task (Calkins et al., 2002; Stifter & Braungart, 1995), infants were placed in a highchair and were allowed to play with a favored toy for 30 seconds. The parent was then instructed to gently restrain the infant’s forearms down to their sides for 30 seconds. Parents refrained from verbally and behaviorally interacting with infants during both phases of the task. This procedure was followed by a two-minute reunion where the caregiver was allowed to freely interact with the infant in the highchair.

During the Still-Face Task (Tronick et al., 1978), infants were seated in a highchair facing the parent. The parent was instructed to interact with the infant in a direct, engaging manner (e.g., playing *peek-a-boo*) for two minutes. They were then instructed to hold the Still-Face for two minutes, during which they were instructed to look directly at their infant with a neutral face while refraining from any form of interaction. This procedure was followed by a two-minute reunion, where the caregiver was allowed to resume interacting with the infant normally. If infants became very distressed during either of the stressor tasks, the experimenter stopped the task and parents were given opportunity to sooth their infants.

Infant Behavioral Coding

Infant emotion regulation and reactivity during the Arm Restraint and Still-Face Tasks were evaluated using manual behavioral coding. Specifically, trained research staff rated two measures of emotion regulation: (i) *avoidance* during arm restraint, (ii) *self-comforting* during still face, and two measures of emotional reactivity: (i) *negative affect* during still face and (ii) *negative affect* during arm restraint. *Avoidance* (escape behaviors, such as arching back, struggling against the restraint, or pushing back against the chair) during the arm restraint segment was coded on a 4-point scale from 0 (no escape behaviors observed during the segment) to 3 (the infant consistently engaged in escape behaviors for the majority of the segment). *Self-comforting* (repetitive fine-motor behaviors such as sucking on hands or stroking their head or ears) during the still face segment was coded on a 4-point scale from 0 (the infant showed no self-comforting behaviors during the segment) to 3 (the infant consistently engaged in self-comforting behaviors throughout the segment). *Negative affect* (the frequency/intensity of infants' fusses/cries) was coded during the arm restraint and still face segments on a 4-point scale ranging from 0 (the infant showed no fussing, whining, or crying during the segment) to 3 (the infant showed moderate to intense crying for the majority of the segment). Inter-rater reliability was evaluated by double-coding 30% of the videos by a second coder. Intraclass correlations were excellent for all categories (avoidance = .95; self-comforting = .89; still face negative affect = .96; arm restraint negative affect = .96).

Analytic Plan

We used latent profile analysis (LPA) to identify distinct profiles of caregiver-infant dyads based on similar patterns of maternal depression/anxiety, maternal perceived stress, household commotion, and household disorganization. Continuous indicators were standardized to facilitate interpretation of results. Missing data was accounted for using the Full Information Maximum Likelihood (FIML) estimator, which yields unbiased estimates when data are missing at random (Muthen & Muthen, 2012).

All LPA analyses were conducted in Mplus Version 8.1 (Muthen & Muthen, 2012). Each LPA model was initialized 200 times, with 50 iterations for the final stage of optimization. The following steps were used to determine the best fitting model (Nylund et al., 2007). As a first step, the model with the lowest Bayesian information criterion (BIC) combined with a statistically significant Lo–Mendell–Rubin likelihood ratio test (LMR) was considered as the best fitting model. In a second step, we ensured that the best fitting model also had a high entropy value (greater than .75, or closest to 1.0, reflecting low classification error; Jedidi, et al., 1993). We also considered the conceptual fit and complexity of the models when determining the best fitting solution. We examined whether membership in a particular profile was associated with differences in infant emotional reactivity and regulation using the Bolck-Croon-Hagenaars approach (BCH; Bakk et al., 2013). The BCH method accounts for measurement error associated with most-likely profile membership and is shown to outperform other approaches where LPAs predict distal outcomes (Asparouhov & Muthén, 2014).

Results

Descriptive statistics

Means and measures of centrality for all measures are reported in Table 2, and assessment of potential correlations across study variables are reported in Table 3.

