A psychophysiological perspective of the transformative experience of pregnancy

Helena JV Rutherford

Yale Child Study Center

Project number: 17-001602

Contents

Aims

Pregnancy is a transformative experience for men and women, accompanied by hormonal, neurobiological, and psychological changes. However, surprisingly few studies have examined this critical period of development for parents and their developing child at the level of mind, brain, and physiology. This is an area of critical importance given extant research that demonstrates prenatal experiences may affect long-term outcomes for parents and children. In the first study of its kind, we examined the psychological construct of mind-mindedness, and its association with neural and physiological measures in expectant parents. The innovation of the approach includes (1) only two studies to date have examined expectant parental mind-mindedness, and this is therefore an under developed research area; (2) no study to date has measured the brain of men during their partner's pregnancy; and (3) no study has adopted a multi-level assessment of mind, brain, and physiology during the prenatal period. Our goal was to therefore assess antenatal mind-mindedness in women and men during their third trimester of pregnancy to determine whether this critical psychological construct predicted their neural responses to infant affective cues, as well as the physiological reactivity of mother and fetus.

Methods

Overview of Sample:

51 expectant mothers of singleton pregnancies and 31 expectant fathers were recruited through the local community. Sample characteristics are described in Table 1. Expectant mothers completed two laboratory visits. The first visit occurred at Yale-New Haven Hospital St Raphael's Campus where women completed the heart rate and fetal monitoring session, mind-mindedness assessment, and additional questionnaires. The second visit occurred at Yale Child Study Center within 5.7 days (*SD*=4.7 days) where they completed the EEG/ERP assessment and additional surveys. Expectant fathers only completed the latter visit, which also included their assessment of prenatal mind-mindedness. During the award period, 51 women completed their first visit, and 39 women completed their second visit. Participant attrition was primarily due to early deliveries. All participants completed signed informed consent, and all procedures were approved by Yale University Human Investigations Committee.

Table 1. All sample characteristics

	Expectant Mothers (n=51)	Expectant Fathers (n=31)
Mean Age	29 years (*SD*=6)	32 years (*SD*=7)
Ethnicity	18 White	11 White
	19 African American	11 African American
	7 Hispanic Latino	5 Hispanic Latino
	6 Mixed Race	4 Mixed Race
	1 Other	
Marital Status	24 Married	14 Married
	18 In a Relationship	13 In a Relationship
	8 Single	4 Single
	1 Widowed	
Mean Education	14 years (*SD*=3)	14 years (*SD*=5)
Parity	30 Primiparous	17 Primiparous
	21 Multiparous	14 Multiparous

<u>Prenatal Mind-Mindedness</u>

For expectant mothers and fathers, the mind-mindedness probes came after being asked if the participant knew the sex of the infant and how many hours a day they thought about the baby to prime their thinking about the current pregnancy. Prenatal mind-mindedness was assessed by asking parents to write a response to the following probes: (1) "What do you think your baby will be like at 6 months of age?" and (2) "Now think of a person you regard as a very close friend or your current romantic partner. Say who they are and can you describe them?" Responses were separated into meaningful comments and then coded by an experienced mind-mindedness coder for the presence of mind-minded or "mentalistic" comments (e.g., "He will be happy," "She'll be smart," "Curious"). Comments repeated verbatim were not counted. All other comments were coded as nonmentalistic. Given variability in the number of comments provided (i.e., 0-9 for baby and (0-41 for partner), the proportion of comments reflecting mind-mindedness was used for both baby and partner probes. This approach is consistent with prior examination of mind-mindedness during pregnancy (Arnott & Meins, 2008) and the employment of postpartum mind-mindedness assessments (Meins & Fernyhough, 2010). Inter-rater reliability was completed for 20% of the responses and was K=1.0 for baby (mother and father) and K=0.80 and 0.76 (mother and father, respectively) for partner probes.

Prenatal ERP Assessment

Net Station 4.2.1 with a sampling rate of 250 Hz and high impedance amplifiers (Net Amps 200, 0.1Hz high-pass, 100Hz low-pass) recorded continuous EEG. A 128 Hydrocel Ag/AgCl electrode net (Tucker, 1993) was soaked in warm potassium chloride solution prior to placement. Cz was positioned at the vertex and electrodes were spaced evenly and symmetrically to cover the scalp. Cz served as the reference electrode and impedances were kept below 40 kΩ. Across two counterbalanced paradigms, infant face and cry stimuli were presented to expectant mothers and fathers.

