# The Impact of Maternal Mental Health on Infant Temperament in the Context of the COVID-19 Pandemic


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**Abstract**

*Aims*: To determine associations between maternal pregnancy and parenting related anxiety during the COVID-19 pandemic and subsequent infant temperament development at 3 to 6 months old, as well as to determine significant contextual mediators.

*Study design*: 380 mother-infant dyads from across the United Kingdom reported on their pregnancy and parenting related anxiety during the COVID-19 pandemic. At 3 to 6 months postnatally, they also reported on aspects of their infant's temperament, ranging from surgency (responsiveness and positive emotions), negative affect (negative emotions), and effortful control (ability to regulate emotions). Structural Equation Modelling (SEM) was used to examine the expected association between prenatal maternal mental health and infant temperament traits, controlling for contemporaneous maternal mental health. Maternal and infant characteristics were examined as potential mediating factors.

*Results*: Pregnancy and parenting related anxiety were associated with less favourable infant surgency and negative affect, when controlling for contextual variables. Effortful control, however, was not related to maternal mental health over the course of the pandemic. Gestational age, general maternal anxiety levels, and maternal education were all correlated with surgency, either directly and/or mediated by parenting related anxiety scores.

*Conclusion*: The findings of this study underline the importance of paying attention to the mental health of expectant and new mothers during the COVID-19 situation and potential future pandemics, as it may be related to their infants' temperament development in their first months of life.



**Keywords**

Maternal anxiety, infant temperament, COVID-19 pandemic, surgency, negative affect, effortful control

**Layman's summary**

The COVID-19 pandemic impacted most people in some way or other. This also goes for pregnant women and new parents, who have often had to deal with pandemic related restrictions at the hospital and birthing unit. For example, some pregnant women had to change their birth plans, and their birth partner's presence may not have been allowed during birth. Just like most people during the pandemic, they also had to deal with isolation from friends and family, whom they normally could rely on for support.

We expect this might have caused increased anxiety in expectant and new mothers, which recent studies have also shown. This is not only a burden for these mothers, but science has shown that it can also have negative consequences for the behavioural development of their baby. More specifically, high levels of anxiety in mothers can affect the development of their baby's temperament, which refers to the overall emotional state or attitude of a person. From birth, temperament has been shown to be influenced by a baby's experiences, parents, and environment.

Temperament in babies can be measured by psychological tests and reports of infant behaviour even in the first months of life, and studies have shown that infants who express more negative emotions such as sadness, fewer positive emotions such as laughter, and who are less able to control their emotions may have more behavioural issues later in childhood and even in young adulthood. Therefore, it is important to determine whether anxiety in mothers during the COVID-19 pandemic is related to less favourable temperament development in their babies (such as laughing less often or expressing more sadness). The current study has investigated this by measuring pregnancy and parenting related anxiety in pregnant women and new mothers, as well as by assessing temperament development of their babies at 3 to 6 months during the COVID-19 pandemic.

Mothers of 380 babies from across the United Kingdom completed a questionnaire on their pregnancy related anxiety levels, and some also reported on their parenting related anxiety levels at 0 to 3, and 3 to 6 months after birth. They also completed questions on their baby's temperament at 3 to 6 months after birth, as well as on family and baby characteristics, such as their family income and the baby's gender. We analysed this data by relating the mothers' anxiety levels at the different timepoints to the temperament scores of their babies.

The results indicated that higher levels of pregnancy and parenting related anxiety in mothers were associated with fewer positive emotions and more negative emotions of their babies at 3 to 6 months after birth. There was no association between anxiety levels and the babies' ability to control their emotions and behaviour. We also found that shorter pregnancy length, higher general anxiety levels in mothers, and a higher educational level of the mother were related to their parenting related anxiety scores. These were, in turn, related to fewer positive emotions of their babies at 3 to 6 months.

In short, this study showed that pregnancy and parenting related anxiety levels in mothers were related to some aspects of their babies' temperament at 3 to 6 months after birth. This underlines the importance of supporting pregnant women and new mothers' mental health during times of crises like the COVID-19 pandemic, as it may be negatively related to their babies' temperament development early in life.

## 1. Introduction

The COVID-19 pandemic has affected society in a variety of ways, with uncertainty playing a key role in the lives of many people as a result. One example of a group of people heavily impacted by the pandemic are expectant and new parents. Compared to before the pandemic, the world in which infants develop has changed dramatically over the past two years, with many expectant and new parents struggling financially (Thayer & Gildner, 2020) and having to deal with isolation from family, friends, co-workers, and other groups of social support (Aydin, Glasgow, Weiss, Austin, et al., 2022). Moreover, families expecting their child during the pandemic, especially during phases of lockdown, have faced many COVID-19 related obstacles due to newly implemented rules and regulations. In the United Kingdom (UK), for instance, communication regarding pregnancy and birth between healthcare professionals and expectant parents has been primarily virtual by means of telephone or video calls. This may have contributed to expectant parents having felt less supported during their pregnancy (Aydin, Glasgow, Weiss, Austin, et al., 2022). Additionally, uncertainties regarding presence of the partner at healthcare appointments and birth may all have contributed to heightened maternal anxiety, stress, and depressive symptoms during the pandemic, as evidenced by several studies (Aydin, Glasgow, Weiss, Austin, et al., 2022, Aydin, Glasgow, Weiss, Khan, et al., 2022; Cameron et al., 2020; Chmielewska et al., 2021; Hessami et al., 2020; Lebel et al., 2020). As increased levels of maternal stress, anxiety and depressive symptoms have been previously shown to correlate negatively with various aspects of infant development such as temperament and cognition (e.g., Bergman et al., 2007; Laplante et al., 2016; Nomura et al., 2019), it is vital to explore this relationship in the context of the COVID-19 pandemic. Therefore, this study will investigate longitudinal associations between changes in maternal mental health and early infant temperament in the context of the COVID-19 pandemic in the UK.

Temperament has been defined as “constitutionally based individual differences in reactivity and self-regulation, influenced over time by heredity and experience” (Putnam et al., 2001, p. 163; Rothbart & Derryberry, 1981). Temperament has been further subdivided into three broad dimensions: surgency, negative affect, and effortful control (also referred to as orienting/regulatory capacity). Surgency is characterised by expressions of positive emotions such as laughter and high activity, while negative affect relates to expressions of negative emotions such as fear, anger, sadness, and frustration. Effortful control refers to the capacity of attentional control over emotions and behaviour (Gartstein & Rothbart, 2003;

Putnam et al., 2001; Rothbart et al., 2003). These temperament dimensions can already be assessed behaviourally in early infancy (Gartstein & Rothbart, 2003; Putnam et al., 2001), and research has shown that early temperament measured by both parent-report and researcher assessment is associated with behaviour in later childhood and even young adulthood. For instance, Abulizi et al. (2017) found that negative affect assessed at 12 months was correlated with overall behaviour at 5.5 years of age. Similarly, Rigato et al. (2020, preprint) showed that all three temperament dimensions assessed in the first year of life were associated with behaviour at 3 years of age. Specifically, they found that increased negative affect was related to less favourable conduct, and higher surgency was related to hyperactivity, as well as to more prosocial behaviour at 3 years of age. Increased effortful control was also correlated with more prosocial behaviour. Furthermore, early childhood effortful control has also been positively linked with early academic achievement (Blair & Razza, 2007). Behavioural inhibition measured in toddlers, defined as a dimension of temperament relating to anxious responses to novelty, has also been indirectly associated with heightened anxiety during the COVID-19 pandemic in young adults (Zeytinoglu et al., 2021), underlining the long-term importance of early temperament development.

While studies have shown that individual ratings of infant temperament generally remain constant over time (Carranza et al., 2013; Komsi et al., 2006), certain characteristics and external factors can be related to individual differences in temperament, as well as to changes in early temperament development. It has been shown, for instance, that a low socioeconomic status (based on parental education, family income, and maternal occupational status) was correlated with less consolable and more reactive infant temperament, which could be partially explained by family stress and maternal psychopathology (Jansen et al., 2009). Furthermore, Buthmann and Gotlib (2021, preprint) found that a higher income-to-needs ratio (i.e., household income divided by the corresponding poverty threshold) was associated with lower negative affect in one-year-old infants. Evidence is mixed, however, as Austin et al. (2005) found no associations between maternal education and family income, and infant temperament. This may be due to the different measures of infant temperament that were used (Jansen et al., 2009). Additionally, infant sex may also play a role in certain temperament attributes, especially in combination with prenatal maternal stress. For instance, Simcock et al. (2017) found that in the context of natural disaster, 6-month-old boys whose mothers experienced relatively high levels of prenatal stress were more often rated as irritable than girls. In contrast, a review by Sutherland and Brunwasser (2018) indicated that girls may be more sensitive to the deleterious effects of prenatal maternal stress on early temperament than boys. More specifically, multiple studies reviewed by Sutherland and Brunwasser (2018) reported associations between prenatal maternal stress and increased negative reactivity and emotionality in girls, but not in boys. This is in line with literature and theories on female vulnerability to anxiety driven by prenatal maternal stress (Glover & Hill, 2012; Sandman et al., 2013). Thus, while evidence is mixed, most studies point towards girls being more sensitive to the negative effects of prenatal maternal stress on temperament. When considering maternal anxiety or depressive symptoms instead of maternal stress, we may expect to see a similar relationship, as these are all closely related maternal mental health concepts.

As already hinted at, a commonality shared by these studies is that the authors considered infant temperament development in the context of maternal mental health, another variable which may be related to individual differences in infant temperament development. In fact, many studies have evidenced associations between maternal mental health (most often defined as either maternal stress or depressive symptoms), and the various dimensions of infant temperament, especially in the context of natural disasters which, as large-scale disastrous events, are somewhat comparable to the COVID-19 pandemic. Considering maternal stress, Laplante et al. (2016) found that prenatal maternal stress as caused by a natural disaster was related to less favourable infant temperament at six months of age, which was characterised by increased fussiness and dullness, as well as by a higher need for attention. Focusing more on maternal depressive symptoms instead of prenatal maternal stress, Nomura et al. (2019) showed that in the context of a natural disaster, prenatal maternal depression was correlated with emotion dysregulation and increased distress in infants at six months of age. They found that these associations were even stronger in infants exposed to natural disaster in-utero. Moreover, while Tees et al. (2010) did not find strong associations between specific natural disaster related maternal stress, they did observe several correlations between maternal stress and depressive symptoms in the context of natural disaster, and less favourable overall temperament in infants aged 2 months, and again at 12 months in the same sample of infants. A unique aspect of the study by Tees et al. (2010) is that they also found similar associations between maternal anxiety levels and infant temperament, as most studies consider only maternal depressive symptoms or prenatal stress in the context of natural disaster.