Table 2
Descriptive Statistics

Variable	*N*	*M* or %	*SD*	*Min*	*Max*	*Skewness*
Maternal psychological distress						
Perceived stress	78	20.97	8.57	3	40	-.01
Depression symptoms	79	3.15	2.93	0	12	1.2
Anxiety symptoms	80	2.88	2.05	0	8	.43
Home environmental variability						
Physical stimulation	104	1.83	0.7	1.0	4.0	.78
Temporal disorder	104	1.78	0.5	1.0	3.17	.65
Infant emotional reactivity						
Negative affect – Arm Restraint	57	.82	.96	.0	3.0	.92
Negative affect – Still Face	50	.65	0.9	.0	3.0	1.4
Infant emotional regulation						
Avoidance – Arm Restraint	57	1.42	1.0	.0	3.0	-.26
Self-comforting – Still Face	50	1.56	.88	.0	3.0	-.31

Table 3
Bivariate correlations among all indicator and outcome variables.

Variable	1	2	3	4	5	6	7
1. Maternal perceived stress	1						
2. Maternal depression symptoms	.62**	1					

3. Maternal anxiety symptoms	.59**	.57**	1				
4. Infant negative affect – Arm Restraint	.11	.13	.19	1			
5. Infant negative affect – Still Face	.04	-.17	-.13	.01	1		
6. Infant avoidance – Arm Restraint	-.13	.15	.01	.30*	-.16	1	
7. Infant self-comforting – Still Face	.07	.24	.29*	-.07	-.33*	.07	1

* $p < .05$, ** $p < .01$

Profiles of infants' proximal environments

Latent profile analysis was used to identify distinct profiles of mother-infant dyads using aspects of maternal mental health (depression/anxiety symptoms and perceived stress) and the physical and temporal dynamics of the home environment (noise/stimulation and a lack of routines/order) as indicators. A 3-profile model was selected as the best fitting model, based on this model demonstrating the highest entropy value (.81 vs. .78 and .75 in the 2- and 4-profile models) and the lowest Bayesian information criterion (1407 vs. 1430 and 1410 in the 2- and 4-profile models). For simplicity in labeling identified models, we use 'environmental variability' to describe variation in the physical and temporal properties of the home environment among profiles. The three identified profiles were: (1) a low caregiver psychological distress/low environmental variability profile (*n* = 54, 52%), who had below-mean depression, anxiety, and perceived stress scores, as well as below-mean physical stimulation and temporal disorder scores; (2) a moderate caregiver psychological distress/low environmental variability profile (*n* = 39, 37%), who had above-mean depression, anxiety, and perceived stress scores and below-mean physical stimulation and temporal disorder scores; and (3) a high caregiver psychological distress/high environmental variability profile (*n* = 11, 11%), who had high depression, anxiety, and perceived stress scores, as well as high physical stimulation and temporal disorder scores.

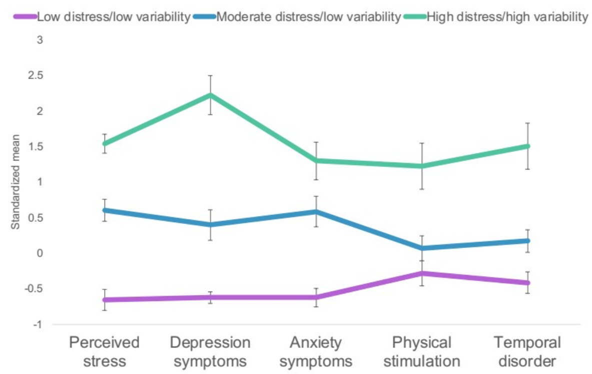

Figure 1. Estimated standardized means for maternal psychological distress (perceived stress, depression symptoms, and anxiety symptoms) and home environmental variability (physical stimulation and temporal

Table 3. Fit statistics for 1- to 6-class models.

Model	*Entropy*	*BIC*	*Smallest profile*	*LMR p value*
1-profile	-	1312	-	-
2-profile	.69	1245	8%	.19
3-profile	.75	1230	11%	.03
4-profile	.78	1226	7%	.16
5-profile	.77	1233	8%	.36

Note: BIC = Bayesian Information Criteria; LMR = Lo-Mendell-Rubin adjusted likelihood ratio test.