Face Paradigm: Infant face stimuli consisted of 6 unique identities (50% Caucasian and 50% African American; reflecting the predominant community demographic), each expressing a distress and neutral expression (12 total) and presented 6 times. Infant faces were grayscale photographs (Strathearn & McClure, 2002) and were sized on average 8.68cm by 7.84cm. Face stimuli had previously been rated to confirm their valence (Rutherford, Byrne, et al., 2017; Rutherford, Guo, et al., 2017). Stimuli were viewed from 74cm in a sound-attenuated room in low ambient illumination. Stimulus visual offset was 19ms. In the task, a trial sequence consisted of a white central fixation cross presented on a black screen (jittered between 400-600ms), face presentation (1000ms), and a blank black screen (1000ms). Infant faces were randomly presented on a black background. There were 2 blocks of 36 experimental trials. Within each block, 18 distress and 18 neutral infant faces were presented. The task took approximately 15 minutes.

Cry Paradigm: Infant cries consisted of two high-distress and two low-distress cries (Gustafson & Green, 1989). In the task, a trial sequence consisted of a white central fixation cross presented on a black screen (jittered between 400-600ms), cry presentation (2000ms), and a blank black screen (1000ms). Infant cries were randomly presented when a black background was present (preventing any visual ERPs). There were 2 blocks of 36 experimental trials. Within each block, 18 low-distress and 18 high-distress cries were presented. The task took approximately 15 minutes.

Preprocessing: Net Station 4.5.7 was employed to pre-process the EEG data. EEG data was 30Hz low-pass filtered before being segmented into 1 second epochs (-100ms to 900ms). Any electrode channel with artifacts remaining in >40% of trials were excluded and replaced through spline interpolation. Next, eye blinks were corrected following recommended guidelines (Gratton, Coles, & Donchin, 1983) with a blink slope threshold=14μV/ms. Eye blink and movement thresholds were 150μV and spline interpolation was employed to replace any channels with artifacts in >40% of trials. Segments were excluded if they contained >10 bad channels. Segmented EEG data were re-referenced to the average reference of all electrodes, baseline-corrected, and averaged within each stimulus condition.

Prenatal Heart Rate: Expectant Mother and Fetus

For women, both their own and the fetus' heart rate was recorded during a caregiving-related stress induction, where they first rested for 20 minutes (baseline). Next, they listened to a 5 minute audio recording of an infant crying. Participants were instructed to close their eyes and imagine the infant crying. Finally, mothers were instructed to open their eyes and sit at rest for another 20 minutes. Maternal heart rate was collected from expectant mothers using the Polar V800 chest strap and wrist watch monitor. Fetal heart rate was collected using the Toitu MT-516 monitor. This cardiac monitor provides a fetal electrocardiogram (EKG) and non-invasively records both fetal EKG signals, fetal movement, and uterine activity. Fetal data was collected through a transducer place on the mothers' abdomen using ultrasound gel. A second transducer was placed at the fundus to measure uterine activity. We had proposed to also collect heart rate data from expectant fathers; however, we were unable to achieve this measurement in our paternal sample given their limited availability for study visits (it was a challenge to enroll expectant fathers for a single EEG visit, a second visit to incorporate heart rate monitoring was therefore not feasible). Data analysis focused exclusively on expectant mothers and their fetuses.

Results and Discussion

Prenatal Mind-Mindedness

With respect to mind-mindedness responses to the describe your baby at 6 months, expectant mothers (*M*=.34; *SD*=.31) reported a slightly higher proportion of mind-related comments than expectant fathers (*M*=.26; *SD*=.36), though this did not reach statistical significance, *U*=635.50, *p*=.108. When asked to describe their close friend/romantic partner, there was no difference in the proportion of mind-related comments between expectant mothers (*M*=.28; *SD*=.20) and fathers (*M*=.26; *SD*=.24; *U*=585.00, *p*=.662).

ERPs

Infant Faces. Grand average waveforms for the P300 are presented in Figure 1. The main effect of emotional expression did not reach statistical significance, $F(1,66)=3.09, p=.08, \eta^2_{partial}=.045$; however, there was a main effect of sex, $F(1,66)=7.63, p=.007, \eta^2_{partial}=.104$, and emotional expression and sex interacted, $F(1,66)=8.34, p=.004, \eta^2_{partial}=.118$. Post-hoc t-tests evidenced while expectant fathers had a larger P300 response to distress versus neutral expressions, $t(29)=2.77, p=.010$, emotional expression did not modulate the P300 measured in expectant mothers, $t(37)=-1.05, p=.302$. Furthermore, the P300 elicited by neutral infant faces was not different between expectant mothers and fathers, $t<1$, however expectant fathers had a larger P300 response to infant distress faces than expectant mothers, $t(66)=3.79, p<.001$.