Based on these studies in the context of natural disaster, it can be expected that maternal mental health in the context of the COVID-19 pandemic, a comparable large-scale disastrous event with potential stress-inducing effects, may also be negatively associated with infant temperament development. Provenzi et al. (2021) showed that prenatal maternal stress in the context of the COVID-19 pandemic was associated with infants' regulatory capacity at 3 months of age. They specifically found that increased pandemic related prenatal stress together with low perceived social support were associated with higher postnatal maternal anxiety. This was then correlated with heightened parenting stress and less maternal bonding, which were in turn associated with lower regulatory capacity in 3-month-old infants. Focusing more on maternal depressive symptoms instead of prenatal maternal stress, Buthmann and Gotlib (2021, preprint) showed that during the COVID-19 pandemic, more maternal prenatal somatisation symptoms (i.e., bodily symptoms with a psychological cause instead of an organic cause) were associated with increased negative affect in one-year-old infants, which was mediated by postnatal maternal depressive symptoms. Another study investigating maternal depressive symptoms and infant temperament in the context of the COVID-19 pandemic of which the current study is a partial replication was conducted by Fiske et al. (2022). While they did not find associations between pandemic-specific maternal depressive symptoms and infant temperament in a subsample of 220 infants aged between 6 and 48 months, they did find correlations between general (i.e., not pandemic-specific) maternal depressive symptoms and infant temperament during the pandemic. Interestingly, they showed that these longitudinal correlations between the three subscales of infant temperament and maternal depressive symptoms were child-driven. More specifically, relatively high levels of infant negative affect or surgency, or relatively low levels of effortful control early in the pandemic were associated with more maternal depressive symptoms later in the pandemic. As most of the infants in their subsample were above the age of 18 months, the authors propose that this might be characteristic of toddlerhood, whereas maternal-driven associations may be more common in early infancy. This is further supported by their finding in a younger subsample that more maternal depressive symptoms were associated with increased negative affect at 10 months of age, while this relation was not present anymore at 16 months. However, a maternal-driven association was also found for effortful control regardless of the infant age, with more depressive symptoms correlating with lower effortful control later in the pandemic. Furthermore, they found that maternal stress related to the pandemic slightly lowered during the pandemic, while more mothers reported some pandemic-specific depressive symptoms. This did not, however, negatively affect infant temperament development.

The findings of Fiske et al. (2022) are notable on their own but could be further strengthened when replicated by other studies using independent data sets. This can be a step towards more generalisability and robustness of the results (Thomason, 2022). As replication studies within the field of developmental psychology are still relatively rare (Duncan et al., 2014), this study aims to partially replicate and extend the study of Fiske et al. (2022). To do so, this study has drawn data from an online longitudinal survey (the COVID in the Context of Pregnancy, Infancy, and Parenting [CoCoPIP] project [Aydin, Weiss, et al., 2022]). CoCoPIP is a nationwide project in the UK, investigating the impact of the COVID-19 pandemic on the lives of expectant and new families, as well as on the development of their infants born during the pandemic. Using data from the CoCoPIP project, we may expect to find somewhat different findings than Fiske et al. (2022), considering their sample was from a limited and affluent region of the UK, while our sample is national, which may reflect the UK population more accurately. Additionally, our study also considers potential contextual mediators of (the relation between) maternal mental health and infant temperament, as an extension to the study of Fiske et al. Moreover, our infant sample is both larger and of a younger age, and our study focuses more on maternal anxiety than on maternal depressive symptoms. Multiple studies have linked prenatal and postnatal maternal anxiety to less favourable infant negative affect, surgency, and effortful control (Blair et al., 2011; Coplan et al., 2005; Henrichs et al., 2009; Tees et al., 2010), but to our knowledge, none to date have done so in the context of the COVID-19 pandemic. Overall, this led to the following research questions, aims, and hypotheses:

*RQ(1): Are consistency and change in pregnancy and parenting related anxiety during the COVID-19 pandemic associated with subsequent infant development, specifically temperament at 3 to 6 months of age?*

The aim of this research question is to determine longitudinal associations between pregnancy and parenting related anxiety, and attributes of infant temperament (surgency, negative affect, and effortful control) at 3 to 6 months of age in the context of the COVID-19 pandemic. Based on the discussed literature, maternal mental health is anticipated to decline over the course of the pandemic, which may in turn be associated with less favourable infant temperament over time, such that infants are characterised by higher negative affect, lower effortful control, and lower surgency.

*RQ(2): How do demographic, infant, and family characteristics affect (the relation between) pregnancy/parenting related anxiety and infant temperament?*

The aim of this research question is to determine significant contextual mediators of pregnancy and parenting related anxiety, and infant temperament at 3 to 6 months in the context of the COVID-19 pandemic. Pregnancy and parenting related anxiety are expected to be mediated by multiple contextual factors, including ethnicity, family income, maternal education, maternal age, general maternal anxiety, and maternal anxiety caused by traumatic events. The three subscales of infant temperament (surgency, negative affect, and effortful control) are also anticipated to be mediated by various contextual factors, including infant gestation, infant age, and infant sex. Furthermore, infant sex and socioeconomic status (in this study drawn from data on maternal educational level and family income), are expected to play an important role in temperament outcome, based on the reviewed literature above. Specifically, girls are expected to be more vulnerable to the deleterious effects of maternal anxiety on early temperament. Additionally, a family from a lower socioeconomic status is anticipated to be associated with less favourable infant temperament, meaning higher negative affect, lower effortful control, and lower surgency in infants.

## 2. Methods

### 2.1 Participants

The CoCoPIP project has enrolled 2,600 families recruited globally from 20 weeks of gestation to 9 months at initial enrolment (Aydin, Weiss, et al., 2022). Families were recruited through various strategies, including collaborating with the National Health Service and partners in the UK, distribution amongst nationwide antenatal and postnatal health groups, online advertising using social media platforms (Facebook, Instagram, and Twitter), targeting specific groups affected by an increase of COVID-19 related restrictions, and public sharing. The CoCoPIP project received ethical approval from the University of Cambridge, Psychology Research Ethics Committee (PREC, PRE.2020.077, for full details please refer to Aydin, Weiss, et al., 2022).

Two subsamples of participants from the CoCoPIP dataset contributed to the current study. The first sample included mother-infant dyads who have contributed data on pregnancy/parenting related anxiety from at least one timepoint (prenatal, 0 to 3, or 3 to 6 months postnatally), as well as data on infant temperament from 3 to 6 months postnatally.

This resulted in 61 eligible mother-infant dyads for sample 1. As CoCoPIP participants could enrol at any of the first timepoints (prenatally, 0 to 3, or 3 to 6 months postnatally), not all participants have completed all timepoints. Of the 61 dyads, 25 contributed prenatal data on pregnancy related anxiety, 50 on parenting related anxiety at 0 to 3 months postnatally, and 61 on parenting related anxiety at 3 to 6 months postnatally. All 61 dyads have contributed complete data on infant temperament at 3 to 6 months, except for 2 dyads which only contributed data on infant surgency. This first sample allowed us to determine preliminary longitudinal relationships between pregnancy/parenting related anxiety and subsequent infant temperament.

However, sample 1 was too small to answer our second research question on potential significant mediators. Moreover, because of the small sample size and missing data, sample 1 also did not allow for addressing relationships between pregnancy and parenting anxiety over the course of the pandemic, necessary to answer our first research question. Therefore, we selected a second sample of the CoCoPIP participants. Sample 2 included mother-infant dyads who contributed prenatal data on pregnancy related anxiety, and on at least one potential mediator, specifically ethnicity, as this yielded the biggest dataset. Of all CoCoPIP participants, 380 dyads were eligible for inclusion in sample 2. Of the 61 dyads in sample 1, 25 were also included in the 380 dyads of sample 2, as they contributed prenatal data on pregnancy related anxiety, as well as data on their ethnicity. Sample 2 ($n$ = 380) was bigger than sample 1 ($n$ = 61) since data collection for CoCoPIP is ongoing, resulting in 343 dyads who have not yet completed the 0 to 3 months timepoint, and 355 who have not yet completed the 3 to 6 months timepoint. In other words, 343 dyads of sample 2 had missing data on parenting anxiety at 0 to 3 months postnatally, and 355 dyads had missing data on parenting anxiety and infant temperament at 3 to 6 months postnatally. Section 2.4 explains how this missing data was statistically simulated and why our analyses on sample 1 were necessary to be able to continue with our analyses on sample 2.

## 2.2 Study design and procedure

Expectant or postnatal participants of the CoCoPIP study were sent a link to an online questionnaire using the survey software Qualtrics, which took approximately 30 minutes to complete. One out of every 100 participants who completed the questionnaire received a £100 gift card as an incentive for participating. Until the infant was 18 months and depending on when they first consented, participants could complete up to six follow-up questionnaires.

The time between each questionnaire was calculated based on the infant's gestation or age. The follow-up questionnaires were shortened so that they only contained relevant questions. These questions were adapted based on previous input of the participants so that they matched participants' current circumstances, such as by updating the infant's age. During each questionnaire, participants were asked for their consent. For this study, we considered the maternal mental health measures filled out by the participants prenatally, at 0 to 3 months postnatally, and 3 to 6 months postnatally (see section 2.1 for a detailed description of the used data). Additionally, participants assessed their infant's temperament development at 3 to 6 months postnatally. Participants also filled out information regarding demographics, family, and infant characteristics. For full details on the CoCoPIP study design, please refer to the protocol paper (Aydin, Weiss, et al., 2022).

## 2.3 Materials

*Pregnancy/parenting related maternal anxiety*

Pregnancy/parenting related maternal anxiety was measured by the Pregnancy/Parenting-Related Anxiety Questionnaire - Revised (PRAQ-R2; Huizink et al., 2016). Five additional questions on COVID-19 specific fears were added. All questions related to the participant's current experience of pregnancy or parenting anxiety. Total scores were calculated, with higher scores indicating higher levels of pregnancy/parenting related maternal anxiety. The parenting and pregnancy related anxiety questionnaires use slightly different score scales, as their questions are adjusted to fit either a prenatal or postnatal situation. Participants could complete the pregnancy related anxiety questionnaire after 20 weeks of pregnancy, and the parenting related anxiety questionnaire between 0 to 3, and 3 to 6 months postnatally.

*Infant temperament*

Infant temperament was measured by the Revised, Very Short Form of the Infant Behaviour Questionnaire (IBQ-R-VSF; Putnam et al., 2014). This test consists of 37 items which relate to the behaviour of the infant over the past week. The items are associated with three temperament attributes: surgency, negative affect, and orienting/regulatory capacity (i.e., effortful control). Some example items that contribute to the surgency scale are smiling and laughter, activity level, and perceptual sensitivity. The negative affect subscale consists of, among others, fear, sadness, and distress to limitations. Duration of orienting and cuddliness are two examples that contribute to the effortful control subscale. Items are scored by parents on an 8-point scale from *Never* (1) to *Always* (8), including the option *Does Not Apply* (0). Based on a standardised scoring system, several items are reverse scored. For each temperament dimension, a mean score is calculated, with higher scores indicating that the infant exhibits more of that trait. The IBQ-R-VSF was completed when the infant was 3 to 6 months of age.

*Covariates*

Data of several covariates which are expected to mediate (the relation between) pregnancy/parenting related anxiety and infant temperament were collected. These covariates included prenatal maternal characteristics (ethnicity, family income, maternal education, and maternal age), as well as infant characteristics (gestation, infant age, and infant sex). Additionally, the presence and severity of a person's trait and state anxiety was assessed by the State Trait Anxiety Index (STAI; Spielberger, 1983). All questions related to the participant's experience of anxiety at the moment of filling out the STAI, as well as in general, thereby assessing the participant's proneness to anxiety. A score of 40 or higher indicates clinically significant anxiety symptoms (Julian, 2011). The Impact of Event Scale – Revised (IES-R) was used to assess subjective anxiety caused by a specific traumatic event as experienced by the participants during the past week (Weiss, 2007). In this study, the traumatic event assessed was the onset of the COVID-19 pandemic. A score of 33 or higher indicates potential post-traumatic stress disorder (Creamer et al., 2003). STAI and IES-R data were extracted from the prenatal timepoint of the CoCoPIP study, to broaden our understanding of the pregnancy related context.