Associations with infant emotional regulation

We then examined whether membership in a particular profile was associated with differences in infant emotional regulation using the BCH procedure, which accounts for measurement error associated with most-likely profile membership. During the arm restraint task, we observed significant differences in infants' recovery from distress, as indicated by negative affect during the reunion phase. Specifically, we found that infants in the high distress/high variability profile showed faster recovery from distress relative to infants in the moderate distress/low variability profile, $\chi^2 = 4.18$, $p = .04$. However, there were no other profile-related differences in negative affect or in infants' regulation strategies (escape behaviors) during any other phase of the Arm Restraint task, $\chi^2 < 3.08$, *ps* $> .08$.

During the Still Face task, infants in the high distress/high variability profile showed substantially lower levels of negative affect during the Still Face phase relative to infants in both the moderate distress/low variability profile, $\chi^2 = 13.62$, $p < .001$, as well as the low distress/low variability profile, $\chi^2 = 8.36$, $p = .004$. Infants in the high distress/high variability profile also demonstrated significantly more self-comforting behaviors during Still Face than infants in the both the moderate distress/low variability profile, $\chi^2 = 7.62$, $p = .006$, and the low distress/low variability profile, $\chi^2 = 4.10$, $p = .04$. Additionally, similar to the Arm Restraint task, infants in the high distress/high variability profile showed lower levels of negative affect during the reunion phase than infants in the moderate distress/low variability profile, $\chi^2 = 11.11$, $p = .001$, and the low distress/low variability profile, $\chi^2 = 4.48$, $p =$

.03. There were no other significant differences among profiles, $\chi^2 < .97$, *ps* > .32.

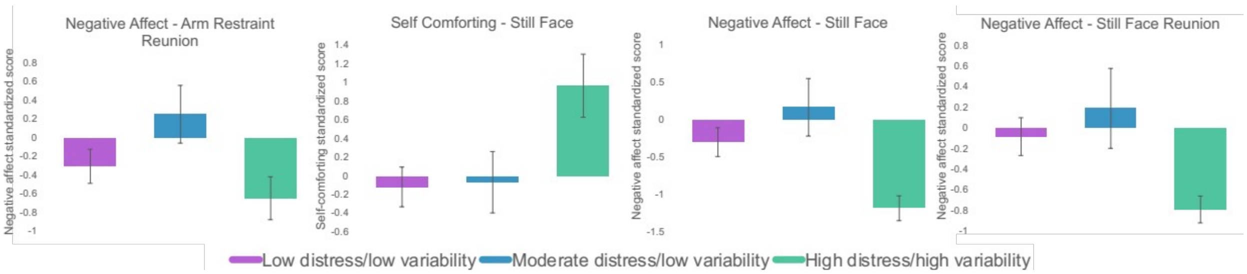

Figure 2. Estimated standardized means by profile for measures of infant emotional reactivity (negative affect during Still Face), recovery from distress (negative affect during the reunion phases of the Arm Restraint and Still Face tasks), and regulation

Discussion

In this study, we examined how different patterns of caregiver psychological distress and the physical and temporal properties of the home environment may differentially impact infants' emotional reactivity and regulation during two stressor tasks. Prior work examining variation in the home environment and caregiver mental health have largely used variable-centered approaches, which quantify linear associations between variables at the group level. In contrast, our use of a person-centered analysis allowed us to directly characterize heterogeneity in infants' early proximal environments and thereby explore potential non-linear associations with infant outcomes. Using latent profile analysis, our results indicated that different patterns of maternal psychological distress and physical/temporal properties of the home environment were associated with systematic differences in infants' behavior during the Arm Restraint and Still Face tasks. Specifically, we observed that infants in profiles with elevated physical stimulation and temporal disorder in the home combined with high caregiver psychological distress demonstrated less reactivity (i.e., lower negative affect during the stressors) and increased regulation (i.e., more self-comforting behaviors and greater recovery following cessation of the stressors).

