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COVID-19 pandemic effects: Examining prenatal internalizing symptoms and infant temperament

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Abstract

For pregnant women, the COVID-19 pandemic has resulted in unprecedented stressors, including uncertainty regarding prenatal care and the long-term consequences of perinatal infection. However, few studies have examined the role of this adverse event on maternal wellbeing and infant socioemotional development following the initial wave of the pandemic when less stringent public health restrictions were in place. The current study addressed these gaps in the literature by first comparing prenatal internalizing symptoms and infant temperament collected after the first wave of the pandemic to equivalent measures in a pre-pandemic sample. Second, associations between prenatal pandemic-related stress and infant temperament were examined. Women who were pregnant during the COVID-19 pandemic endorsed higher pregnancy-specific anxiety relative to the pre-pandemic sample. They also reported greater infant negative emotionality and lower positive affectivity and regulatory capacity at 2 months postpartum. Prenatal infection stress directly predicted infant negative affect. Both prenatal infection and preparedness stress were indirectly related to infant negative emotionality through depression symptoms during pregnancy and at 2 months postpartum. These results have implications for prenatal mental health screening procedures during the pandemic

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and the development of early intervention programs for infants born to mothers during this adverse event.

1 | INTRODUCTION

1.1 | Maternal wellbeing during the COVID-19 pandemic

A growing body of literature suggests pregnant women have experienced elevated rates of depression and anxiety symptoms during the COVID-19 pandemic, a novel public health event that has resulted in unprecedented stressors for millions of Americans (Ayaz et al., 2020; Berthelot et al., 2020; Moyer et al., 2020). Recent research has identified pandemic-related stress as a strong predictor of these increased internalizing symptoms. For example, pregnant women with a higher number of COVID-19 related stressors endorsed greater increases in pregnancy-specific anxiety during the pandemic (Moyer et al., 2020). Specific stressors have also been linked with elevated prenatal depression symptoms, including financial difficulties, low social support, and fear of infection (Matsushima & Horiguchi, 2020; Thayer & Gildner, 2021).

Many studies in the extant literature have examined perinatal mental health during the first wave of the pandemic from March 2020 to September 2020 when much of the world was in lockdown (Ayaz et al., 2020; Barbosa-Leiker et al., 2021; Berthelot et al., 2020; Moyer et al., 2020). Following this period, fewer restrictions were in place, but pregnant women continued to face stressors, such as new viral variants that resulted in more severe and transmissible versions of COVID-19 (Wu et al., 2020). Poor maternal wellbeing during pregnancy can predict adverse infant outcomes such as preterm birth and low birthweight, making it critical to better understand whether pregnant women remain at an increased risk for greater internalizing symptoms following the first year of the pandemic, which will likely be more predictive of future outbreaks (Bussières et al., 2015; Liu et al., 2016). Elevated internalizing symptoms during later phases of the pandemic have been reported in pregnant women living in the United States (Godleski et al., 2022) and other regions of Europe (Penengo et al., 2022; Tauqeer et al., 2023). However, very few studies have utilized a pre-pandemic comparison group to determine whether symptoms during this period occur above and beyond typical prenatal levels. Italian researchers have demonstrated mixed findings (Chieffo et al., 2022; Scandurra et al., 2023), warranting additional research with women living in the United States given COVID-19 related policies and the severity of outbreaks differed across countries. Moreover, no known studies have compared pregnancy-specific anxiety prior to and during later waves of the pandemic, which may be an especially salient form of anxiety during this period due to uncertainty regarding how perinatal infection may affect the developing fetus.

1.2 | Pandemic-related stress and infant temperament

According to the psychobiological model, temperament is defined as "constitutionally based individual differences in reactivity and self-regulation in the domains of affect, activity, and attention" (Rothbart et al., 2011, p. 207). Reactivity refers to the expression of positive emotions as well as fear, sadness, and anger, whereas self-regulation encompasses processes such as attention that are used to modulate this reactivity. During the first few months of life, individual differences in temperament can already be observed in approach, distress proneness, positive affect, and attentional orienting (Gartstein, Hookenson et al., 2016; Gartstein, Putnam et al., 2016). Previous research has demonstrated

consistent links between prenatal psychosocial stress and offspring temperament profiles marked by distress proneness/dysregulation during infancy and early childhood prior to the COVID-19 pandemic (Fuller et al., 2018; Huizink et al., 2002).

Despite known links between prenatal stress and infant temperament, few studies have examined these associations during the COVID-19 pandemic. Given a generation of children were born during the pandemic, it is imperative to understand how prenatal exposure to this adverse event has influenced offspring socioemotional functioning. It is critical to consider temperament, as it manifests early in development, predicting later emotional and behavioral difficulties (Edwards & Hans, 2015). Better understanding these associations could guide the development of prevention programs and identify children who may require early intervention.

Among the limited existing studies, researchers in Italy found pandemic-related stress during pregnancy indirectly predicted poorer infant self-regulation and positive affect at 3 months through factors such as parenting stress, mother-infant bonding, and epigenetic changes on stress-related genes (Provenzi, Grumi et al., 2021; Provenzi, Mambretti et al., 2021). Prenatal pandemic-related stress has also been demonstrated to continue to predict temperament during late infancy, specifically greater negative affect (Buthmann et al., 2022; Schweizer et al., 2023). In contrast, Sacchi et al. (2023) did not find significant associations between pandemic-related stress during pregnancy and infant temperament. These discrepant findings may be related to methodological limitations. For example, several studies in the extant literature did not use standardized measures of pandemic-related stress, warranting additional research with validated surveys (Provenzi, Grumi et al., 2021; Provenzi, Mambretti et al., 2021; Sacchi et al., 2023).

Only one known study has compared temperament differences in infants exclusively born during COVID-19 to a pre-pandemic comparison sample, which is critical in determining whether the pandemic has altered temperament profiles relative to prior to the onset of this adverse event and ongoing stressor (Morris & Saxbe, 2023). Morris and Saxbe (2023) found that mothers who were pregnant during the pandemic rated their infants as having greater negative emotionality but not positive affectivity or effortful control at 3 months postpartum. Of note, only the pre-pandemic comparison group consisted of first-time parents, which represents a limitation of this study, as demographic differences between the two samples may have contributed to the reported temperament findings. Further studies are needed using more comparable samples of pregnant women to gain greater insight into whether the COVID-19 pandemic has impacted temperament development during infancy.

Several gaps remain in our understanding of infant temperament during the COVID-19 pandemic, warranting additional research. First, existing studies have largely examined how prenatal stress during the first wave of the pandemic influenced socioemotional outcomes during infancy. It is critical to determine whether these associations also occur during later phases when there were fewer public health restrictions (Iyengar et al., 2021; Provenzi, Grumi, et al., 2021). Second, no known studies conducted during the pandemic have examined infant temperament at the fine-grained level, which is often more predictive of distal outcomes relative to the overarching factors (i.e., negative emotionality, positive affectivity, regulatory capacity; Bridgett et al., 2009; Gartstein, et al., 2010). Only examining temperament development at the factor-level may obscure divergent patterns that could help identify children at higher risk for later emotional and behavioral difficulties, making it important to examine fine-grained temperament dimensions. Finally, few studies have explored underlying mechanisms linking maternal pandemic-related stress and infant temperament, which could help to inform treatment recommendations. Given previous research suggests heightened stress contributed to elevated maternal depression and anxiety during the pandemic, perinatal internalizing symptoms represent a strong candidate for mediation. In support of this mechanism, López-Morales et al. (2022) found exposure to stressful events during the pandemic indirectly predicted infant negative affect at

6 months through associations with prenatal anxiety. It is also important to consider maternal postpartum symptoms in this pathway, given prenatal depression and anxiety often persist following birth, which can impact infant temperament through mechanisms such as parent-child interactions (Heron et al., 2004; Kiviruusu et al., 2020; McGrath et al., 2008). Despite these associations, no known studies have simultaneously examined both prenatal and postpartum internalizing symptoms as mediators in the relationship between prenatal pandemic-related stress and temperament during early infancy.