## 2.4 Analysis

Firstly, outliers for each continuous variable were defined using boxplots, which identify the participants whose scores are a Mahalanobis distance of greater than 2.5 from the sample median. If any outliers were due to incorrectly entered data, they were corrected if possible and otherwise deleted. Legitimate univariate outliers were kept in the dataset, whereas multivariate outliers were deleted. Descriptive statistics were then conducted on both sample 1 and 2 to check for normality of all measures of maternal mental health (PRAQ, STAI, and IES-R) at the three timepoints (prenatally, 0 to 3 months postnatally, and 3 to 6 months postnatally), and of the three subscales of infant temperament assessed at 3 to 6 months of age, if available. PRAQ scores were then standardised into z-scores which were used in all following analyses, as the score scales of the prenatal assessment differ from those of the postnatal assessments due to adjusted questions. It is important to note that the standardised PRAQ scores thus reflect sample-specific effects, but the hypothesised associations are still expected to be of comparable magnitude as seen in other studies discussed in section 1. Descriptive statistics included the mean, median, standard deviation, skewness, kurtosis, and Shapiro-Wilk tests. Normality was assumed when the skewness and kurtosis values were less than 2.5. Additionally, Shapiro-Wilk tests were conducted to check for normality as well. If the *p* value was below .05, we assumed that the data was not normally distributed. Furthermore, frequency tables of the nominal and ordinal contextual factors (ethnicity, family income, maternal education, gestation, and infant sex) were generated. The mean and standard deviation of the continuous contextual factors (maternal and infant age) were also determined.

To investigate preliminary longitudinal relationships between pregnancy/parenting anxiety and the three infant temperament subscales, Pearson's correlations were conducted on the PRAQ z-scores at all three timepoints and the three subscales of infant temperament at 3 to 6 months, corrected for multiple comparisons. Sample 1 ($n$ = 61) was used for all Pearson's correlations as well as for all following linear regressions, as this sample was selected on complete PRAQ data of any of the three timepoints and IBQ-R-VSF scores. Subsequently, six linear regressions were conducted to determine the impact of pregnancy/parenting anxiety on the three infant temperament subscales. The first three linear regressions were run using each subscale of infant temperament at 3 to 6 months as dependent variables. Prenatal maternal mental health as measured by the PRAQ z-scores at all three timepoints (prenatal, 0 to 3, and 3 to 6 months) were included as independent variables. Then, three additional linear regressions were conducted to investigate the impact of change in postnatal maternal anxiety over the course of the COVID-19 pandemic (rather than the individual postnatal PRAQ timepoints), again using each subscale of infant temperament at 3 to 6 months as dependent variables. Prenatal PRAQ z-scores and change in postnatal PRAQ z-scores (defined as PRAQ z-scores at 3 to 6 months – PRAQ z-scores at 0 to 3 months) were included as independent variables. All regressions were corrected for multiple comparisons.

Finally, if the previous correlations and regressions revealed potential longitudinal effects between pregnancy/parenting anxiety and any of the three temperament scales, we were able to run six models using SEM to answer our two research questions as previously specified. As sample 1 was not sufficiently large for SEM (Wolf et al., 2013), we used sample 2 *(n* = 380), which included mother-infant dyads who had complete prenatal PRAQ scores and data on at least one potential mediator, namely ethnicity (see section 2.1). As specified in section 2.1, sample 2 contained missing data of PRAQ scores at 0 to 3 and 3 to 6 months postnatally, as well as of IBQ-R-VSF data at 3 to 6 months. SEM handles missing data using full information maximum likelihood, so the missing PRAQ and IBQ-R-VSF scores were simulated based on statistically valid patterns. Our first SEM model was longitudinal, including the three subscales of infant temperament assessed at 3 to 6 months, prenatal PRAQ z-scores, and PRAQ z-scores at 0 to 3, and 3 to 6 months postnatally. The second model focused on PRAQ z-scores at all three timepoints and contextual mediators (prenatal maternal characteristics: ethnicity, family income, maternal education, maternal age, prenatal STAI and IES-R scores). The third model included contextual mediators (infant characteristics: gestation, infant age, and infant sex) and the three subscales of infant temperament at 3 to 6 months. The fourth, fifth, and sixth models included PRAQ z-scores at all three timepoints, significant contextual factors found in the second and third models, and one of the three IBQ-R-VSF subscales for each model. Each of these final three models had only one IBQ-R-VSF subscale instead of including all three temperament subscales in one large model, as the latter would have made the model overidentified and it would have specified no valid fit criteria. Thus, having three separate models for each IBQ-R-VSF subscale was the most appropriate approach. All analyses were conducted using JASP Team (2022).

## 3. Results

### 3.1 Descriptive results

Table 1 contains characteristics of the mother-infant dyads of both sample 1 *(n* = 61) and sample 2 *(n* = 380), including ethnicity, family income, maternal education, gestation, and infant sex. Since sample 2 mostly consisted of mother-infant dyads without complete follow-up *(*see section 2.1 for specifics on missing data and overlap in samples)*,* Table 1 only includes variables which were collected prenatally. Mothers in sample 1 were on average 32.8 years of age at the prenatal assessment (*SD* = 5.0), and 32.1 years of age in sample 2 (*SD* = 4.5). Infants in sample 1 were on average 4.5 months of age at the IBQ-R-VSF assessment (*SD* = 1.3). As 355 mother-infant dyads in sample 2 have not yet completed the 3 to 6 months data collection timepoint, data on infant age was not available for this sample. Additionally,

Table 2 and Figure 1 show the descriptive data of the three IBQ-R-VSF subscales at 3 to 6 months of sample 1, and they reveal that all subscales had a similar mean score. The Shapiro-Wilk test was significant for effortful control *($p$ = .024)*, indicating that this scale was not normally distributed. To normalise this data, a log, log10, and square root transformations were attempted, but as the *p* value further decreased *($p$* = <.001, <.001, and .005, respectively), the original effortful control scores were used in all subsequent analyses, noting that it was not normally distributed.

Subsequently, Table 3 and Figure 2 show the descriptive results of the PRAQ scores at all three timepoints of sample 1 and 2. For sample 2, only prenatal PRAQ scores were included, as most mother-infant dyads have not yet participated in any follow-up *(*see section 2.1 for specifics). Sample 1 and 2 had a similar prenatal PRAQ mean score. Table 3 also reveals that the mean scores of the PRAQ 0 to 3, and PRAQ 3 to 6 months of sample 1 were similar. Additionally, Table 4 and Figure 3 present the descriptive results of the prenatal STAI and IES-R scores of sample 2. These results are only reported for sample 2, as all participants of sample 1 did neither complete the STAI, nor the IES-R. Figure 3 reveals that most participants scored below the clinical cut-off point of the IES-R, in contrast to the STAI, of which the scores were more evenly distributed around the clinical cut-off point. The prenatal IES-R, STAI, and PRAQ scores of sample 2 all had a significant Shapiro-Wilk test. The prenatal STAI scores were normalised using a square root transformation, after which the Shapiro-Wilk test was not significant anymore ($p$ = .194). As the prenatal PRAQ scores were already planned to be transformed into z-scores to ensure the data of all PRAQ timepoints were comparable, no additional transformations were performed. The IES-R scores could not be normalised using log, log10, or square root transformations, so the original IES-R scores were used in all subsequent analyses.

**3.2 Preliminary correlations and linear regressions (Sample 1)**

Using sample 1, Pearson's correlations were conducted to assess the relationship between PRAQ z-scores at all three timepoints and the three subscales of the IBQ-R-VSF at 3 to 6 months. A marginally significant negative correlation was found between prenatal PRAQ z-scores and effortful control scores at 3 to 6 months of age ($r(23)$ = -.39, $p$ = .051). Additionally, a marginally significant positive correlation was found between PRAQ z-scores assessed at 0 to 3 months and negative affect scores at 3 to 6 months of age ($r(46)$ = .28, $p$ = .055). All other correlations were not (marginally) significant.

Subsequently, three linear regressions including PRAQ z-scores at all three timepoints and the three subscales of the IBQ-R-VSF measured at 3 to 6 months were conducted. Only PRAQ z-scores assessed at 0 to 3 months postnatally were marginally significantly associated with negative affect at 3 to 6 months *(B* = 1.39, *t*(9) = 2.25, *p* = .051 [95% *CI*, -.01 to 2.79]*)*. Three additional linear regressions included prenatal PRAQ z-scores and change in postnatal PRAQ z-scores (defined as PRAQ z-scores at 3 to 6 months – PRAQ z-scores at 0 to 3 months), and the three IBQ-R-VSF subscales assessed at 3 to 6 months. Change in postnatal PRAQ z-scores was marginally significantly correlated with negative affect at 3 to 6 months (*B* = -1.07, *t*(10) = -2.15, *p* = .057 [95% *CI*, -2.18 to .04]). It should be noted that in total, 13 participants were included in these preliminary analyses on negative affect, and 14 on surgency and effortful control, as they were the only participants of sample 1 with data on all three PRAQ timepoints and on infant temperament at 3 to 6 months postnatally (see section 2.1 for more information on missing data). While the sample sizes of these analyses were thus very small and the results should be treated with caution, the marginally significant effects found in this smaller sample allowed us to continue to explore potential longitudinal associations in our larger sample 2 using SEM.

**3.3 SEM (Sample 2)**

The first longitudinal model using SEM on sample 2 (*n* = 380) assessed PRAQ z-scores at all three timepoints and the three IBQ-R-VSF subscales. There were no significant direct effects of prenatal PRAQ z-scores on the three IBQ-R-VSF subscales at 3 to 6 months, as can be seen in Table 5. A marginally significant indirect effect was found for prenatal PRAQ z-scores on effortful control, mediated by PRAQ z-scores at 0 to 3 months postnatally (Table 5). Specifically, prenatal PRAQ z-scores were marginally positively related to PRAQ z-scores at 0 to 3 months (*B* = .67), which were, in turn, marginally negatively correlated with effortful control at 3 to 6 months (*B* = -.35).

The second model focused on PRAQ z-scores at all three timepoints and prenatal maternal characteristics, including ethnicity, family income, maternal education, maternal age, prenatal STAI and IES-R scores. As can be seen in Table 6, results indicated a significant direct effect of family income on PRAQ z-scores at 0 to 3 months. There was also a significant direct effect of maternal education on PRAQ z-scores at 0 to 3 months. Furthermore, a significant direct effect was found for prenatal STAI scores on PRAQ z-scores at 0 to 3 months. There was also a significant indirect effect of prenatal STAI scores on PRAQ z-scores at 3 to 6 months through prenatal PRAQ z-scores. Specifically, prenatal STAI scores were positively related to prenatal PRAQ z-scores ($B$ = .52), which were, in turn, positively associated with PRAQ z-scores at 3 to 6 months ($B$ = .84). Additionally, an indirect effect was found between prenatal STAI scores and PRAQ z-scores at 0 to 3 months, mediated by prenatal PRAQ scores. Prenatal STAI scores were positively related to prenatal PRAQ z-scores ($B$ = .52), which were, in turn, positively correlated with PRAQ z-scores at 0 to 3 months ($B$ = .54). There were no significant effects found for ethnicity, maternal age, and IES-R scores.