These findings suggest that different patterns of maternal psychological distress and household dynamics may have differential, and possibly non-additive, effects on infant emotional reactivity and regulation. There are several possible explanations for these findings. For instance, variation in physical stimulation (e.g., noise, clutter) in the home may be associated with variation in the sensory input available to the infant. As such, increased noise or clutter in the home could provide a source of enriched sensory input that may stimulate neurodevelopment. Moreover, enriched sensory input may even help mitigate adverse effects of other stressors, such as heightened caregiver psychological distress, on infant development (Macartney et al., 2022).

Caregiver psychological distress may also be due to different underlying factors in households with different physical or temporal properties. For example, prior findings in both animal and human models show that some elements of the physical home environment, such as crowding and noise, are associated with increases in stress (Evans & Cohen, 1984; Haines et al., 2001; Michaud et al., 2022). Thus, it is possible that psychological distress may reflect shared environmental variance in households with high levels of physical stimulation. That is, psychological distress in the high distress/high variability profile may reflect transient effects of the temporal or physical properties of the home environment, rather than the presence of an underlying mood/anxiety disorder. Delineating the independent and shared aspects of maternal distress and household dynamics may be important for considering impacts on infant outcomes. In particular, psychological distress primarily attributable to variation in household dynamics may have relatively minor impacts on infants. In contrast, heightened caregiver psychological distress that is attributable to dysregulated stress biology or mood disorders may have compounding impacts on infant outcomes by altering caregiving behaviors (Lovejoy et al., 2000) or caregiver-infant stress physiology and co-regulation (Granat et al., 2017; Miller et al., 2023).

Another possibility is that children reared in households with heightened physical stimulation and temporal disorder may develop regulatory strategies to help filter environmental input (Evans, Kliewer, & Martin, 1991). These adaptations may make them less sensitive to their environment, consequently weakening effects of the child's external environment on their development (Belsky et al., 2007). In other words, being less sensitive or reactive to the external environment may attenuate impacts of caregiver psychological distress on infant emotional development. This possibility is consistent with our results, which indicate that infants in households with high physical stimulation and temporal disorder did not show patterns of heightened emotional reactivity that are typically observed in infants of caregivers with high psychological distress (Granat et al., 2017).

However, it is important to note that even if these altered patterns of emotional reactivity and regulation may be adaptive in the short-term, they may not be beneficial for long-term cognitive and socioemotional outcomes. For instance, increased exposure to linguistic input is generally found to promote language development in infants (Brito, 2017; Golinkoff et al., 2019). Notably, however, prior work has shown that increased linguistic input is in fact associated with *worse* outcomes in infants residing in homes with high temporal/physical disorder (Brito et al., 2020). Moreover, it is developmentally-normative for infants to demonstrate high reactivity and low self-regulation when experiencing stressors in early postnatal life, a time when infant emotional regulation is highly dependent on species-expected parental care (Tottenham, 2012). The altered patterns of emotional reactivity and regulation we observed in infants in the high distress/high variability profile may reflect an adaptive response that helps infants cope with immediate stressors in environments with disruptions to parental care. Although these adaptions may be helpful in the short-term, they could also consequently impair the child’s ability to cope with changing environmental demands that accompany development. As such, more research is needed to directly explore interactions and tradeoffs between the effects of the home environment and caregiver psychological distress on long-term socioemotional and cognitive outcomes.

In summary, our findings demonstrate that distinct patterns of maternal psychological distress and the physical and temporal properties of the home environment have differential effects on infant emotional reactivity and regulation. These findings indicate the importance of considering the heterogeneity and complexity of infants' early environments in shaping developmental processes, and raise novel insights into how infant emotional regulation may be adapted to the unique characteristics of the early environment.

References

Asparouhov, T., & Muthén, B. (2014). Auxiliary Variables in Mixture Modeling: Three-Step Approaches Using Mplus. *Structural Equation Modeling*, *21*(3), 329–341. https://doi.org/10.1080/10705511.2014.915181

Belsky, J., Bakermans-Kranenburg, M. J., & Van, M. H. (2007). For Better and for Worse: Differential Susceptibility to Environmental Influences. In *Psychological Science* (Vol. 16, Issue 6).