1.3 | Study aims

The aim of the present study was to examine the influence of the COVID-19 pandemic on prenatal internalizing symptoms and infant temperament at two months following the first wave in the United States. This study represents an extension of an existing project exploring prenatal stress-infant temperament associations prior to the pandemic. Therefore, this research is a "natural experiment" of sorts, allowing direct comparisons of prenatal depression/anxiety symptoms and infant temperament prior to and during the pandemic.

First, self-reported markers of maternal internalizing symptoms and infant temperament collected during the pandemic were compared to equivalent measures in a pre-pandemic-comparison group. It was hypothesized that women who were pregnant during the COVID-19 pandemic would self-report increased psychological distress, specifically greater depression, general anxiety, and pregnancy-specific anxiety relative to the pre-pandemic sample (Ayaz et al., 2020; Berthelot et al., 2020; Moyer et al., 2020). Pregnancy data were collected from January 2021 to December 2021, allowing us to examine whether pregnant women experienced elevated depression and anxiety symptoms during later stages of COVID-19. It was also expected that these mothers would endorse greater distress proneness as well as lower regulation and positive affect in their infants, compared to those responding to parallel measures prior to the pandemic.

Second, within the pandemic sample, the unique effects of prenatal pandemic-related stress on infant temperament were explored in women who were pregnant during COVID-19. Based on previous research, pandemic-related stress during pregnancy was expected to directly predict infant temperament (Buthmann et al., 2022; Schweizer et al., 2023). The current study also examined whether depression and anxiety symptoms during the perinatal period serve as a mediator linking pandemic-related stress with infant temperament at 2 months. Prenatal pandemic-related stress was hypothesized to indirectly predict infant temperament sequentially through both prenatal and postpartum symptoms. Depression and anxiety symptoms were expected to serve as unique predictors, given their distinct influence on infant temperament (Erickson et al., 2017).

2 | METHOD

2.1 | Samples

Secondary analyses were performed with existing data from two studies conducted at Washington State University. Both studies used longitudinal designs to examine the role of maternal well-being during the third trimester of pregnancy on infant temperament at 2 months postpartum and were conducted according to the Declaration of Helsinki, with written informed consent obtained from mothers prior to data collection. All procedures were approved by the Institutional Review Board at Washington State University. Data from the first sample were collected prior to the COVID-19 pandemic from July 2015 to August 2017. Data collection for the second sample occurred after the

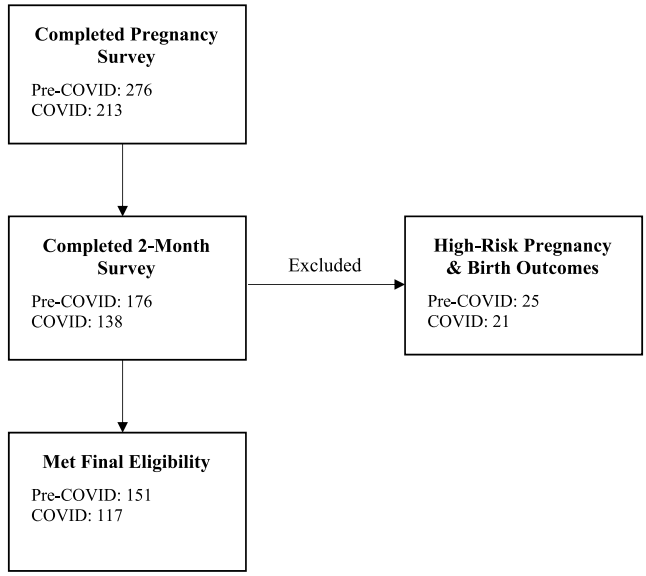

FIGURE 1 Progression of participants for both the Pre-COVID and COVID samples.

onset of the COVID-19 pandemic. Women completed the pregnancy surveys from January 2021 to December 2021 and the 2-month postpartum questionnaires from June 2021 to July 2022.

For both studies, pregnant women in their third trimester were recruited through a combination of social media advertisements as well as community flyers and hospitals in the Eastern Washington/Northern Idaho area. Only women living in the United States were eligible to participate. Participants were excluded due to high-risk pregnancy factors and birth outcomes. The most common reasons for exclusion in both samples included preeclampsia ($n = 7$), gestational diabetes ($n = 9$), premature birth (i.e., before 37 weeks; $n = 6$), time spent on the Neonatal Intensive Care Unit ($n = 13$), and low birth weight (i.e., below 2500 g; $n = 4$). For the pre-COVID sample, 276 women consented to participate in the study and completed questionnaires during the third trimester of pregnancy. A total of 176 were administered follow-up questionnaires at two months postpartum, and 151 met final inclusion criteria. For the COVID sample, 213 participants were enrolled in the study. A total of 138 completed the follow-up questionnaires at two months postpartum, and 117 met final inclusion criteria. See Figure 1 for a flow chart depicting the progression of participants for both studies.

See Table 1 for demographic information for the pre-COVID and COVID samples. Relative to the pre-COVID sample, women in the COVID sample were older ($t\,(260) = -5.95$, $p < 0.001$), completed the pregnancy survey earlier in gestation ($t\,(264) = 2.74$, $p < 0.01$), and had a higher family income ($t\,(249) = -9.82$, $p < 0.001$). A greater number of women in the COVID sample also reported working during pregnancy ($\chi^2\,(1) = 16.69$, $p < 0.001$). Seventeen women in the COVID sample were pregnant during the first wave of the pandemic from March 2020 to September 2020 when much of the world was in lockdown. Weeks of exposure to this lockdown period ranged from 1 to 13 weeks. Sixteen of the women were in their first trimester. One woman was exposed to this lockdown period for her entire first trimester and 1 week of her second trimester.

TABLE 1 Descriptive statistics for Pre-COVID and COVID samples.

	Pre-COVID					During COVID				
	N	***M***	***SD***	**Range**	**Percent**	***N***	***M***	***SD***	**Range**	**Percent**
Maternal Age	150	29.05	4.75	19–41		113	32.21	3.85	23–41	
Weeks Gestation	151	32.33	3.98	27–40		117	31.10	3.35	27–39	
Total Family Income	145	$69,825 (median $60,000)	$51,164	$8000–$300,000		114	$144,079 (median $127,500)	$92,342	$0–$650,000	
Race/Ethnicity	151					117				
Caucasian					86.8					87.2
Asian					1.3					6.0
African American					0.7					0.9
Filipino					0.7					0.9
Hispanic/Latino					6.0					5.1
Native American					2.0					0
Other					2.6					0
Work Status	150					117				
Work					65.3					87.2
Stay at home					28.7					10.3
Student					6.0					2.6
Partnership Status	151					117				
Partnered					96.7					98.3
Single					3.3					1.7
Parity	151					117				
Primiparous					40.4					41.9
Multiparous					59.6					58.1
COVID in Pregnancy	-					117				
Yes					-					83.8
No					-					16.2

(Continues)

TABLE 1 (Continued)

	Pre-COVID					During COVID				
	N	***M***	***SD***	**Range**	**Percent**	***N***	***M***	***SD***	**Range**	**Percent**
Weeks into Pandemic	-	-	-	-		117	80.62	14.88	48–101	
Infant Sex	150					116				
Male					46.0					49.1
Female					54.0					50.9
Infant Age (weeks)	151	9.77	1.72	6.00–17.00		116	9.46	1.66	6.43–17.00	
Birthweight (grams)	151	3531.95	442.86	2608.15–4904.16		117	3482.12	452.93	2553.72–4821.68	
Gestational Age at Birth (weeks)	151	39.57	1.25	37–43		117	39.36	1.17	37–42	

Note: For binary variables, reference groups included single partnership status, primiparous birth, COVID-19 infection, and male sex.