The third model investigated infant characteristics (gestation, infant age, and infant sex) and the three subscales of infant temperament at 3 to 6 months (Table 7). Only longer infant gestation was directly related to higher negative affect. There were no significant direct effects for infant age and sex.

The fourth, fifth, and sixth models included the contextual variables that were found to be significant in the previous analyses (family income, maternal education, prenatal STAI scores, and infant gestation), PRAQ z-scores at all three timepoints, and one of the three IBQ-R-VSF subscales. The fourth model (Table 8 & Figure 4) showed that PRAQ z-scores at 0 to 3 months significantly mediated the relationship between prenatal PRAQ z-scores and surgency at 3 to 6 months. Specifically, prenatal PRAQ z-scores were positively associated with PRAQ z-scores at 0 to 3 months ($B$ = 1.0), which were, in turn, negatively correlated with surgency at 3 to 6 months ($B$ = -1.0). There was still, however, a direct effect of prenatal PRAQ z-scores on surgency at 3 to 6 months. Furthermore, there was an indirect effect of infant gestation on surgency at 3 to 6 months, mediated by PRAQ z-scores at 0 to 3 months. Infant gestation was negatively related to PRAQ z-scores at 0 to 3 months ($B$ = -.44), which were, in turn, negatively associated with surgency at 3 to 6 months ($B$ = -1.0). Nevertheless, there was still a direct effect of infant gestation on surgency at 3 to 6 months. Additionally, PRAQ z-scores at 0 to 3 months significantly mediated the relationship between prenatal STAI scores and surgency at 3 to 6 months. Specifically, prenatal STAI scores were positively related to PRAQ z-scores at 0 to 3 months ($B$ = .93), which were, in turn, negatively associated with surgency at 3 to 6 months ($B$ = -1.0). Lastly, PRAQ z-scores at 0 to 3 months significantly mediated the relationship between maternal education and surgency at 3 to 6 months. Maternal education was positively correlated with PRAQ z-scores at 0 to 3 months ($B$ = .34), which were, in turn, negatively associated with surgency at 3 to 6 months

(*B* = -1.0). There were no significant (mediating) effects found for family income and PRAQ z-scores at 3 to 6 months.

The fifth model (Table 9 & Figure 5) showed a significant indirect effect of prenatal PRAQ z-scores on negative affect at 3 to 6 months, mediated by PRAQ z-scores at 3 to 6 months. Prenatal PRAQ z-scores were positively related to PRAQ z-scores at 3 to 6 months (*B* = .85), which were, in turn, positively associated with negative affect at 3 to 6 months (*B* = 1.0). There were no significant effects found for maternal education, family income, prenatal STAI scores, and infant gestation.

The final model (Table 10 & Figure 6) which focused on effortful control at 3 to 6 months, did not reveal any significant direct or indirect effects of maternal education, prenatal STAI scores, family income, infant gestation, and any PRAQ z-scores.

## 4. Discussion

This study investigated the relationship between maternal mental health during the COVID-19 pandemic and subsequent infant temperament at 3 to 6 months of age. It also aimed to study the potential mediating effects of several contextual variables on maternal mental health and infant temperament. Overall, the results suggested that pregnancy and parenting related anxiety are related to surgency and negative affect at 3 to 6 months in a sample of 380 mother-infant dyads from the UK, but not to effortful control, when controlling for contextual variables. Additionally, infant gestation, prenatal state trait anxiety scores, family income, and maternal education also played a significant role in mediating (the relationship between) maternal mental health and infant temperament.

The results of this study showed that in a sample of 380 mother-infant dyads, an increase in pregnancy anxiety as measured by the PRAQ was related to an increase in parenting anxiety at 3 to 6 months. This was, in turn, associated with increased negative affect at 3 to 6 months, when controlling for contextual variables. This partially confirms our hypothesis, as high levels of maternal anxiety over the course of the pandemic were expected to be related to increased negative affect. Similar results were found linking infant negative affect to prenatal maternal anxiety prior to the pandemic. For instance, Henrichs et al. (2009) found that higher maternal pregnancy anxiety was related to increased negative affect in infants aged 6 months. Increased prenatal maternal distress and depression, both closely related to prenatal maternal anxiety, have also been shown to be linked to higher infant negative affect at 6 months postnatally (Buthmann et al., 2019). Similarly, Laplante et al. (2016) found that prenatal maternal distress was positively correlated with fussiness in infants aged 6 months, and Nomura et al. (2019) showed that prenatal maternal depression was linked with increased infant sadness and distress at 6 months. Moreover, Fiske et al. (2022) found that increased prenatal maternal depressive symptoms were associated with increased negative affect in 10-month-old infants. However, these depressive symptoms were not specifically linked to the pandemic, while the PRAQ (pregnancy or parenting anxiety) in our study also considered COVID-19 specific fears. Thus, our results not only strengthen existing findings on the association between maternal mental health and negative affect in infants, but they also suggest an important role of COVID-19 specific pregnancy/parenting anxiety in early infant temperament development. Moreover, the fact that the prenatal STAI scores were not related to infant negative affect potentially indicates that even in mothers not prone to anxiety in general, the specific experience of being pregnant during the COVID-19 pandemic may have been related to their infant's negative affect, further underlining the significant role of COVID-19 specific pregnancy/parenting anxiety.

Furthermore, higher pregnancy anxiety was related to higher parenting anxiety at 0 to 3 months, which was, in turn, associated with lower surgency at 3 to 6 months. This is in line with our hypothesis that increased anxiety would be related to decreased surgency. However, increased pregnancy anxiety was also directly linked to increased surgency, which seems to contradict both our hypothesis and initial findings. Previous studies on maternal mental health and infant surgency outcomes have also found inconsistent results. Considering maternal stress (closely related to maternal anxiety), Laplante et al. (2016) found no effects of prenatal maternal stress as caused by a natural disaster on infant surgency at 6 months of age. Similarly, Buthmann et al. (2019) did not find any relationship between prenatal and postnatal maternal stress as caused by a natural disaster on surgency at 6 months postnatally in a sample of 380 mother-infant dyads. However, Zhang et al. (2018) found that increased prenatal maternal stress as caused by a natural disaster was linked to parental reports of infants showing increased pleasure seeking, perceptual sensitivity, and approach (all part of the IBQ surgency subscale). Considering prenatal maternal anxiety, similar results were found by Henrichs et al. (2009), as increased pregnancy anxiety was related to increased infant activity levels, another item of the IBQ-R-VSF surgency subscale. Focusing more on maternal depression, Fiske et al. (2022) did not find any association between maternal depressive symptoms and later infant surgency levels over the course of the COVID-19 pandemic. In contrast, Nomura et al. (2019) showed that parents reporting prenatal maternal depression also reported perceiving their infants to have lower levels of smiling and to seek less pleasure compared to infants whose parents did not report prenatal maternal depressive symptoms.

The fact that these studies show differential relationships (positive, negative, or none) between maternal mental health and aspects of surgency may explain the seemingly contradictory results of the current study. High surgency levels, which are associated with an infant who is socially receptive but also seeks attention, activity, and interaction, may not always point towards a calm infant temperament, as it may depend on the individual surgency item scores. However, as the current study only considered the three IBQ-R-VSF subscales to assess infant temperament instead of the individual items, it is difficult to identify why the pattern emerged differentially in the direct versus indirect effect of prenatal anxiety and surgency. That said, once controlled for longitudinal changes in maternal pregnancy/parenting anxiety, however, we observed the effect we expected. Taking together the direct and indirect effect, it can potentially be extrapolated that parents who reported high pregnancy anxiety, but not on-going parenting anxiety, may have been more anxious about birth, but once postnatal, easily identify or anticipate social behaviour within interactions with their infants. Future analyses may therefore be conducted to include the individual temperamental items that make up the surgency subscale to be able to draw more precise conclusions, as well as to examine subsamples through moderation (e.g., comparing mothers high in pregnancy but not parenting anxiety to mothers with consistent high pregnancy and parenting anxiety).

Additionally, surgency was either directly or indirectly affected by prenatal STAI scores, infant gestation, and maternal education. When controlling for contextual variables, prenatal STAI scores were related to increased parenting anxiety at 0 to 3 months, which was, in turn, associated with lower surgency at 3 to 6 months. This is in line with findings that general anxiety scores as measured by the STAI are positively related to maternal parenting anxiety (Skreden et al., 2012; Vismara et al., 2016). Furthermore, shorter gestation was related to higher parenting anxiety at 0 to 3 months, which was, in turn, related to lower surgency, when controlling for contextual variables. This finding is supported by several studies which have evidenced that parents of preterm babies often experience more anxiety due to a stressful pregnancy and/or neonatal period (e.g., Miles et al., 2007; Singer et al., 1999). Moreover, shorter infant gestation was also directly linked to higher surgency when controlling for contextual factors. As preterm infants have been shown to develop less socially attentive behaviour later in life (Spittle et al., 2009), higher surgency levels may not have been as favourable as initially hypothesised. Shorter gestation may have been correlated with, for instance, higher levels of perceptual sensitivity and approach (Zhang et al., 2018). As discussed previously, this remains speculation since this study did not consider the individual temperamental items that the surgency scale consists of. Lastly, higher educated mothers had, on average, higher parenting anxiety levels at 0 to 3 months when controlling for contextual variables, which were, in turn, related to lower infant surgency at 3 to 6 months. However, we instead expected that lower maternal education would be related to lower surgency scores, as Jansen et al. (2009), for instance, found that families with a lower socioeconomic status, as measured by several variables including maternal education, experienced more stress, which negatively affected infant temperament at 6 months old. It must be noted though, that it is difficult to compare our results to those of Jansen et al. (2009) since they focused on maternal stress and overall psychopathology, while our study considered maternal anxiety. Moreover, Jansen et al. (2009) measured socioeconomic status using several variables (maternal and paternal education, family income, and maternal occupational status), while our study defined socioeconomic status as maternal education and family income only. Furthermore, another key difference between our study and that of Jansen et al. (2009) is the presence of the COVID-19 pandemic, which may have made buffers that are usually protective such as a high socioeconomic status, non-protective instead, due to the impact of, and changes related to, the pandemic. Another possibility could be that highly educated mothers compared to lower educated mothers may have been more conscious of the risks of COVID-19, for example due to more exposure to news sources (Effati-Daryani et al., 2020). This may have increased their anxiety, thereby negatively affecting their infant's surgency levels. Thus, not only does the fact that studies measure socioeconomic status often in different ways complicate comparison of results, the COVID-19 pandemic may have also impacted and changed the relationships between maternal education, maternal anxiety, and infant temperament commonly seen in studies from prior to the pandemic.

Moreover, effortful control could not be predicted based on any of the PRAQ measures, even when controlling for contextual variables. This contradicts our hypothesis, as we anticipated increased pregnancy/parenting anxiety to be related to lower effortful control. For instance, Fiske et al. (2022) found an association between maternal depressive symptoms and lower effortful control in a sample of infants between 6 and 48 months of age. Similar results were found by Nomura et al. (2019), who showed that prenatal maternal depression was related to lower soothability and cuddliness, two aspects of effortful control, in 6-month-old infants. The results of these studies could differ from ours as they considered maternal depression, while our study considered maternal anxiety. Studies on maternal anxiety and infant effortful control are limited, but Coplan et al. (2005) found that maternal trait anxiety was related to lower soothability in infants aged 3 months. Furthermore, studies on the relationship between maternal stress and effortful control have found inconsistent results. For instance, Laplante et al. (2016) showed that prenatal subjective distress was related to an increased need for attention in infants aged 6 months, while Simcock et al. (2017) did not find any associations between prenatal maternal stress and measures of effortful control at 6 months of age in a sample of 121 infants. Moreover, Provenzi et al. (2021) showed that prenatal maternal stress during the COVID-19 pandemic was related to lower effortful control in 3-month-old infants. Overall, these contrasting results could potentially be explained by the use of different infant temperament and maternal mental health assessment tools, as well as by the inclusion of different confounding variables, which complicates comparison of results. Therefore, future research may want to focus on replicating existing studies on maternal mental health and infant temperament, as this may generate more robust results (Thomason, 2022).