Berry, D., Blair, C., Willoughby, M., Garrett-Peters, P., Vernon-Feagans, L., Mills-Koonce, W. R., Cox, M., Burchinal, P., Burton, L., Crnic, K., Crouter, A., Greenberg, M., Lanza, S., & Werner, E. (2016). Household chaos and children's cognitive and socio-emotional development in early childhood: Does childcare play a buffering role? *Early Childhood Research Quarterly*, *34*, 115–127. https://doi.org/10.1016/j.ecresq.2015.09.003

Brennan, P. A., Pargas, R., Walker, E. F., Green, P., Jeffrey Newport, D., & Stowe, Z. (2008). Maternal depression and infant cortisol: Influences of timing, comorbidity and treatment. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *49*(10), 1099–1107. https://doi.org/10.1111/j.1469-7610.2008.01914.x

Brito, N. H. (2017). Influence of the Home Linguistic Environment on Early Language Development. *Policy Insights from the Behavioral and Brain Sciences*, *4*(2), 155–162. https://doi.org/10.1177/2372732217720699

Brito, N. H., Troller-Renfree, S. V., Leon-Santos, A., Isler, J. R., Fifer, W. P., & Noble, K. G. (2020). Associations among the home language environment and neural activity during infancy. *Developmental Cognitive Neuroscience*, *43*, 100780. https://doi.org/10.1016/j.dcn.2020.100780

Brouwers, E. P. M., Van Baar, A. L., & Pop, V. J. M. (n.d.). *Does the Edinburgh Postnatal Depression Scale measure anxiety?*

Burghy, C. A., Stodola, D. E., Ruttle, P. L., Molloy, E. K., Armstrong, J. M., Oler, J. A., Fox, M. E., Hayes, A. S., Kalin, N. H., Essex, M. J., Davidson, R. J., & Birn, R. M. (2012). Developmental pathways to amygdala-prefrontal function and internalizing symptoms in adolescence. *Nature Neuroscience*, *15*(12), 1736–1741. https://doi.org/10.1038/nn.3257

Calkins, S. D., Dedmon, S. E., Gill, K. L., Lomax, L. E., & Johnson, L. M. (2002). Frustration in Infancy: Implications for Emotion Regulation, Physiological Processes, and Temperament. *Infancy*, *3*(2), 175–197. https://doi.org/10.1207/S15327078IN0302_4

Caporaso, J. S., & Marcovitch, S. (2021). The effect of taxing situations on preschool children's responses to peer conflict. *Cognitive Development*, *57*. https://doi.org/10.1016/j.cogdev.2020.100989

Cavicchioli, M., Tobia, V., & Ogliari, A. (2023). Emotion Regulation Strategies as Risk Factors for Developmental Psychopathology: a Meta-analytic Review of Longitudinal Studies based on Cross-lagged Correlations and Panel Models. In *Research on Child and Adolescent Psychopathology* (Vol. 51, Issue 3, pp. 295–315). Springer. https://doi.org/10.1007/s10802-022-00980-8