2.2 | Measures

Pandemic-Related Stress. During the third trimester of pregnancy, women in the COVID sample completed the Pandemic-Related Pregnancy Stress Scale (PREPS; Preis et al., 2020). The PREPS is a self-report measure that was developed to measure stress levels in pregnant women during the COVID-19 pandemic. It includes 15 items that rely on a 5-point Likert scale ranging from 1 ('Very Little') to 5 ('Very Much'). The measure is composed of three scales: 1) Preparedness Stress (PREPS-PS); 2) Prenatal Infection Stress (PREPS-PIS); and 3) Positive Appraisal (PREPS-PA). Pandemic-Related Pregnancy Stress Scale-Preparedness Stress assesses feeling unprepared for delivery and the postpartum period; PREPS-PIS evaluates fear of perinatal infection with COVID-19; and PREPS-PA represents a strategy for coping with pandemic-related stress and was not included in the current analyses. Total scores for each of the scales range from 1–5, with higher scores reflecting greater pandemic-related stress. The instrument has been found to demonstrate acceptable to good internal consistency (Preis et al., 2020). In the present study, both PREPS-PS ($\alpha = 0.78$) and PREPS-PIS ($\alpha = 0.88$) had acceptable to good internal consistency.

Perinatal Internalizing Symptoms. Women in both samples were administered the Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987) and State-Trait Anxiety Inventory (STAI; Spielberger et al., 1970) during the third trimester of pregnancy and at 2 months postpartum. The EPDS is a 10-item self-report measure of depressive symptoms. Scores range from 0 to 30, with higher values reflecting greater symptom severity. The STAI is comprised of two 20-item self-report scales measuring state and trait anxiety, respectively. State anxiety is conceptualized as a more time-limited emotional state that includes feelings of tension and apprehensiveness, whereas trait-anxiety is a relatively stable indicator of anxiety that is more personality-based (Spielberger et al., 1970). Given the current study's focus on the timing of anxiety symptoms, only the state subscale of the STAI was included. Total scores for the state anxiety subscale range from 20 to 80, with higher scores indicating more severe symptomatology. Women in both samples also completed the Pregnancy Related Anxiety Questionnaire (PRAQ-R; Huizink et al., 2004) during the third trimester of pregnancy. The PRAQ-R is a 10-item self-report measure of anxiety concerns specific to the prenatal period including fear of giving birth, having a handicapped child, and appearance concerns during pregnancy. Total scores range from 10 to 40, with higher values reflecting greater pregnancy-specific anxiety. The EPDS, STAI, and PRAQ-R have been validated with perinatal samples and found to demonstrate strong psychometric properties (Cox et al., 1987; Newham et al., 2012; Spielberger et al., 1970). In the present study, all the above measures had acceptable to excellent internal consistency during pregnancy and at 2 months postpartum across both samples ($\alpha = 0.74$–0.96).

Infant Temperament. At 2 months postpartum, mothers in both samples completed the Infant Behavior Questionnaire-Revised, Short Version (IBQ-R; Gartstein & Rothbart, 2003; Putnam et al., 2014). The IBQ-R is an established parent-report of infant temperament that uses a fine-grained approach consistent with the psychobiological model. It consists of 91 items that each have a 7-point Likert response scale ranging from 'Never' to 'Always.' The measure produces three broad, domain-based factors, including negative emotionality, positive affectivity/surgency, and regulatory capacity. Each factor can be divided into fine-grained subscales: negative emotionality (distress to limitations, fear, sadness, falling reactivity), positive affectivity (activity level, approach, smiling/laughter, vocal reactivity, perceptual sensitivity, high intensity pleasure), and regulatory capacity (duration of orienting, low intensity pleasure, cuddliness, soothability). The IBQ-R has been found to demonstrate satisfactory cross-rater agreement, test-retest reliability, and internal consistency with Cronbach's alphas ranging from 0.77 to 0.96 (Bosquet Enlow et al., 2016; Gartstein & Rothbart, 2003; Parade & Leerkes, 2008). In the present study, most of the factors and subscales had acceptable to

excellent internal consistency for both the pre-COVID and COVID samples ($\alpha = 0.71$–0.97). In the COVID sample, activity ($\alpha = 0.66$), approach ($\alpha = 0.63$), and cuddliness ($\alpha = 0.67$) had marginally adequate internal consistency.

2.3 | Analyses

Prior to hypothesis testing, descriptive statistics and correlational analyses were conducted for variables of interest using IBM SPSS 26 for Windows. Several variables were found to have outliers defined as values three standard deviations away from the mean. These included: 1) prenatal depression (3.28, 3.72, 4.60), pregnancy-specific anxiety (3.59), prenatal state anxiety (3.33, 3.42, 3.61), 2-month depression (3.11, 3.30, 3.68), 2-month state anxiety (3.34, 3.70, 3.87), and infant regulatory capacity (−3.54).

2.3.1 | Structural equation modeling

Models evaluating the main study aims were performed in Mplus (Muthén & Muthén, 1998-2017). Models were estimated using maximum likelihood estimation and bias-corrected bootstrapped 95% confidence intervals. Overall model fit was evaluated using the chi square value, root-mean-square error of approximation (RMSEA) (study criterion ≤0.05), comparative fit index (CFI) (study criterion ≥0.95), and standardized root-mean-square residual (SRMR) (study criterion ≤0.05). Standardized beta coefficients were used to determine effect size (Fritz & MacKinnon, 2007). Adjustments for multiple models/statistical tests were not applied in the interest of ensuring sufficient power for this investigation, unique in its ability to examine pandemic-related effects.

Aim 1. Structural equation modeling (SEM) was used to compare the pre-COVID and COVID samples on prenatal mental health and infant temperament. Pandemic status (i.e., pre-pandemic vs. during the pandemic) was included as a predictor. Separate models were performed for each of the prenatal mental health variables, which included pregnancy-specific anxiety, state anxiety, and depression. The three temperament factors (i.e., positive affectivity, negative emotionality, and regulatory capacity) were also evaluated using separate models. If significant results were found for the factors, the fine-grained component scales were examined.

Aim 2. Serial mediation was used to investigate the direct effect of prenatal pandemic-related stress on infant temperament at 2 months using only the COVID sample. The indirect effect of prenatal pandemic-related stress on infant temperament was also examined sequentially via the prenatal and 2-month postpartum mental health variables (Figure 2). Separate models were performed for each of the pandemic-related stress scales (i.e., fear of infection and feeling unprepared for birth) to determine their unique influence. Depression, state anxiety, and pregnancy-specific anxiety were also analyzed separately, as these symptoms have been found to uniquely influence infant temperament in pre-pandemic samples, making it critical to examine whether these differences are similarly present during the COVID-19 pandemic (Erickson et al., 2017). In models including pregnancy-specific anxiety, a composite measure of depression and state anxiety symptoms was used for the postpartum time point (Gartstein, Hookenson et al., 2016; Gartstein, Putnam et al., 2016). Pregnancy-specific anxiety often persists after birth in the form of postpartum anxiety and depression (Blackmore et al., 2016; Walker et al., 2021). Given postpartum anxiety and depression have been found to impact infant temperament (Feldman et al., 2009), we made the a priori decision to control for these variables in models examining pregnancy-specific anxiety. Finally, separate models were also conducted for each of the temperament factors. As in Aim 1, if significant results were found for the factors, the component fine-grained scales were examined.