As previously discussed, our hypothesis that a lower socioeconomic status would be related to less favourable infant temperament at 3 to 6 months has been partially rejected, as high maternal education was indirectly linked to lower surgency. Moreover, since family income was not a significant factor in any of the models including infant temperament, combined with the fact that similar results were found for maternal education and negative affect, as well as effortful control, we can fully reject our second hypothesis. While a higher family income was related to lower parenting anxiety at 0 to 3 months, it was not indirectly related to any temperament subscales. While these results do not match those of Jansen et al. (2009) and Buthmann and Gotlib (2021, preprint), they are in line with those from Austin et al. (2005), who also found no effects of family income and education on infant temperament in a sample of 970 infants aged 4 and 6 months. However, it could be possible that we would see similar results as the studies of Jansen et al. (2009) and Buthmann and Gotlib (2021, preprint), if socioeconomic status would have been defined differently or more extensively. For instance, future work within the CoCoPIP project may want to include multiple deprivation indices of family address, maternal occupational status, or even paternal education. Moreover, as many families have had to deal with financial struggles during the COVID-19 pandemic (Thayer & Gildner, 2020), future studies may want to consider including change in financial situation over the course of the pandemic, as this may be associated with maternal anxiety levels, and as a result with infant temperament as well.

Additionally, we expected an important role of infant sex on temperament. Specifically, girls were expected to be more vulnerable to the deleterious effects of maternal anxiety on early temperament. However, as infant sex was not a significant variable in any of the analyses, this hypothesis is rejected. Studies on the association between maternal mental health and infant temperament which also considered the role of infant sex have found inconsistent results. For instance, Simcock et al. (2017) found that boys whose mothers experienced relatively high levels of prenatal stress were more often rated as irritable than girls at 6 months of age, while a review by Sutherland and Brunwasser (2018) indicated that multiple studies showed correlations between prenatal maternal stress and increased negative affect in girls only. More in line with our results are the findings by Austin et al. (2005), who also found no significant role of infant sex when investigating the relationship between maternal trait anxiety, life event stress, and depression, and infant temperament. These different results regarding infant sex could potentially be explained by the inclusion of different confounders in each study, as well as by the different measures of infant temperament and maternal mental health.

Strengths of this study include the inclusion of several contextual variables. As more confounding variables may have been present, future studies might want to include other potential confounding variables as well. An example of such a variable could be a measure of maternal depression, since several studies have found associations between maternal depressive symptoms and infant temperament (e.g., Fiske et al., 2022; Nomura et al., 2019; Tees et al., 2010). Another strength of this study is the focus on maternal anxiety instead of maternal stress or depressive symptoms, as most studies to date on maternal mental health and infant temperament in the context of the COVID-19 pandemic have considered the latter. Moreover, the assessment of infant temperament as early as 3 months of age is also a strength of this study. As more data from later timepoints within the CoCoPIP project comes in, future studies using CoCoPIP data may want to include later infant temperament data as well, as studies have shown differential relationships between maternal mental health and the development of infant temperament over a longer period (Fiske et al., 2022). Additionally, while we used a large, nationwide sample, most mothers were highly educated and white, which could have created a bias in the results, and it limits the generalisability of our results. Another limitation is the use of maternal report for all variables, including infant temperament. Not only could maternal mood have affected the mothers' assessments of their infant's temperament (Najman et al., 2000), the COVID-19 pandemic and related restrictions, such as working from home and phases of lockdown, may have caused parents to worry more about and fixate more on their infant's behavioural and emotional development, especially considering their infants experienced limited social contact due to these same restrictions. This may have, in turn, affected how mothers in this study perceived and reported on their infant's temperament development, which could be an interesting avenue for future research. Therefore, the results of this study could have been strengthened by including a more objective measure of infant temperament. Due to the societal restrictions related to the COVID-19 pandemic, however, this would have been extremely challenging to achieve at the time of data collection. Lastly, as most mothers in this study have not yet completed all data collection timepoints (prenatally, 0 to 3, and 3 to 6 months postnatally), both sample 1 and sample 2 had a great deal of missing data (see section 2.1 for specific numbers of missing data). While our statistical method (SEM) generally handles missing data well, our sample size could still have been too low to provide valid results due to issues with error and bias (Wolf et al., 2013). Besides the fact that data collection is still ongoing within the CoCoPIP project, the missing data was also a result of some participants completing only one data collection timepoint, which complicates longitudinal analyses. To motivate participants to contribute to multiple data collection timepoints, future studies working with longitudinal data collection via an online survey may want to include more incentives for participants who complete more than one data collection timepoint.

## 5. Conclusion

In a large cohort of 380 mother-infant dyads from across the UK, pregnancy and parenting anxiety during the COVID-19 pandemic were associated with less favourable infant surgency and negative affect at 3 to 6 months postnatally, when controlling for contextual variables. Effortful control, however, did not seem to be related to maternal mental health over the course of the pandemic. Additionally, infant gestation, general maternal anxiety levels, and maternal education were related to surgency at 3 to 6 months, often mediated by parenting related anxiety scores. While family income was related to parenting related anxiety, it was not correlated with infant temperament. Together, this study adds to the growing body of research on the relationship between maternal mental health and infant temperament during the COVID-19 pandemic. The results underline the importance of paying attention to the mental health of expectant and new mothers during the COVID-19 situation and potential future pandemics, as it may be related to their infant's temperament development in their first months of life.

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**Table 1**

*Mother-Infant Dyad Characteristics of Sample 1 and 2*

| | Sample 1 (*n* = 61) | Sample 2 (*n* = 380) |
|---|---|---|
| Characteristic | *n* (%) | *n* (%) |
| Ethnicity | | |
| White | 55 (90.2%)[a] | 339 (89.2%) |
| Black | - | 7 (1.8%) |
| Asian | 2 (3.3%) | 13 (3.4%) |
| Multiracial | 2 (3.3%) | 16 (4.2%) |
| Hispanic | - | 1 (0.3%) |
| Other | - | 4 (1.1%) |
| Family income (annually) | | |
| 5,001 – 10,000 | - | 3 (0.8%) |
| 10,000 – 20,000 | 6 (9.8%) | 8 (2.1%) |
| 20,001 – 30,000 | 2 (3.3%) | 14 (3.7%) |
| 30,001 – 50,000 | 19 (31.1%) | 72 (18.9%) |
| 50,001 – 75,000 | 10 (16.4%) | 86 (22.6%) |
| 75,001 – 100,000 | 12 (19.7%) | 88 (23.2%) |
| 100,001 – 150,000 | 5 (8.2%) | 61 (16.1%) |
| 150,001 – 200,000 | 2 (3.3%) | 17 (4.5%) |
| 200,001 – 250,000 | - | 2 (0.5%) |
| > 250,000 | - | 2 (0.5%) |
| Maternal education | | |
| Some high school to age 16 | 1 (1.6%)[b] | 9 (2.4%)[c] |
| High school degree / college level education to age 18 | 16 (26.2%) | 42 (11.1%) |
| Associate degree, technical certificate and/or some university courses | - | 22 (5.8%) |
| Undergraduate degree | 19 (31.1%) | 150 (39.5%) |
| Postgraduate degree (Master's, PhD) | 25 (41.0%) | 154 (40.5%) |
| Infant gestation | | - |
| Later preterm | 2 (3.3%) | |
| Early term | 15 (24.6%) | |
| Full term | 41 (67.2%) | |
| Post term | 3 (4.9%) | |
| Infant sex | | - |
| Female | 28 (45.9%) | |
| Male | 33 (54.1%) | |

*Note.* Infant gestation and infant sex are missing for sample 2 as most participants have not yet contributed postnatal data (343 for the 0 to 3 months timepoint, and 355 for the 3 to 6 months timepoint). 25 participants of sample 1 were also included in sample 2.

[a] 2 were missing

[b] 5 were missing

[c] 3 were missing

**Table 2**

*Descriptive Data of the IBQ-R-VSF Subscales at 3 to 6 Months of Sample 1 (n = 61)*

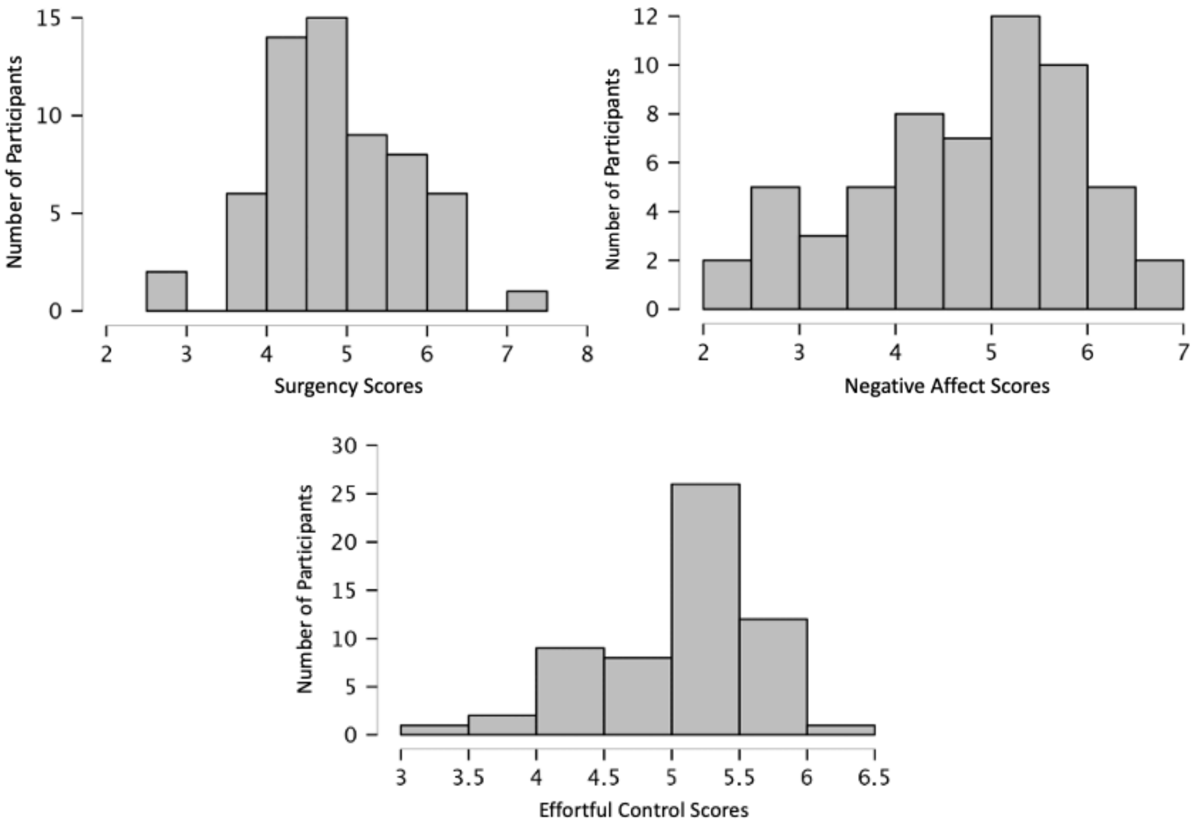
| | Surgency | Negative affect[a] | Effortful control[a] |
|---|---|---|---|
| *M* | 4.9 | 4.8 | 5.1 |
| *Mdn* | 4.8 | 5.0 | 5.2 |
| *SD* | 0.9 | 1.1 | 0.6 |
| Skewness | .03 | -.39 | -.74 |
| Kurtosis | .28 | -.63 | .54 |
| Shapiro-Wilk *p* value | .564 | .091 | **.024** |

*Note.* Significant results in **bold** ($p < .05$). IBQ-R-VSF scores are not reported for sample 2 ($n$ = 380) as 355 participants have not yet completed the 3-6 months timepoint.