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, *24*(4), 385–396.
Coldwell, J., Pike, A., & Dunn, J. (2006). Household chaos - Links with parenting and child behaviour. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*(11), 1116–1122. https://doi.org/10.1111/j.1469-7610.2006.01655.x
Cortina, J. M. (1993). What Is Coefficient Alpha? An Examination of Theory and Applications. In *Journal of Applied Psychology* (Vol. 78, Issue 1).
Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of Postnatal Depression. *British Journal of Psychiatry*, *150*(6), 782–786. https://doi.org/10.1192/bjp.150.6.782
Dix, T., & Yan, N. (2014). Mothers' depressive symptoms and infant negative emotionality in the prediction of child adjustment at age 3: Testing the maternal reactivity and child vulnerability hypotheses. *Development and Psychopathology*, *26*(1), 111–124. https://doi.org/10.1017/S0954579413000898
Eisenberg, N., Cumberland, A., & Spinrad, T. L. (n.d.). *Parental Socialization of Emotion*.
Evans, G. W. (2003). A multimethodological analysis of cumulative risk and allostatic load among rural children. *Developmental Psychology*, *39*(5), 924–933. https://doi.org/10.1037/0012-1649.39.5.924
Evans, G. W. (2006). Child Development and the Physical Environment. *Annual Review of Psychology*, *57*(1), 423–451. https://doi.org/10.1146/annurev.psych.57.102904.190057
Evans, G. W., & Cohen, S. (n.d.). Environmental Stress. In *CUP Archive*.
Evans, G. W., & Kim, P. (2007). Childhood Poverty and Health. *Psychological Science*, *18*(11), 953–957. https://doi.org/10.1111/j.1467-9280.2007.02008.x
Evans, G. W., & Wachs, T. D. (2010). Chaos and its influence on children's development. . In *American Psychological Association*.
Feldman, R. (2003). Infant-mother and infant-father synchrony: The coregulation of positive arousal. *Infant Mental Health Journal*, *24*(1), 1–23. https://doi.org/10.1002/imhj.10041
Feng, X., Shaw, D. S., Kovacs, M., Lane, T., O'Rourke, F. E., & Alarcon, J. H. (2008). Emotion regulation in preschoolers: The roles of behavioral inhibition, maternal affective behavior, and maternal depression. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *49*(2), 132–141. https://doi.org/10.1111/j.1469-7610.2007.01828.x
Gable, S., & Isabella, R. A. (1992). *Maternal Contributions to Infant Regulation of Arousal*.
Garrett-Peters, P. T., Mokrova, I., Vernon-Feagans, L., Willoughby, M., & Pan, Y. (2016). The role of household chaos in understanding relations between early poverty and children's academic achievement. *Early Childhood Research Quarterly*, *37*, 16–25. https://doi.org/10.1016/j.ecresq.2016.02.004
Gartstein, M. A., Bridgett, D. J., Rothbart, M. K., Robertson, C., Iddins, E., Ramsay, K., & Schlect, S. (2010). A latent growth examination of fear development in infancy: Contributions of maternal depression and the risk

for toddler anxiety. *Developmental Psychology*, *46*(3), 651–668. https://doi.org/10.1037/a0018898
Gelfo, F. (2019). Does experience enhance cognitive flexibility? An overview of the evidence provided by the environmental enrichment studies. In *Frontiers in Behavioral Neuroscience* (Vol. 13). Frontiers Media S.A. https://doi.org/10.3389/fnbeh.2019.00150
Golinkoff, R. M., Hoff, E., Rowe, M. L., Tamis-LeMonda, C. S., & Hirsh-Pasek, K. (2019). Language Matters: Denying the Existence of the 30-Million-Word Gap Has Serious Consequences. *Child Development*, *90*(3), 985–992. https://doi.org/10.1111/cdev.13128
Goodman, S. H., & Gotlib, I. H. (1999). Risk for Psychopathology in the Children of Depressed Mothers: A Developmental Model for Understanding Mechanisms of Transmission. In *Psychological Review* (Vol. 106, Issue 3).
Granat, A., Gadassi, R., Gilboa-Schechtman, E., & Feldman, R. (2017). Maternal depression and anxiety, social synchrony, and infant regulation of negative and positive emotions. *Emotion*, *17*(1), 11–27. https://doi.org/10.1037/emo0000204
GUNNAR, M. R., & VAZQUEZ, D. M. (2001). Low cortisol and a flattening of expected daytime rhythm: Potential indices of risk in human development. *Development and Psychopathology*, *13*(3), 515–538. https://doi.org/10.1017/S0954579401003066
Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B., & Head, J. (2001). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine*, *31*(2), 265–277. https://doi.org/10.1017/S0033291701003282
Kopp, C. B. (1989). Regulation of Distress and Negative Emotions: A Developmental View. In *Developmental Psychology* (Vol. 25).
Lovejoy, M. C., Graczyk, P. A., O'Hare, E., & Neuman, G. (2000). Maternal depression and parenting behavior. *Clinical Psychology Review*, *20*(5), 561–592. https://doi.org/10.1016/S0272-7358(98)00100-7
Martin, R. E., & Ochsner, K. N. (2016). The neuroscience of emotion regulation development: Implications for education. In *Current Opinion in Behavioral Sciences* (Vol. 10, pp. 142–148). Elsevier Ltd. https://doi.org/10.1016/j.cobeha.2016.06.006
Matheny, A. P., Wachs, T. D., Ludwig, J. L., & Phillips, K. (1995). Bringing order out of chaos: Psychometric characteristics of the confusion, hubbub, and order scale. *Journal of Applied Developmental Psychology*, *16*(3), 429–444. https://doi.org/10.1016/0193-3973(95)90028-4
Matthey, S. (2008). Using the Edinburgh Postnatal Depression Scale to screen for anxiety disorders. *Depression and Anxiety*, *25*(11), 926–931. https://doi.org/10.1002/da.20415
Matthey, S., Fisher, J., & Rowe, H. (2013). Using the Edinburgh postnatal depression scale to screen for anxiety disorders: Conceptual and methodological considerations. *Journal of Affective Disorders*, *146*(2), 224–230. https://doi.org/10.1016/j.jad.2012.09.009