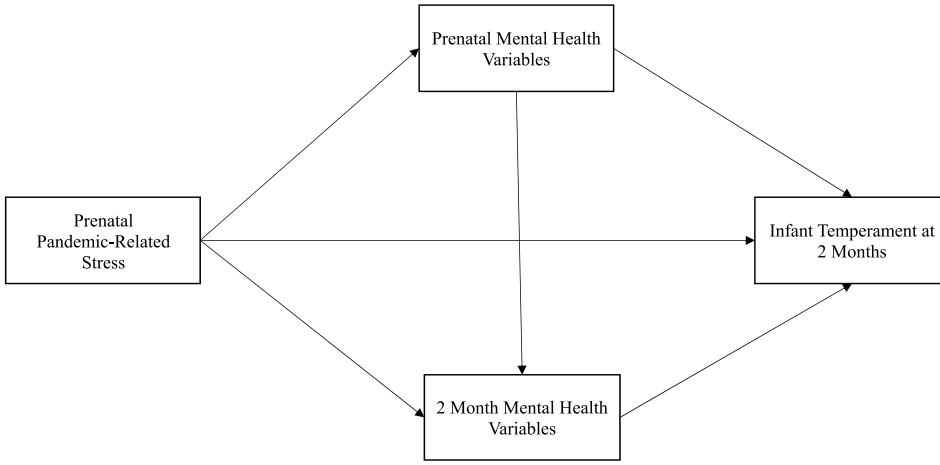

FIGURE 2 Mediation Model Examining the Indirect Effect of Prenatal Pandemic-Related Stress on Infant Temperament at Two Months via Prenatal and Postpartum Mental Health. Separate models were run for each of the mental health variables (i.e., pregnancy-specific anxiety, depression, state anxiety), temperament factors (i.e., negative emotionality, positive affectivity, regulatory capacity), and pandemic stress scales (i.e., infection stress, preparedness stress).

2.3.2 | Missing data

Missing data analyses revealed that state anxiety was missing for 7 cases during pregnancy and at 2 months postpartum. Each of the three temperament factors also had 6 missing cases. Missing data occurred when participants skipped items. Missing data were classified as completely missing at random using Little's MCAR test (χ^2 (25) = 31.25, $p = 0.18$).

Missing data were accommodated using full information maximum likelihood estimation to maximize statistical power. This procedure estimates all parameters based on available data and has been shown to provide less biased estimates for longitudinal samples compared to other approaches, such as multiple imputation (Rosseel, 2020).

2.3.3 | Covariate selection

Pearson bivariate correlations between demographic and dependent variables were considered to determine covariates to include in the primary analyses. Candidate demographic variables included maternal age, race, marital status, parity, employment status, income, and weeks gestation, as well as infant birthweight, gestational age at birth, and infant sex. This approach helped to limit the number of covariates included in analyses, thus preserving power for substantive variables.

For the Aim 2 analyses involving only the COVID sample, duration of time from the start of the pandemic to prenatal data collection was included as a covariate. This variable was important to control for given stress levels may have changed during the course of the pandemic, influencing outcomes of interest (Wu et al., 2020). COVID-19 infection during pregnancy was also controlled for in these analyses, as recent research has demonstrated associations between perinatal infection and maternal internalizing symptoms (Felder et al., 2023). Of note, these variables were only included as covariates in the Aim 2 analyses, as they caused poor fit in models involving both samples due to being coded as missing in the pre-COVID sample.

3 | RESULTS

3.1 | Preliminary analyses

Pearson bivariate correlations examining associations between the perinatal internalizing and infant temperament variables are presented in Table 2 for the pre-COVID sample and Table 3 for the COVID sample. The pre-COVID and COVID samples were combined to determine covariates for the Aim 1 analyses, given both samples were included in these models. For the combined sample, maternal age was negatively associated with prenatal depression ($r = -0.14$, $p = 0.03$) and infant positive emotionality ($r = -0.15$, $p = 0.02$). Family income was negatively associated with prenatal depression ($r = -0.16$, $p = 0.01$), prenatal state anxiety ($r = -0.19$, $p = 0.003$), and infant positive emotionality ($r = -0.13$, $p = 0.04$). Family income was also positively correlated with pregnancy-specific anxiety ($r = 0.13$, $p = 0.03$). Infant age at the 2-month time point was positively associated with infant surgency ($r = 0.14$, $p = 0.03$) and regulatory capacity ($r = 0.16$, $p = 0.01$). Infants born to mothers who were in a partnered relationship had higher regulatory capacity at 2 months (t (260) = −2.31, $p = 0.02$). Given these findings, family income, maternal age, and infant age were retained in

TABLE 2 Correlation coefficients for main study variables for Pre-COVID sample.

Variable	1	2	3	4	5	6	7	8
1. Negative emotionality	-							
2. Positive affectivity	−0.03	-						
3. Regulatory capacity	−0.42**	0.56**	-					
4. Prenatal depression	0.27**	−0.03	−0.22**	-				
5. Prenatal state anxiety	0.32**	−0.08	−0.18*	0.76**	-			
6. Pregnancy anxiety	0.18*	−0.02	−0.12	0.35**	0.43**	-		
7. 2 Month depression	0.34**	−0.05	−0.26**	0.68**	0.62**	0.32**	-	
8. 2 Month state anxiety	0.34**	−0.07	−0.17*	0.58**	0.69**	0.32**	0.82**	-

*$p < 0.05$, **$p < 0.01$.

TABLE 3 Correlation coefficients for main study variables for COVID sample.

Variable	1	2	3	4	5	6	7	8	9	10
1. Negative emotionality	-									
2. Positive affectivity	0.10	-								
3. Regulatory capacity	−0.25**	0.57**	-							
4. Prenatal depression	0.17	−0.12	−0.22*	-						
5. Prenatal state anxiety	0.11	−0.14	−0.12	0.60**	-					
6. Pregnancy anxiety	0.30**	0.02	−0.10	0.41**	0.37**	-				
7. Infection stress	0.26**	0.05	−0.08	0.30**	0.20*	0.24*	-			
8. Preparedness stress	0.12	−0.09	−0.03	0.32**	0.36**	0.32**	0.58**	-		
9. 2 Month depression	0.35**	0.04	−0.24*	0.56**	0.37**	0.37**	0.25**	0.21*	-	
10. 2 Month state anxiety	0.34**	−0.08	−0.22*	0.36**	0.44**	0.35**	0.15	0.24**	0.70**	-

*$p < 0.05$, **$p < 0.01$.

subsequent analyses. Although marital status was significantly associated with infant regulation, there was a very small number of participants who reported being single ($n = 7$), creating convergence problems in the larger models; thus, this variable was not included as a covariate in subsequent analyses.

Only the COVID sample was used to determine covariates for the Aim 2 analyses. For the COVID sample, weeks gestation during the pregnancy time point was associated with higher infant negative emotionality at 2 months postpartum ($r = 0.22$, $p = 0.02$) and therefore retained in Aim 2 analyses. COVID-19 infection during pregnancy and the timing of the prenatal surveys during the pandemic were also included as covariates in the Aim 2 analyses based on a priori hypotheses regarding their relation to study variables. Women who were infected with COVID-19 during the pregnancy had higher prenatal depression ($t\,(115) = -2.93$, $p = 0.004$), pregnancy-specific anxiety ($t\,(115) = -2.02$, $p = 0.05$), and prenatal state anxiety ($t\,(115) = -2.81$, $p = 0.006$). The amount of time from the start of the pandemic to when the pregnancy surveys were collected was significantly associated with prenatal infection stress. That is, women who completed the questionnaires later during the pandemic had greater stress related to being infected with COVID-19 ($r = 0.28$, $p = 0.002$).

3.2 | Aim 1: Pre-COVID and COVID sample differences

All models were just-identified, thus by default a perfect fit was conveyed by the fit indicators. Table 4 displays descriptive statistics for the prenatal internalizing and infant temperament variables prior to and during the COVID-19 pandemic. Table 5 presents the standardized path coefficients for models examining associations between pandemic status (i.e., pre-vs. post-pandemic onset), prenatal internalizing symptoms and infant temperament. Pandemic status significantly predicted pregnancy-specific anxiety ($\beta = 0.19$, $p = 0.007$). Women who were pregnant during the COVID-19 pandemic reported higher pregnancy-specific anxiety relative to those in the pre-COVID sample. Pandemic status also significantly predicted infant positive affectivity ($\beta = -0.16$, $p = 0.03$), negative emotionality ($\beta = 0.20$, $p = 0.004$), and regulatory capacity ($\beta = -0.20$, $p = 0.004$) at 2 months postpartum. Infants born during the pandemic had higher negative emotionality as well as lower positive affectivity and regulatory capacity compared to those in the pre-COVID sample. This same pattern occurred for several subscales within the overarching factors. Infants born during the pandemic were reported to have higher distress to limitations ($\beta = 0.17$, $p = 0.01$). They also demonstrated lower falling reactivity (i.e., more difficulty recovering from distress; $\beta = -0.20$, $p = 0.006$), perceptual sensitivity ($\beta = -0.18$, $p = 0.012$), smiling/laughter ($\beta = -0.25$, $p < 0.001$), cuddliness ($\beta = -0.14$, $p = 0.03$), and low intensity pleasure ($\beta = -0.18$, $p = 0.011$). All significant effects demonstrated effect sizes in the small range.