[a] 2 were missing

**Figure 1**

*Distributions of the IBQ-R-VSF Subscales at 3 to 6 Months of Sample 1 (n = 61)*




*Note.* 2 were missing for negative affect and effortful scores. IBQ-R-VSF scores are not reported for sample 2 ($n$ = 380) as 355 participants have not yet completed the 3-6 months timepoint.

**Table 3**

*PRAQ Descriptive Data of Sample 1 and 2*

| | Sample 1 ($n$ = 61) | | | Sample 2 ($n$ = 380) |
|---|---|---|---|---|
| | Prenatal PRAQ[a] | PRAQ 0-3[b] | PRAQ 3-6 | Prenatal PRAQ |
| *M* | 40.1 | 29.6 | 30.9 | 42.3 |
| *Mdn* | 37.0 | 29.5 | 29.0 | 41.0 |
| *SD* | 18.3 | 8.4 | 8.7 | 17.3 |
| Skewness | .60 | .14 | .39 | .63 |
| Kurtosis | -.27 | -.67 | -.36 | .27 |
| Shapiro-Wilk *p* value | .175 | .373 | .091 | **<.001** |

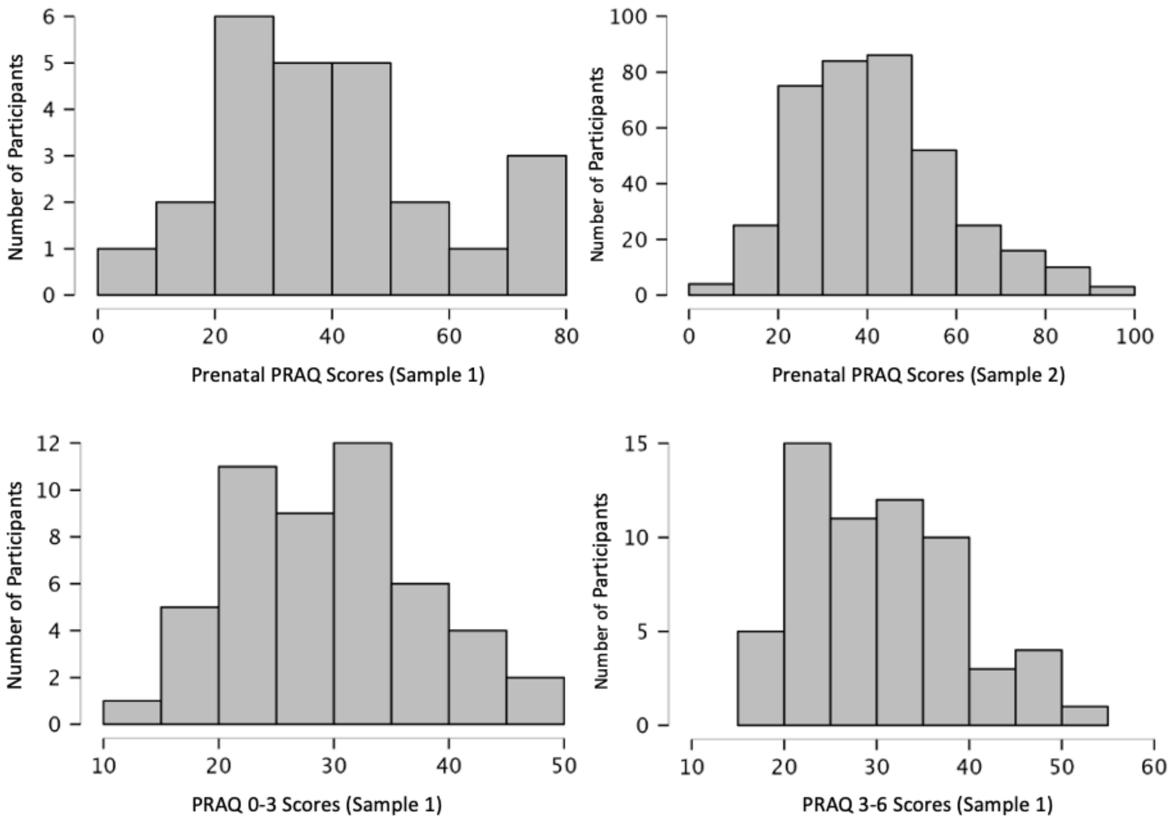
*Note.* Significant results in **bold** ($p$ <.05). PRAQ 0-3 and PRAQ 3-6 are not reported for sample 2 as 343 participants have not yet completed the 0-3 months timepoint, and 355 have not yet completed the 3-6 months timepoint.

[a] 36 were missing

[b] 11 were missing

**Figure 2**

*Distributions of the PRAQ at All Timepoints of Sample 1 (n = 61) and Sample 2 (n = 380)*




*Note.* Of sample 1, 36 were missing for the prenatal PRAQ, and 11 for PRAQ 0-3. PRAQ 0-3 and PRAQ 3-6 are not reported for sample 2 as 343 participants have not yet completed the 0-3 months timepoint, and 355 have not yet completed the 3-6 months timepoint.

**Table 4**

*Prenatal STAI and IES-R Scores of Sample 2 (n = 380)*

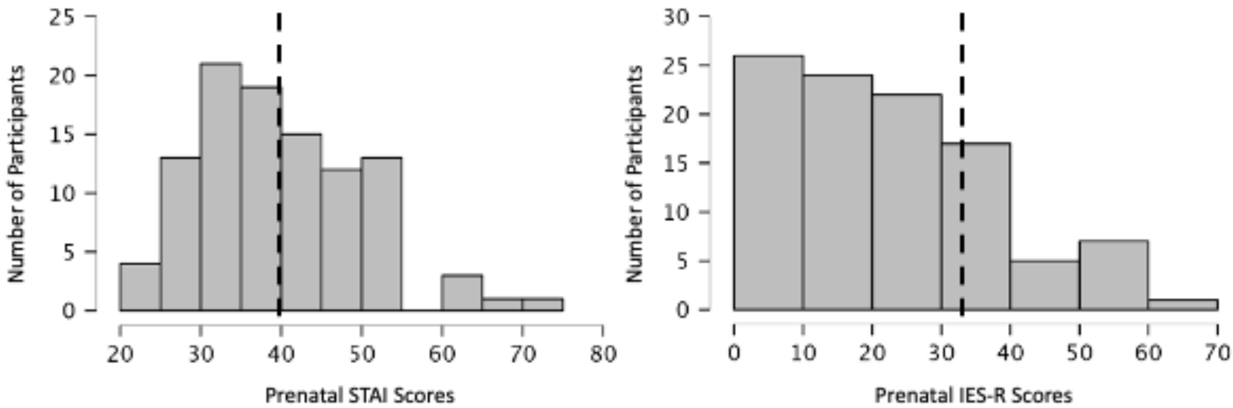
| | Prenatal STAI[a] | Prenatal IES-R[a] |
|---|---|---|
| *M* | 40.3 | 22.4 |
| *Mdn* | 39.0 | 21.5 |
| *SD* | 10.1 | 16.1 |
| Skewness | 0.71 | 0.60 |
| Kurtosis | 0.40 | -.05 |
| Shapiro-Wilk *p* value | **.005** | **.001** |

*Note.* Significant results in **bold** (*p* <.05). STAI and IES-R scores are not reported for sample 1 as they were not completed.

[a] 278 were missing as they were not completed.

**Figure 3**

*Distributions of the Prenatal STAI and IES-R Scores of Sample 2 (n = 380)*




*Note.* 278 were missing for both the STAI and IES-R scores as they were not completed. Dashed lines indicate clinical cut-off scores. STAI and IES-R scores are not reported for sample 1 as they were not completed.

**Table 5**

*Direct and Indirect Effects of the Prenatal PRAQ on the IBQ-R-VSF Subscales at 3-6 Months (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Direct effects | *B* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → Surgency | -.02 | .27 | -.06 | .954 | -.54 | .51 |
| Prenatal PRAQ → Negative affect | -.13 | .32 | -.41 | .681 | -.76 | .49 |
| Prenatal PRAQ → Effortful control | -.16 | .17 | -.97 | .333 | -.49 | .17 |
| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → PRAQ 0-3 → Surgency | -.35 | .21 | -1.69 | .092 | -.76 | .06 |
| Prenatal PRAQ → PRAQ 3-6 → Surgency | .20 | .15 | 1.36 | .172 | -.09 | .49 |
| Prenatal PRAQ → PRAQ 0-3 → Negative affect | .20 | .23 | .86 | .391 | -.26 | .66 |
| Prenatal PRAQ → PRAQ 3-6 → Negative affect | -.03 | .20 | -.13 | .895 | -.42 | .36 |
| *Prenatal PRAQ → PRAQ 0-3 → Effortful control* | *-.24* | *.12* | *-1.92* | *.055* | *-.48* | *.01* |
| Prenatal PRAQ → PRAQ 3-6 → Effortful control | .19 | .10 | 1.87 | .061 | -.01 | .40 |

*Note.* Marginally significant results in *italics* ($p$ <.05). This Table relates to SEM model 1. For the indirect effects, the *ab* values are the products of the *B* values of paths a (prenatal PRAQ to PRAQ 0-3 or 3-6) and b (PRAQ 0-3 or 3-6 to surgency, negative affect, or effortful control).