McEwen, B. S., Nasca, C., & Gray, J. D. (2016). Stress Effects on Neuronal Structure: Hippocampus, Amygdala, and Prefrontal Cortex. In *Neuropsychopharmacology* (Vol. 41, Issue 1, pp. 3–23). Nature Publishing Group. https://doi.org/10.1038/npp.2015.171

McGrath, J. M., Records, K., & Rice, M. (2008). Maternal depression and infant temperament characteristics. *Infant Behavior and Development*, *31*(1), 71–80. https://doi.org/10.1016/j.infbeh.2007.07.001

McLennan, J., & Offord, D. R. (2003). CLINICAL AND POLICY IMPLICATIONS FOR PREVENTION. *Journal of the American Academy of Child & Adolescent Psychiatry*, *42*(5), 513. https://doi.org/10.1097/01.CHI.0000056735.04343.13

Michaud, D. S., Thomson, E. M., van Oosterhout, P., & McNamee, J. P. (2022). Hair cortisol as a viable tool for the assessment of an association between environmental noise exposure and chronic stress. *The Journal of the Acoustical Society of America*, *152*(2), 866–876. https://doi.org/10.1121/10.0012887

Miller, J. G., Armstrong-Carter, E., Balter, L., & Lorah, J. (2023). A meta-analysis of mother–child synchrony in respiratory sinus arrhythmia and contextual risk. *Developmental Psychobiology*, *65*(1). https://doi.org/10.1002/dev.22355

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural Equation Modeling*, *14*(4), 535–569. https://doi.org/10.1080/10705510701575396

Roos, L. E., Beauchamp, K. G., Giuliano, R., Zalewski, M., Kim, H. K., & Fisher, P. A. (2018). Children’s biological responsivity to acute stress predicts concurrent cognitive performance. *Stress*, *21*(4), 347–354. https://doi.org/10.1080/10253890.2018.1458087

Stifter, C. A., & Braungart, J. M. (1995). The Regulation of Negative Reactivity in Infancy: Function and Development. In *Developmental Psychology* (Vol. 31, Issue 3).

Thompson, R. A. (1991). Emotional Regulation and Emotional Development. In *Psychology Review* (Vol. 3, Issue 4). https://www.jstor.org/stable/23359228

Tottenham, N. (2012). Human amygdala development in the absence of species-expected caregiving. *Developmental Psychobiology*, *54*(6), 598–611. https://doi.org/10.1002/dev.20531

Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The Infant’s Response to Entrapment between Contradictory Messages in Face-to-Face Interaction. *Journal of the American Academy of Child Psychiatry*, *17*(1), 1–13. https://doi.org/10.1016/S0002-7138(09)62273-1

Werchan, D. M., & Amso, D. (2017). A Novel Ecological Account of Prefrontal Cortex Functional Development. *Psychological Review*, *124*(6), 720–739.

Werchan, D. M., Collins, A. G. E., Frank, M. J., & Amso, D. (2015). 8-Month-Old Infants Spontaneously Learn and Generalize Hierarchical Rules. *Psychological Science*, *26*(6), 805–815. https://doi.org/10.1177/0956797615571442