Given prior work indicating that parity modulates the maternal P300, we repeated this analysis including parity. The emotional expression and sex interaction remained, *F*(1,65)=8.60,*p*=.005,$\eta^2_{partial}$=.117. Also, when we covaried for depression symptoms, the emotional expression and sex interaction remained, *F*(1,65)=8.35,*p*=.005,$\eta^2_{partial}$=.114.

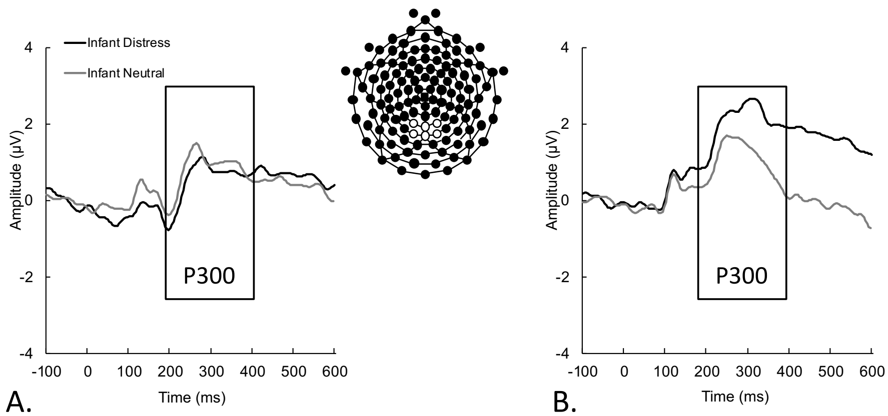

Figure 1. Grand average waveforms illustrating the P300 for expectant mothers (Panel A) and expectant fathers (Panel B) viewing distress and neutral infant faces averaged across six neighboring electrodes over centro-parietal scalp regions shaded in white (61, 62, 67, 72, 77, 78).

ERPs and Prenatal Mind-Mindedness

Infant Faces. To examine associations between parental ERPs and mind-mindedness, we calculated a difference score between the P300 distress and neutral conditions, where a positive number indicated a greater response to the distress infant face (versus the neutral face). This approach allowed differential reactivity to distress as compared to neutral faces, which varied between expectant mothers and fathers, to be taken into consideration in these analyses. When examining the distribution of the differential P300 response to distress and neutral faces, two outliers were noted (one mother, one father) and their data was removed from this analysis. When examining expectant mothers, there was a weak correlation between their P300 responsivity and their mind-related comments when thinking about their child, *r*=.020,*p*=.909 (Figure 2, Panel A), and their close friend/romantic partner, *r*=.214,*p*=.204. However, when examining expectant fathers, there was a moderate correlation between their P300 responsivity and mind-related comments regarding their child, *r*=.494,*p*=.008 (Figure 2, Panel A), but not their close friend/romantic partner, *r*=.018,*p*=.928. When we re-ran these correlations including the two outliers and controlling for depression symptoms, the results held.

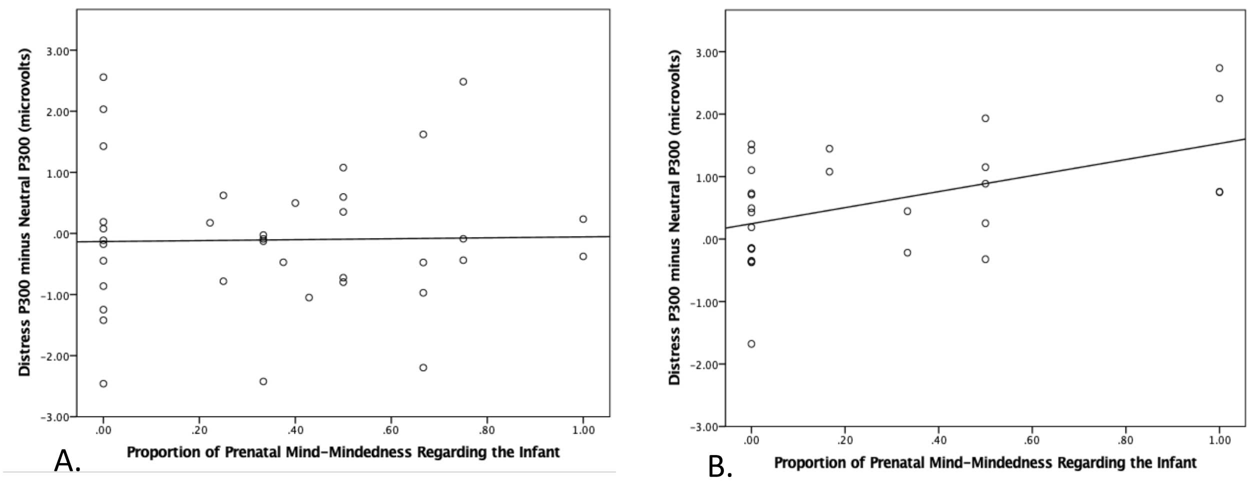

Figure 2. Associations between changing neural response to the distress and neutral infant faces (reactivity) and levels of prenatal mind-mindedness in expectant mothers (Panel A) and expectant fathers (Panel B).