3.3 | Aim 2: Pandemic-related stress and temperament

All the models demonstrated strong fit (i.e., non-significant chi-square value, CFI >0.95, RMSEA <0.05, and SRMR <0.05). The direct effect of prenatal infection stress on infant negative emotionality at 2 months was significant controlling for perinatal depression ($\beta = 0.26$, $p = 0.009$), state anxiety ($\beta = 0.27$, $p = 0.004$), or pregnancy-specific anxiety ($\beta = 0.20$, $p = 0.04$). That is, greater prenatal infection stress was positively associated with higher infant negative emotionality, controlling for perinatal depression or anxiety symptoms. At the fine-grained level, this effect was only present for infant fear ($\beta = 0.36$, $p = 0.001$). All significant direct effects demonstrated effect sizes in the small or small-to-medium range. Prenatal infection stress did not significantly predict infant positive affectivity or regulatory capacity at 2 months postpartum.

TABLE 4 Descriptive statistics for prenatal internalizing symptoms and infant temperament at two months.

	Pre-COVID		During COVID	
	M	**SD**	***M***	**SD**
Prenatal symptoms				
Depression	6.98	4.95	7.08	4.19
Pregnancy Anxiety	16.47	4.56	18.54	5.14
State Anxiety	34.98	10.56	34.97	10.61
Preparedness Stress	-	-	2.24	0.85
Infection Stress	-	-	2.80	1.08
Positive affectivity	22.69	5.97	20.47	5.12
Activity	3.69	1.05	3.63	0.91
Approach	3.69	1.44	3.22	1.32
High intensity pleasure	4.66	1.31	4.35	1.29
Perceptual sensitivity	3.25	1.62	2.71	1.59
Smiling/Laughter	3.76	1.41	2.97	1.25
Vocal reactivity	4.14	1.15	3.78	1.18
Negative emotionality	12.73	3.13	13.86	3.27
Distress to limitations	3.87	1.04	4.11	0.99
Falling reactivity	5.05	0.98	4.75	1.07
Fear	2.53	1.05	2.79	1.34
Sadness	3.38	1.26	3.70	1.17
Regulatory capacity	20.70	2.84	19.82	2.76
Cuddliness	6.24	0.69	6.12	0.66
Duration of orienting	3.62	1.46	3.24	1.25
Low intensity pleasure	5.52	0.88	5.27	1.04
Soothability	5.42	0.94	5.21	1.10

The specific indirect effect of prenatal infection stress on infant negative emotionality mediated sequentially by prenatal depression and postpartum depression was significant (β = 0.06, 95% CI [0.01, 0.11]; Figure 3a). This same pattern of results occurred for two fine-grained subscales within the negative emotionality factor, specifically distress to limitations (β = 0.06, 95% CI [0.01, 0.11]; Figure 3b) and sadness (β = 0.06, 95% CI [0.01, 0.11]; Figure 3c). A small effect size characterized all three significant indirect effects. The specific indirect effects of prenatal infection stress on infant negative emotionality via prenatal depression and postpartum depression separately were not significant. Models including pregnancy-specific anxiety and state anxiety as mediators did not yield significant indirect effects.

Prenatal preparedness stress did not directly relate to infant negative emotionality, positive affectivity, or regulatory capacity controlling for perinatal depression, state anxiety, or pregnancy-specific anxiety. However, the specific indirect effect of prenatal preparedness stress on infant negative emotionality mediated sequentially by prenatal depression and postpartum depression was significant (β = 0.06, 95% CI [0.01, 0.11]; Figure 4a). This pattern also occurred for subscales within the negative emotionality factor, specifically distress to limitations (β = 0.06, 95% CI [0.01, 0.10]; Figure 4b) and sadness (β = 0.06, 95% CI [0.01, 0.11]; Figure 4c). A small effect size characterized all three significant indirect effects. The specific indirect effects of prenatal preparedness stress on infant negative

TABLE 5 Sample differences on prenatal internalizing symptoms and infant temperament at two months.

	β[a]	SE	R^2
Prenatal symptoms			
Pregnancy anxiety			0.06
Pandemic status	0.19**	0.07	
Maternal age	−0.13	0.08	
Family income	0.11	0.08	
Positive affectivity			0.06
Pandemic status	−0.16*	0.07	
Maternal age	−0.09	0.08	
Family income	0.02	0.09	
Infant age	0.12	0.07	
Perceptual sensitivity			0.03
Pandemic status	−0.18*	0.07	
Maternal age	0.03	0.09	
Family income	0.01	0.09	
Infant age	0.03	0.08	
Smiling/Laughter			0.12
Pandemic status	−0.25**	0.07	
Maternal age	−0.07	0.07	
Family income	0.00	0.08	
Infant age	0.17**	0.06	
Negative emotionality			0.04
Pandemic status	0.20**	0.07	
Maternal age	−0.02	0.08	
Family income	−0.08	0.09	
Infant age	−0.07	0.07	
Distress to limitations			0.04
Pandemic status	0.17**	0.07	
Maternal age	−0.07	0.08	
Family income	−0.06	0.09	
Infant age	−0.03	0.07	
Falling reactivity			0.04
Pandemic status	−0.20**	0.07	
Maternal age	0.10	0.08	
Family income	0.05	0.08	
Infant age	0.04	0.06	
Regulatory capacity			0.06
Pandemic status	−0.20**	0.07	
Maternal age	0.10	0.08	
Family income	0.05	0.08	
Infant age	0.15*	0.07	

(Continues)

TABLE 5 (Continued)

	β[a]	SE	R^2
Cuddliness			0.03
Pandemic status	−0.14*	0.06	
Maternal age	0.13	0.08	
Family income	0.03	0.08	
Infant age	0.00	0.07	
Low intensity pleasure			0.03
Pandemic status	−0.18*	0.07	
Maternal age	0.09	0.08	
Family income	0.03	0.09	
Infant age	0.04	0.07	

[a]The pre-COVID sample was coded as the reference group. Only models where pandemic status significantly predicted outcomes are presented. All significant paths were determined to have small effect sizes using the standardized beta coefficient.

*$p < 0.05$, **$p < 0.01$.

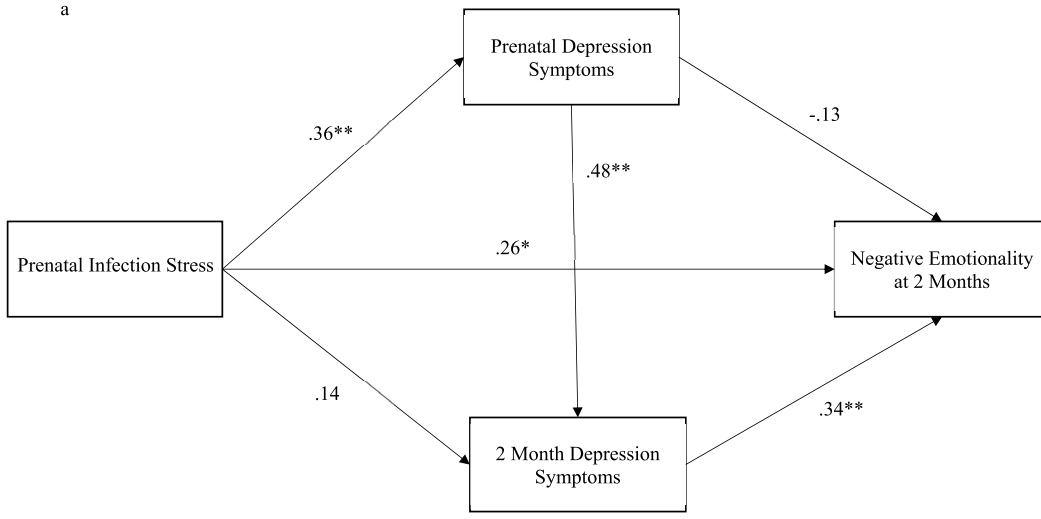

FIGURE 3 (a) Infection stress-negative emotionality path model. (b) Infection stress-distress to limitations path model. (c) Infection stress-sadness path model. Values represent standardized path coefficients. Covariances and covariates are not depicted. Model fit = $\chi^2 = 0.78$ (2), $p = 0.68$, RMSEA = 0.00, CFI = 1.00, SRMR = 0.013. **$p < 0.01$; *$p < 0.05$.

emotionality via prenatal depression and postpartum depression were not significant when examined separately. Models including pregnancy-specific anxiety and state anxiety did not yield significant direct or indirect effects.