**Table 6**

*Direct and Indirect Effects of Prenatal Maternal Characteristics on the PRAQ at All Timepoints (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Direct effects | *B* | Std. Error | z-value | *p* | Lower | Upper |
| Ethnicity → PRAQ 0-3 | .02 | .28 | .07 | .945 | -.52 | .56 |
| **Family income → PRAQ 0-3** | **-.25** | **.12** | **-2.14** | **.032** | **-.47** | **-.02** |
| Maternal age → PRAQ 0-3 | -.01 | .01 | -.97 | .330 | -.04 | .01 |
| **Maternal education → PRAQ 0-3** | **.35** | **.18** | **1.98** | **.047** | **.004** | **.69** |
| Prenatal IES-R → PRAQ 0-3 | -.01 | .01 | -.70 | .485 | -.04 | .02 |
| **Prenatal STAI → PRAQ 0-3** | **1.28** | **.29** | **4.37** | **<.001** | **.71** | **1.86** |
| Ethnicity → PRAQ 3-6 | -.01 | .32 | -.02 | .983 | -.64 | .63 |
| Family income → PRAQ 3-6 | -.02 | .13 | -.16 | .875 | -.27 | .23 |
| Maternal age → PRAQ 3-6 | -.01 | .02 | -.88 | .378 | -.05 | .02 |
| Maternal education → PRAQ 3-6 | .18 | .14 | 1.26 | .207 | -.10 | .46 |
| Prenatal IES-R → PRAQ 3-6 | .01 | .01 | .46 | .644 | -.02 | .03 |
| Prenatal STAI → PRAQ 3-6 | .31 | .30 | 1.04 | .300 | -.27 | .88 |
| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
| Ethnicity → Prenatal PRAQ → PRAQ 0-3 | -.03 | .04 | -.76 | .448 | -.12 | .05 |
| Family income → Prenatal PRAQ → PRAQ 0-3 | -.02 | .03 | -.50 | .619 | -.08 | .05 |
| Maternal age → Prenatal PRAQ → PRAQ 0-3 | -0.001 | .01 | -.10 | .917 | -.02 | .02 |

| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
|---|---|---|---|---|---|---|
| Maternal education → Prenatal PRAQ → PRAQ 0-3 | -.01 | .04 | -.29 | .771 | -.09 | .07 |
| Prenatal IES-R → Prenatal PRAQ → PRAQ 0-3 | .01 | .003 | 1.37 | .172 | -.002 | .01 |
| **Prenatal STAI → Prenatal PRAQ → PRAQ 0-3** | **.28** | **.14** | **2.0** | **.046** | **.01** | **.55** |
| Ethnicity → Prenatal PRAQ → PRAQ 3-6 | -.05 | .07 | -.79 | .432 | -.18 | .08 |
| Family income → Prenatal PRAQ → PRAQ 3-6 | -.03 | .05 | -.51 | .613 | -.12 | .07 |
| Maternal age → Prenatal PRAQ → PRAQ 3-6 | -.001 | .01 | -.10 | .917 | -.03 | .02 |
| Maternal education → Prenatal PRAQ → PRAQ 3-6 | -.02 | .06 | -.29 | .770 | -.14 | .02 |
| Prenatal IES-R → Prenatal PRAQ → PRAQ 3-6 | .01 | .01 | 1.55 | .121 | -.002 | .02 |
| **Prenatal STAI → Prenatal PRAQ → PRAQ 3-6** | **.44** | **.16** | **2.79** | **.005** | **.13** | **.74** |

*Note.* Significant results in **bold** ($p$ <.05). This Table relates to SEM model 2. For the indirect effects, the *ab* values are the products of the *B* values of paths a (any maternal characteristic to prenatal PRAQ) and b (prenatal PRAQ to PRAQ 0-3 or 3-6).

**Table 7**

*Direct Effects of Infant Characteristics on the IBQ-R-VSF Subscales at 3-6 Months (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | *B* | Std. Error | z-value | *p* | Lower | Upper |
| Infant age → Surgency | .06 | .21 | .30 | .764 | -.34 | .47 |
| Gestational age → Surgency | -.17 | .26 | -.65 | .516 | -.69 | .35 |
| Infant sex → Surgency | -.12 | .38 | -.31 | .757 | -.86 | .63 |
| Infant age → Negative affect | -.13 | .20 | -.66 | .507 | -.53 | .26 |
| **Gestational age → Negative affect** | **.98** | **.26** | **3.81** | **<.001** | **.47** | **1.48** |
| Infant sex → Negative affect | -.06 | .37 | -.18 | .861 | -.79 | .66 |
| Infant age → Effortful control | .09 | .14 | .65 | .516 | -.18 | .36 |
| Gestational age → Effortful control | -.25 | .18 | -1.39 | .164 | -.59 | .10 |
| Infant sex → Effortful control | .08 | .25 | .31 | .757 | -.42 | .57 |

*Note.* Significant results in **bold** ($p$ <.05). This Table relates to SEM model 3.

**Table 8**

*Direct and Indirect Relationships between the Prenatal PRAQ, Contextual Variables, and Surgency at 3-6 Months (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Direct effects | *B* | Std. Error | z-value | *p* | Lower | Upper |
| **Prenatal PRAQ → Surgency** | **1.82** | **.24** | **7.45** | **<.001** | **1.34** | **2.30** |
| Maternal education → Surgency | .11 | .12 | .94 | .346 | -.12 | .35 |
| Family income → Surgency | .10 | .11 | .96 | .336 | -.11 | .31 |
| **Gestational age → Surgency** | **-.38** | **.12** | **-3.05** | **.002** | **-.62** | **-.14** |
| Prenatal STAI → Surgency | .040 | .31 | .13 | .898 | -.56 | .64 |
| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
| **Prenatal PRAQ → PRAQ 0-3 → Surgency** | **-1.01** | **.23** | **-4.40** | **<.001** | **-1.45** | **-.56** |
| Prenatal PRAQ → PRAQ 3-6 → Surgency | -.07 | .12 | -.55 | .580 | -.31 | .17 |
| **Maternal education → PRAQ 0-3 → Surgency** | **-.34** | **.17** | **-2.0** | **.045** | **-.68** | **-.01** |
| Maternal education → PRAQ 3-6 → Surgency | -.01 | .03 | -.51 | .610 | -.07 | .04 |
| Family income → PRAQ 0-3 → Surgency | .18 | .12 | 1.52 | .129 | -.05 | .40 |
| Family income → PRAQ 3-6 → Surgency | -.001 | .01 | -.06 | .955 | -.02 | .02 |
| **Gestational age → PRAQ 0-3 → Surgency** | **.43** | **.20** | **2.15** | **.031** | **.04** | **.83** |
| Gestational age → PRAQ 3-6 → Surgency | -.00001 | .02 | -.001 | .999 | -.04 | .04 |
| **Prenatal STAI → PRAQ 0-3 → Surgency** | **-.93** | **.35** | **-2.67** | **.008** | **-1.61** | **-.25** |
| Prenatal STAI → PRAQ 3-6 → Surgency | -.04 | .07 | -.53 | .600 | -.17 | .10 |

*Note.* Significant results in **bold** ($p < .05$). This Table relates to SEM model 4 (Figure 4). For the indirect effects, the *ab* values are the products of the *B* values of paths a and b (see Figure 4).

**Table 9**

*Direct and Indirect Relationships between the Prenatal PRAQ, Contextual Variables, and Negative Affect at 3-6 Months (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Direct effects | *B* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → Negative affect | -.35 | .55 | -.64 | .520 | -1.42 | .72 |
| Maternal education → Negative affect | -.07 | .28 | -.27 | .791 | -.62 | .48 |
| Family income → Negative affect | -.14 | .21 | -.64 | .524 | -.56 | .28 |
| Gestational age → Negative affect | .30 | .36 | .84 | .402 | -.40 | 1.0 |
| Prenatal STAI → Negative affect | .13 | .71 | .18 | .860 | -1.27 | 1.52 |
| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → PRAQ 0-3 → Negative affect | -.44 | .43 | -1.02 | .308 | -1.28 | .41 |
| **Prenatal PRAQ → PRAQ 3-6 → Negative affect** | **.86** | **.41** | **2.08** | **.038** | **.05** | **1.66** |
| Maternal education → PRAQ 0-3 → Negative affect | -.24 | .23 | -1.04 | .300 | -.68 | .21 |
| Maternal education → PRAQ 3-6 → Negative affect | .17 | .17 | 1.02 | .306 | -.16 | .50 |
| Family income → PRAQ 0-3 → Negative affect | .16 | .15 | 1.08 | .279 | -.13 | .45 |
| Family income → PRAQ 3-6 → Negative affect | -.02 | .14 | -.17 | .864 | -.29 | .24 |
| Gestational age → PRAQ 0-3 → Negative affect | .14 | .19 | .73 | .463 | -.23 | .50 |
| Gestational age → PRAQ 3-6 → Negative affect | -.05 | .26 | -.19 | .846 | -.56 | .46 |
| Prenatal STAI → PRAQ 0-3 → Negative affect | -.69 | .59 | -1.16 | .246 | -1.84 | .47 |
| Prenatal STAI → PRAQ 3-6 → Negative affect | .37 | .34 | 1.08 | .282 | -.30 | 1.04 |

*Note.* Significant results in **bold** ($p < .05$). This Table relates to SEM model 5 (Figure 5). For the indirect effects, the *ab* values are the products of the *B* values of paths a and b (see Figure 5).

**Table 10**

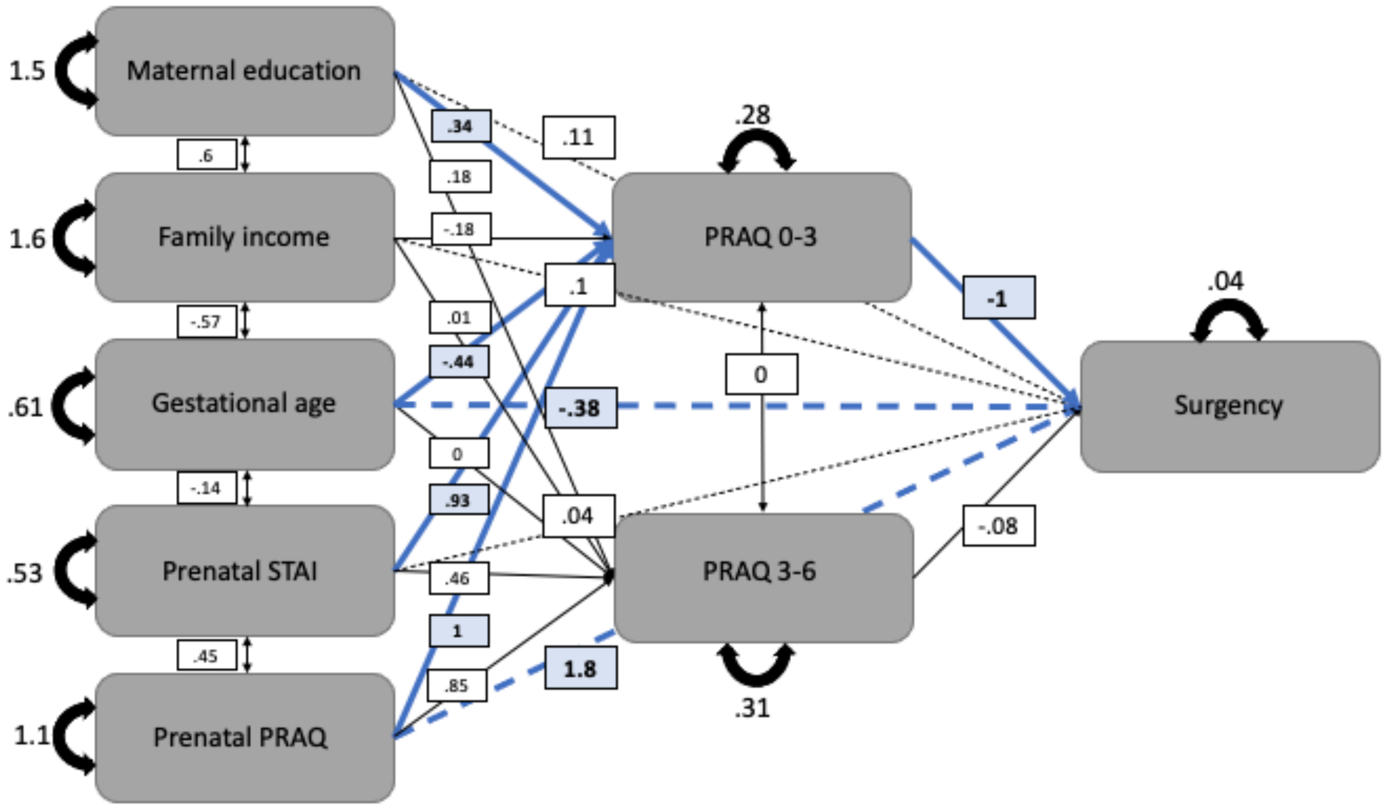
*Direct and Indirect Relationships between the Prenatal PRAQ, Contextual Variables, and Effortful Control at 3-6 Months (n = 380)*