Taken together, we examined the P300 elicited by infant distress and neutral faces during the third trimester of pregnancy in expectant mothers and fathers. While the maternal P300 response was unaffected by infant emotional expression, we found expectant fathers had a greater response to distress than neutral infant faces. Furthermore, reactivity to infant distress (relative to neutral) faces was associated with prenatal mind-mindedness regarding the future child in expectant fathers. Although extension and replication of these findings are warranted, they raise important insight into sex differences in the experience of pregnancy and the neural and psychological preparedness of expectant fathers. Critically, our findings indicate that expectant parents can take the perspective of their future child and suggest an important interplay between neural and psychological factors in the preparation for parenthood in expectant mothers and fathers.

Infant Cries. We found no associations between prenatal mind-mindedness and responding to infant cries for any ERP components (N1, P2, and LPP). However, we also measured levels of prenatal stress in our expectant parents, which while not correlated with prenatal mind-mindedness, was correlated with ERP data. Although prenatal stress did not impact the N1 and P2, the LPP elicited by infant cries was impacted by prenatal stress. Specifically, there was an interaction between infant cry distress level and parents' prenatal stress level, $F = 4.87$, $p = .031$. Higher prenatal stress was associated with a larger LPP amplitude to low-distress, but not high-distress, infant cries. The LPP has been implicated in the sustained attentional processing of motivationally-relevant stimuli, suggesting that low-distress cries were particularly salient to expectant parents in the presence of elevated levels of prenatal stress. Notably, these findings were independent of parental sex, F's < 1, suggesting a comparable association between prenatal cry responses and stress levels for expectant mothers and fathers. Consequently, these LPP findings suggest that expectant parents experiencing higher levels of prenatal stress show greater neural responses to low-distress infant cries than high-distress infant cries. This increased sustained attentional processing of low-distress cries in highly stressed parents may reflect mothers' and fathers' uncertainty regarding how distressed an infant might be (or become), requiring a greater degree of interpretation. This uncertainty may also elicit anxiety, which may be problematic when parents are already experiencing higher levels of stress during their pregnancy. In contrast, the attenuated LPP response to high-distress infant cries may be indicative of parents allocating less attentional resources to infant distress cues that are less ambiguous.

Maternal Mind-Mindedness and Maternal Heart Rate

As a reminder: during their first visit, women completed a caregiving-related stress induction, where they first rested for 20 minutes (baseline). Next, they listened to a 5 minute audio recording of an infant crying. Participants were instructed to close their eyes and imagine the infant crying. Finally, mothers were instructed to open their eyes and sit at rest for another 20 minutes. As evidenced in Figure 3, maternal heart rate variability was modulated by experimental condition, $F(2,70) = 3.81$, $p=.038$, with maternal heart rate variability being increased in response to the infant cry exposure. Next, we examined correlations between maternal mind-mindedness and maternal heart rate variability. However, there were only weak, and not statistically significant, correlations between levels of mind-mindedness and maternal heart rate variability.

Figure 3. Change in maternal heart rate variability as a function of the experimental condition.

Maternal Mind-Mindedness and Fetal Heart Rate

Fetal heart rate was also recorded during women's first visit. We examined the number of heart rate accelerations during each recording (representing short-term increases in heart rate activity of the developing child). Across the sample, there were on average 15.64 (SD=7.76) accelerations during the 45 minute recording. There was a weak correlation between prenatal mind-mindedness and the number of heart rate accelerations when describing their prospective infant, $r=-.23$, $p=.11$, as well as their partner, $r=.10$, $p=.49$.

Conclusions and Recommendations

The current proposal enabled for the first time a comprehensive assessment of mind, brain, and physiology during the prenatal period. The most robust associations were found between parental mind-mindedness and ERPs to infant faces, specifically for expectant fathers. However, associations were also observed between prenatal stress and infant cries in expectant mothers and fathers. We did not find associations between prenatal mind-mindedness and heart rate measures in expectant mothers and their fetus. This opportunity from the BIAL Foundation will make a lasting contribution to our understanding of the transformative experience of pregnancy for expectant mothers and fathers. Additional analyses are underway to further probe the additional outcomes listed here and the BIAL Foundation will continue to be acknowledged in disseminations of this work, whether as publications or as presentations.