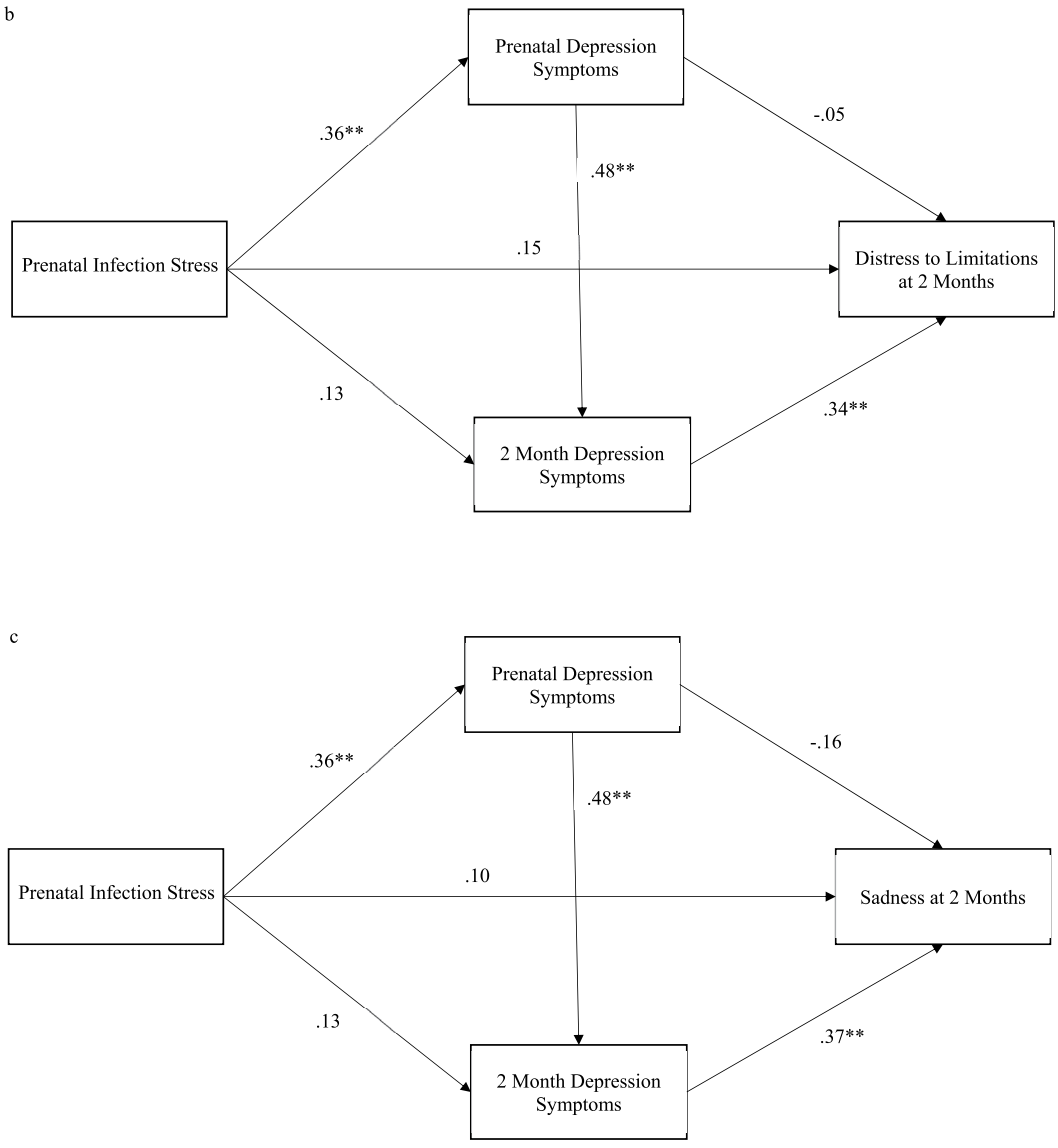

FIGURE 3 (Continued)

4 | DISCUSSION

The COVID-19 pandemic has resulted in numerous stressors for pregnant women and parents of young children. The current study aimed to better understand how this unprecedented adverse event has impacted maternal mental health during pregnancy as well as subsequent socioemotional development in their offspring. More specifically, this study compared measures of prenatal mental health and infant temperament at two months postpartum prior to and following the onset of COVID-19, in otherwise comparable perinatal samples. Second, prenatal pandemic-related stress was examined as a predictor of infant temperament among children born during the COVID-19 pandemic,