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Direct effects | *B* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → Effortful control | -.01 | .34 | -.02 | .982 | -.67 | .66 |
| Maternal education → Effortful control | .18 | .23 | .78 | .438 | -.27 | .62 |
| Family income → Effortful control | -.09 | .18 | -.49 | .627 | -.45 | .27 |
| Gestational age → Effortful control | -.08 | .24 | -.33 | .738 | -.55 | .39 |
| Prenatal STAI → Effortful control | .46 | .56 | .82 | .415 | -.64 | 1.55 |
| Indirect effects | *ab* | Std. Error | z-value | *p* | Lower | Upper |
| Prenatal PRAQ → PRAQ 0-3 → Effortful control | -.27 | .27 | -1.02 | .310 | -.79 | .25 |
| Prenatal PRAQ → PRAQ 3-6 → Effortful control | .23 | .26 | .88 | .377 | -.28 | .73 |
| Maternal education → PRAQ 0-3 → Effortful control | -.18 | .21 | -.90 | .369 | -.59 | .22 |
| Maternal education → PRAQ 3-6 → Effortful control | .04 | .06 | .71 | .476 | -.08 | .16 |
| Family income → PRAQ 0-3 → Effortful control | .13 | .14 | .92 | .356 | -.14 | .40 |
| Family income → PRAQ 3-6 → Effortful control | -.001 | .03 | -.04 | .968 | -.07 | .07 |
| Gestational age → PRAQ 0-3 → Effortful control | .08 | .11 | .66 | .512 | -.15 | .30 |
| Gestational age → PRAQ 3-6 → Effortful control | -.01 | .07 | -.12 | .902 | -.14 | .12 |
| Prenatal STAI → PRAQ 0-3 → Effortful control | -.50 | .49 | -1.03 | .304 | -1.46 | .45 |
| Prenatal STAI → PRAQ 3-6 → Effortful control | .09 | .13 | .73 | .464 | -.16 | .34 |

*Note.* This Table relates to SEM model 6 (Figure 6). For the indirect effects, the *ab* values are the products of the *B* values of paths a and b (see Figure 6).

**Figure 4**

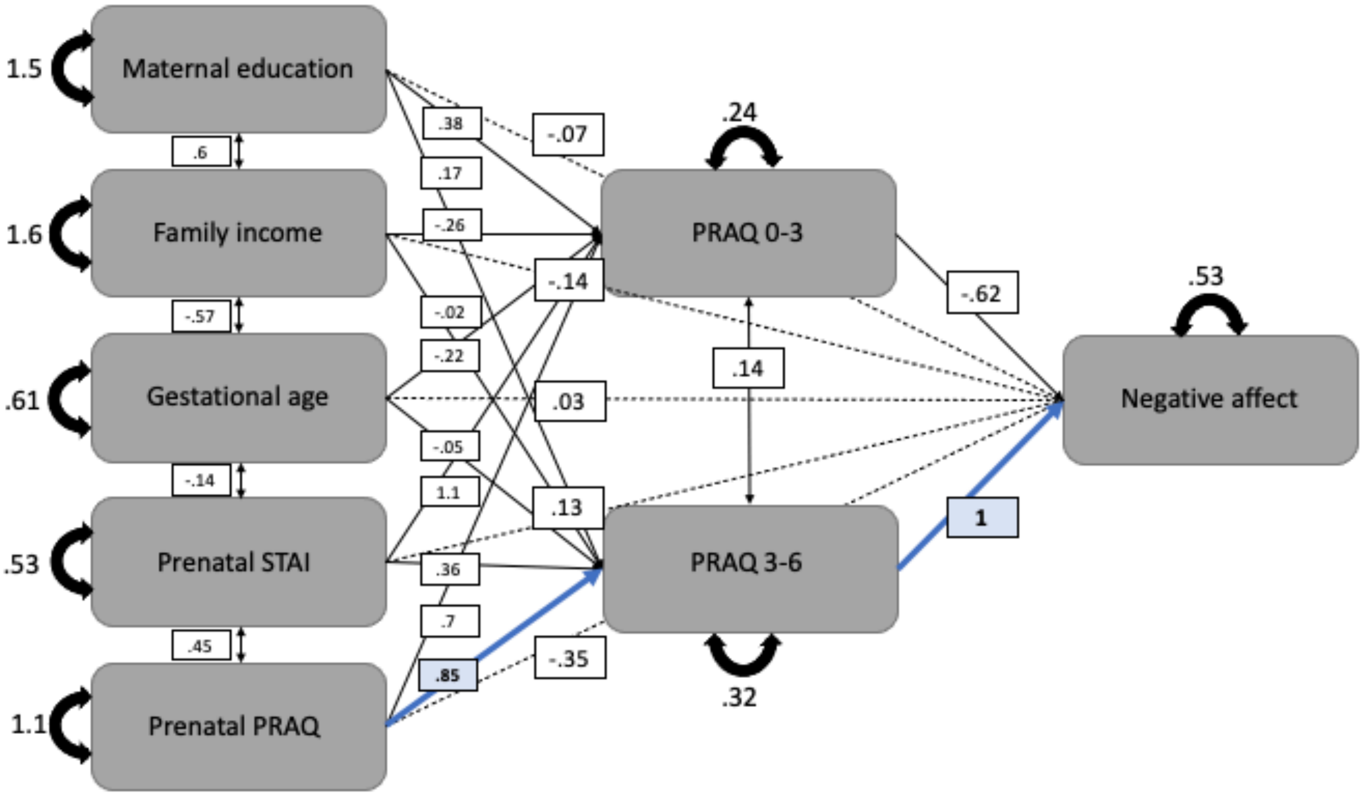
*SEM Model 4: Estimates of Relationships between Contextual Variables, PRAQ at All Timepoints, and Surgency at 3 to 6 Months (n = 380)*




*Note.* This model relates to Table 8. The *ab* values of Table 8 are the products of the *B* values of paths a (any contextual variable to PRAQ 0-3 or 3-6) and path b (PRAQ 0-3 or 3-6 to surgency), as indicated by the solid arrows. Dashed arrows indicate the direct effects, and two-headed curved arrows indicate the residual variances. Vertical two-headed arrows indicate the residual covariances, and significant relationships are in blue.

**Figure 5**

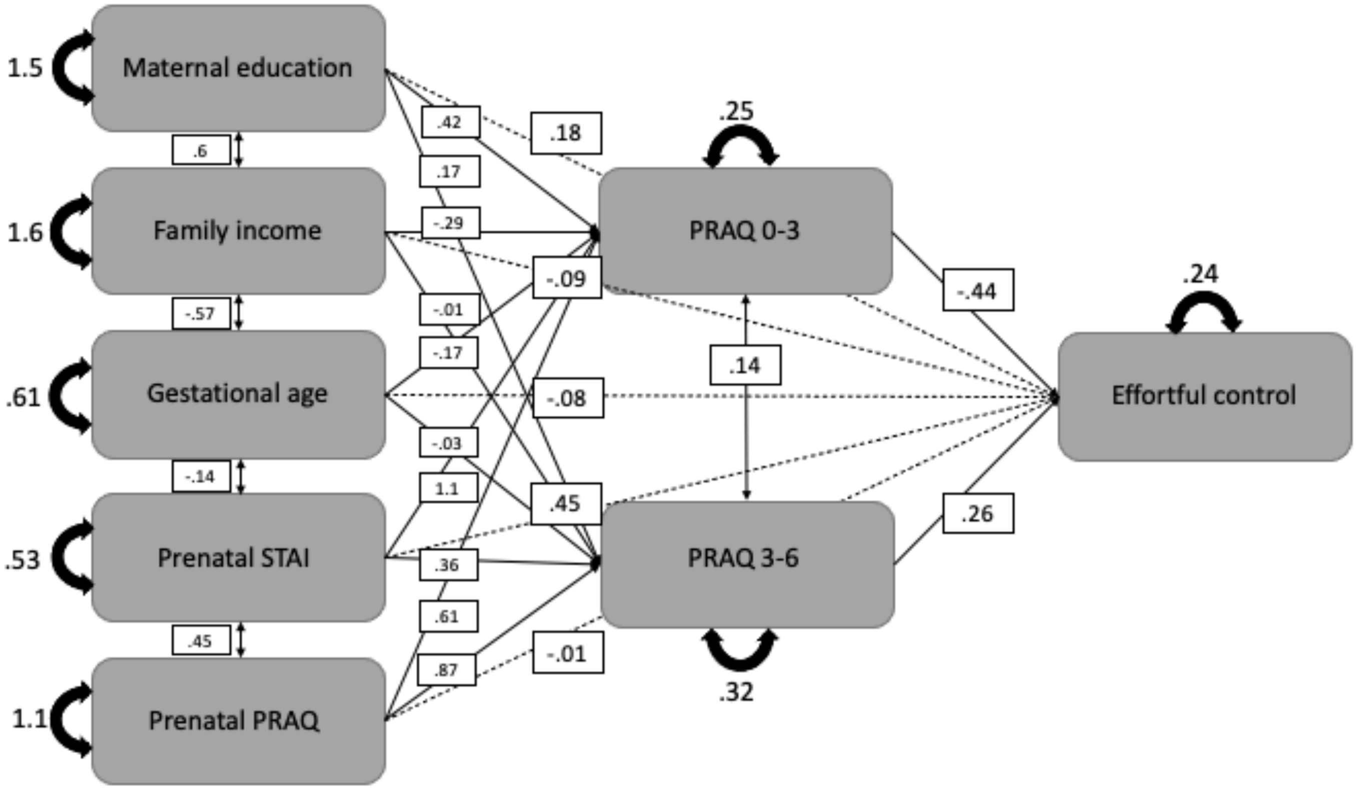
*SEM Model 5: Estimates of Relationships between Contextual Variables, PRAQ at All Timepoints, and Negative Affect at 3 to 6 Months (n = 380)*




*Note.* This model relates to Table 9. The *ab* values of Table 9 are the products of the *B* values of paths a (any contextual variable to PRAQ 0-3 or 3-6) and path b (PRAQ 0-3 or 3-6 to negative affect), as indicated by the solid arrows. Dashed arrows indicate the direct effects, and two-headed curved arrows indicate the residual variances. Vertical two-headed arrows indicate the residual covariances, and significant relationships are in blue.

**Figure 6**

*SEM Model 6: Estimates of Relationships between Contextual Variables, PRAQ at All Timepoints, and Effortful Control at 3 to 6 Months (n = 380)*




*Note.* This model relates to Table 10. The *ab* values of Table 10 are the products of the *B* values of paths a (any contextual variable to PRAQ 0-3 or 3-6) and path b (PRAQ 0-3 or 3-6 to effortful control), as indicated by the solid arrows. Dashed arrows indicate the direct effects, and two-headed curved arrows indicate the residual variances. Vertical two-headed arrows indicate the residual covariances, and significant relationships are in blue.