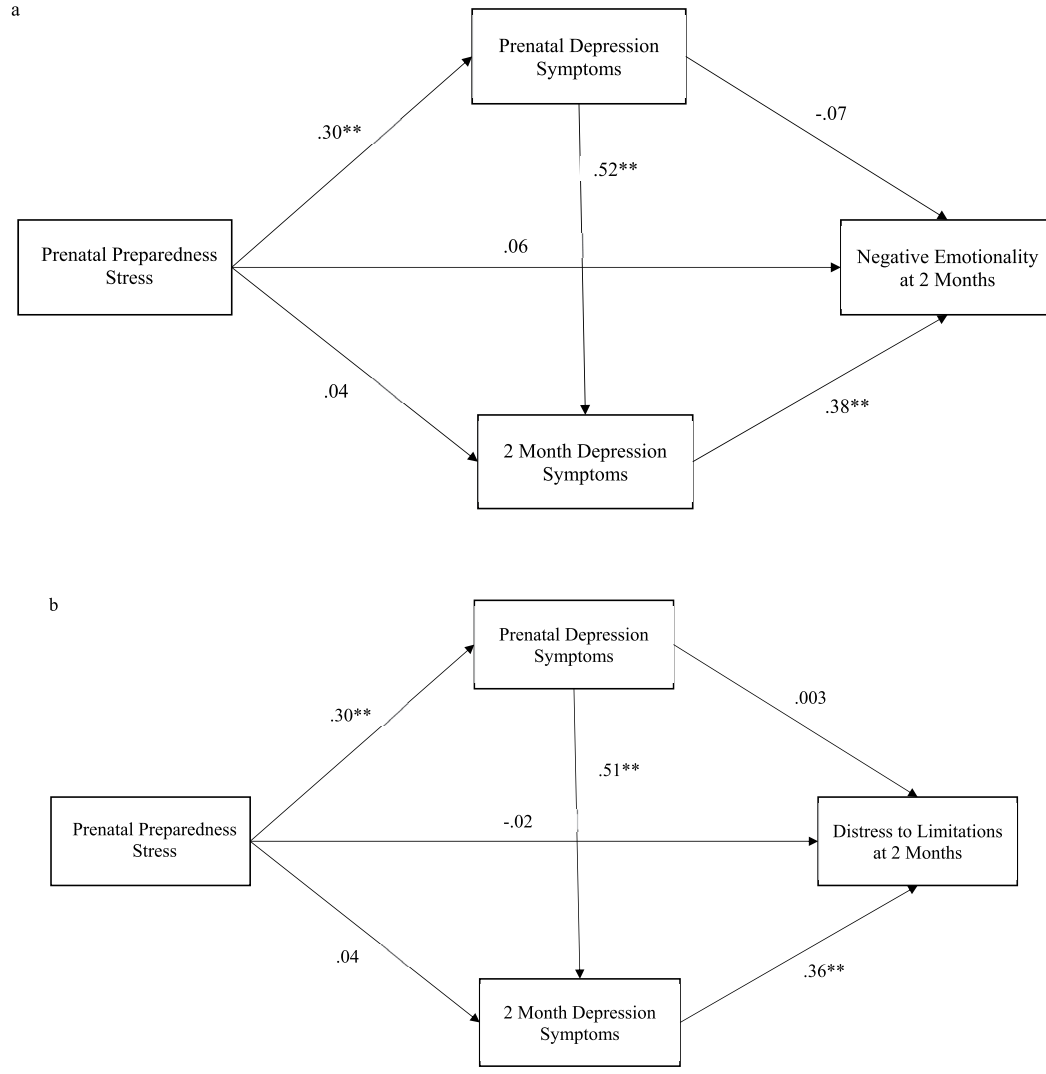

FIGURE 4 (a) Preparedness stress-negative emotionality path model. (b) Preparedness stress-distress to limitations path model. (c) Preparedness stress-sadness path model. Values represent standardized path coefficients. Covariances and covariates are not depicted. Model fit = $\chi^2 = 0.39$ (2), $p = 0.82$, RMSEA = 0.00, CFI = 1.00, SRMR = 0.009. $^{**}p < 0.01$; $^{*}p < 0.05$.

with perinatal depression and anxiety symptoms explored as mediators of these associations. These aims addressed current gaps in the literature, as few studies have examined the role of prenatal stress on infant temperament during later waves of the pandemic (i.e., 2021 and beyond) using validated measures of pandemic-related stress, nor is there a thorough understanding of potential mechanisms underlying these associations.

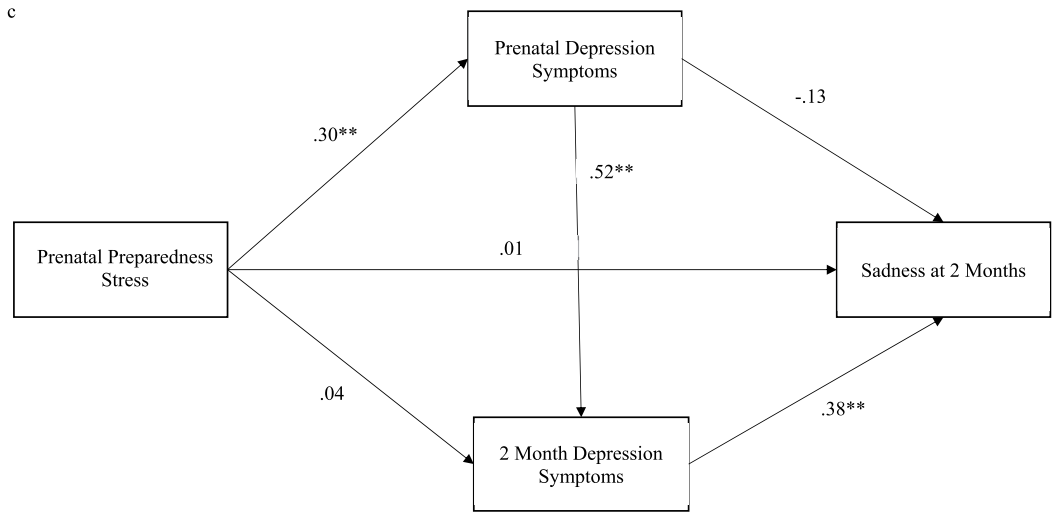

FIGURE 4 (Continued)

4.1 | Prenatal mental health and temperament prior to and during the pandemic

The first goal of the current study was to examine prenatal stress in a sample of women who were pregnant during the pandemic compared to a cohort of pregnant women who gave birth prior to COVID-19. It was anticipated that women who were pregnant during the pandemic would report greater pregnancy-specific anxiety, state anxiety, and depression symptoms due to additional stressors associated with this adverse event. This hypothesis was supported for pregnancy-specific anxiety but not prenatal depression or state anxiety. These findings align with previous research demonstrating elevated pregnancy-specific anxiety during the beginning of the pandemic (Moyer et al., 2020). The current study suggests a community sample of women in the United States continued to experience heightened fears specific to their pregnancy during later phases of the pandemic relative to those pregnant prior to the onset of COVID-19. Even though less stringent pandemic-related public health restrictions were present during the time the current study was conducted, pregnant women still faced notable stressors, including uncertainty regarding exposure to more transmissible variants of the virus, which likely contributed to their greater endorsement of pregnancy-specific anxiety (Wu et al., 2020).

In contrast to several studies conducted during later waves of the pandemic, the current study did not find higher levels of prenatal state anxiety or depression 1 year into the pandemic (Godleski et al., 2022; Tauqeer et al., 2023). Prior research demonstrating significant differences did not include a pre-pandemic comparison group, which could have contributed to these discrepant findings. For example, Godleski et al. (2022) compared prenatal depression and anxiety symptoms to a sample of non-pregnant women during the pandemic, which provides less insight into whether women pregnant during the COVID-19 outbreak experienced significantly greater mental health symptoms above and beyond more typical levels observed during the prenatal period. In line with the current study, pregnant women living in Argentina endorsed decreased state anxiety in response to policies easing pandemic-related restrictions like social distancing (López-Morales et al., 2021). The researchers hypothesized that women may have adapted to general stressors associated with the pandemic (e.g., changes in daily routines), causing them to experience declines in state anxiety. Depression symptoms may have also decreased during later phases of the pandemic due to restrictions being lifted, allowing women to engage in more activities outside of the home such as spending time with loved ones.

As part of the first goal of the study, infant temperament at two months postpartum was also examined prior to and during the COVID-19 pandemic across two samples of mother-infant dyads. It was anticipated that infants born during the pandemic would exhibit greater distress proneness in addition to lower positive affect and regulatory capacity. This hypothesis was supported in the expected direction for all three temperament factors, suggesting infants born in the age of COVID-19 display less-optimal temperament profiles, which could increase their risk for internalizing and externalizing problems later in development (Gartstein et al., 2012). Differences were also observed at the fine-grained temperament level, including greater distress to limitations and more difficulty recovering from distress, as well as lower smiling/laughter, sensitivity to subtle environmental stimuli, cuddliness, and enjoyment of low-intensity activities. Only one known study has compared temperament profiles in infants exclusively born during the COVID-19 pandemic to a pre-pandemic comparison sample (Morris & Saxbe, 2023). Morris and Saxbe (2023) found fewer differences relative to the current analyses, only demonstrating greater negative emotionality in infants born during the pandemic. As mentioned previously, these researchers utilized a pre-pandemic comparison group consisting of only first-time mothers, resulting in demographic differences between the two samples, which may have contributed to discrepant findings with the present analyses. Moreover, most of the women included in the study conducted by Morris and Saxbe (2023) were in the second or third trimester of pregnancy at the beginning of the COVID-19 pandemic, resulting in infants on average being exposed to the stress of the pandemic for around half of the pregnancy. In contrast, all the women in the present analyses conceived during the pandemic. The results of the current study suggest that longer exposure to the prenatal stress related to the pandemic may have a more adverse impact on temperament development. In line with these findings, research conducted prior to the pandemic has demonstrated that prolonged prenatal psychosocial stress starting in early pregnancy predicts poor socioemotional outcomes in infancy (Porter et al., 2019). Future studies should explore the timing of exposure to prenatal stress during the COVID-19 outbreak to better understand how this factor may impact temperament development during infancy.

4.2 | Pandemic-related stress and temperament

The second goal of the study was to investigate the unique role of maternal pandemic-related stress (i.e., infection stress and preparedness stress) during pregnancy in relation to infant temperament. Prenatal pandemic-related stress was expected to directly predict infant temperament at 2 months. Consistent with this hypothesis, prenatal infection stress was positively associated with infant negative emotionality controlling for perinatal depression and anxiety symptoms. These findings align with two previous studies, which found pandemic-related stress during pregnancy predicted greater negative affect during late infancy (Buthmann et al., 2022; Schweizer et al., 2023). The current study adds to the extant literature by demonstrating these associations during early infancy, which could aid in identifying infants at a younger age who may be at risk for problematic behavioral/emotional outcomes, such as later internalizing and externalizing problems (Gartstein et al., 2012). Moreover, prenatal pandemic-related stress was shown to impact infant negative emotionality during later phases of the pandemic, highlighting the importance of monitoring prenatal stress levels during future outbreaks, even when less stringent restrictions are in place. These results build on the Morris and Saxbe (2023) study by demonstrating that differences in negative emotionality prior to and during the pandemic also appear to be explained by prenatal pandemic-related stress above and beyond more general distress. Specifically examining this form of stress therefore appears critical for elucidating underlying mechanisms of the pandemic on infant temperament as well as informing treatment recommendations for pregnant women.

Prenatal preparedness stress was not a direct predictor of temperament during early infancy. Recent research has found prenatal preparedness stress, but not infection stress, decreased over the course of

the pandemic (Penengo et al., 2022). Thus, fear of perinatal infection likely remained high during later waves due to the emergence of more transmissible variants of COVID-19, wherein vaccines provided less protection against the virus. Conversely, preparedness stress may have decreased as a result of easier access to prenatal care and less stringent hospital restrictions, making this form of stress a less salient direct predictor of infant temperament after the first year of the pandemic. These findings highlight the importance of examining the role of specific forms of pandemic-related stress with respect to infant temperament, especially during later phases of the pandemic when stressors experienced by pregnant women have changed relative to the initial lockdown period.

Furthermore, perinatal depression and anxiety symptoms were each hypothesized to serve as mediators linking pandemic-related stress during pregnancy with temperament in two-month-old infants. Prenatal infection and preparedness stress were only found to indirectly predict infant negative affect sequentially via prenatal and postpartum depression symptoms. That is, women with higher pandemic-related stress experienced greater depression symptoms prenatally, which persisted into the postpartum period. Greater maternal depression at 2 months was then associated with increased negative affect during early infancy. In response to the pandemic, women may have experienced depression symptoms during pregnancy due to difficulty coping with the stressors associated with this event (Firouzbakht et al., 2022; Werchan et al., 2022). These symptoms did not resolve by 2 months postpartum and may have impacted infant temperament through mechanisms such as mother-infant interactions. Postpartum depression has been demonstrated to adversely influence how mothers interact with their infants (Hoffman et al., 2006). For example, mothers with postpartum depression symptoms are more likely to interact with their infants in a less sensitive manner, increasing the risk for non-optimal temperament profiles (Parade et al., 2018). Examining infant temperament at the fine-grained level suggests that within the negative emotionality factor, prenatal infection stress exerts the greatest indirect impact on distress proneness as opposed to recovery from distress, perhaps due to greater salience during early infancy. Based on these findings, future studies should examine whether maternal sensitivity during parent-child interactions serves a protective function against the adverse effects of prenatal pandemic-related stress on infant temperament, which would aid in the development of early intervention efforts.

Only a few known studies have examined mechanisms linking prenatal pandemic-related stress with infant temperament (López-Morales et al., 2022; Sacchi et al., 2023). In contrast to the present findings, López-Morales et al. (2022) found prenatal pandemic stress indirectly predicted infant negative affect and surgency at 6 months through prenatal anxiety rather than depression symptoms during pregnancy. Of note, these researchers utilized a COVID-19 measure that identified whether women were exposed to a series of stressful events during the pandemic, whereas the current study evaluated perceived stress related to perinatal infection and preparing for their baby's arrival. Recent research has found perceived stress to relate more strongly to prenatal depression during the pandemic relative to objective measures, which may explain why depression symptoms served as a significant mediator in the present analyses (King, et al., 2021). In line with previous research, postpartum symptoms alone did not mediate associations between prenatal pandemic-related stress and infant temperament (Sacchi et al., 2023). Thus, the present study highlights the importance of examining the continuity of prenatal and postpartum symptoms when understanding mechanisms linking prenatal pandemic-related stress with negative emotionality during early infancy.

Finally, pandemic-related stress during pregnancy did not significantly relate to infant positive affectivity or regulatory capacity in the current study. During the initial lockdown period of the pandemic in Italy, Provenzi and colleagues (2021a, 2021b) found maternal perceived stress in response to the pandemic indirectly predicted lower self-regulation and positive affect in three-month-old infants. In addition, they examined several mediators that were not considered in the present analyses, such as

epigenetic changes and parenting stress, which should continue to be explored in the ongoing wake of the COVID-19 pandemic. Given the current study demonstrated lower infant self-regulation and positive affectivity in a sample of infants born during COVID-19 relative to a pre-pandemic comparison group, it is imperative to conduct further research to identify factors contributing to temperament differences during later phases of the pandemic, which are more likely to resemble future outbreaks.

4.3 | Limitations and conclusions

The present study had several limitations. First, temperament was assessed using a parent-report measure. Although the IBQ-R has been found to display strong psychometric properties, parent-report measures can be influenced by maternal factors such as depression or anxiety (Daryanani et al., 2015). Including an observational assessment of temperament could provide a more comprehensive picture of the infants' functioning. Second, this was not a diverse sample in terms of demographic factors such as race, as a majority of participants identified as white. Recent research suggests prenatal internalizing symptoms may differ for women from diverse backgrounds during the pandemic (Felder et al., 2023; King et al., 2021), which could have implications for how maternal distress in response to COVID-19 relates to infant temperament. Therefore, the results of the present study may differ among women from racially diverse backgrounds, which warrants the need for replication among a more racially diverse sample. Third, the current study did not include a measure of pandemic-related stress during the postpartum period. Following the birth of their babies, women likely continued to experience perceived stress in response to the pandemic, including fear of infection with COVID-19 (Miranda et al., 2022). Therefore, we cannot determine the specificity of prenatal pandemic-related stress above and beyond that present in the postpartum period, which should be explored in future research. Fourth, we did not examine the clinical significance of differences in the prenatal mental health measures prior to and during the COVID-19 pandemic, which should be explored further to help inform treatment recommendations. Fifth, although only women living in the United States were eligible to participate, more specific geographical information was not collected. Given COVID-19 related policies and the severity of outbreaks differed across the nation, this information could have impacted maternal stress levels and represents an important variable to consider in future studies. Finally, we did not correct for the number of statistical tests, which can be viewed as a limitation. However, given that in many respects this investigation is first of a kind, we prioritized controlling Type 2 error to maintain adequate power. This approach is typical for investigations addressing temperament with similarly sized samples (Balle et al., 2022; Blandon et al., 2010; Zhang et al., 2018) and the influence of pandemic stress on maternal-child health (Chang et al., 2023; Morales et al., 2021; Morris & Saxbe, 2023; Sacchi et al., 2023). Nonetheless, future studies are needed to follow-up and discern the most robust pathways of the COVID-19 pandemic on prenatal mental health and infant temperament.

In conclusion, infants born during the pandemic demonstrated less-optimal temperament development during early infancy relative to those born prior to COVID-19. This finding occurred even during later waves of the pandemic (i.e., from 2021 and beyond). Pandemic-related stress during pregnancy contributed to greater negative emotionality in these infants, demonstrating the intergenerational impact of prenatal maternal stress during the COVID-19 pandemic on offspring socioemotional development. These associations were present during later waves of the pandemic when less stringent restrictions were in place, highlighting the importance of continued monitoring of COVID-19 related stress levels in pregnant women, as this may have important implications for reducing the risks and later adversity in their infants. Depression symptoms during the perinatal period were also found to serve as a mediator linking pandemic-related stress with infant temperament, representing another important target for intervention. Given a generation of children have been impacted by the pandemic,

longitudinal studies will be critical in determining whether these effects persist later in childhood and will aid in the development of early intervention efforts.

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