Maternal depression and anxiety symptoms across pregnancy and the postnatal period: modest associations between depression symptoms and infant sleep outcomes

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Abstract

Maternal depression and anxiety symptoms are common across the perinatal period and are associated with a raised risk for adverse child outcomes. While substantial evidence exists for child outcomes such as behaviour, language and cognition, infant sleep has been less studied. In this longitudinal study, we examined the association between maternal symptoms of depression and anxiety and mother-reported infant sleep at 6 and 12 months. Across the four infant sleep outcomes, total sleep time, sleep onset latency, number of awakenings and a maternal perception variable, we found modest effects for concomitant depression symptoms. There were almost no additional effects for anxiety symptoms beyond that already accounted for by depression. Using trajectory modelling of maternal symptoms at five time points, we found more robust effects for maternal groups with postnatally emerging symptoms over prenatally present symptoms across all four sleep outcomes. Our strongest finding was that mothers with postnatal depression symptoms were more likely to perceive their infant's sleep as problematic compared with all other mothers. Where we found effects on duration-based infant sleep outcomes overall, these were small and clearest for depressive symptoms over anxiety symptoms. For both nighttime awakenings and perception of sleep as a problem, effects were apparent only for mothers in the postnatal symptom groups, and not for prenatal symptoms, at both infant ages six and 12 months. Our sample was a relatively high-socioeconomic group with low symptoms overall, and findings may not generalize to more vulnerable populations.

Maternal mental health difficulties in the perinatal period are common and associated with a raised risk for a range of adverse child developmental outcomes. Perhaps the most widely studied mental health difficulty, depression, has been estimated at 9.2% prevalence in the antenatal period and 9.5% in the postnatal period in high-income countries [1]. Maternal anxiety is also common, and the prevalence of a clinical diagnosis of any anxiety disorder during pregnancy has been estimated at 15.2% and at 9.9% postnatally until 24 weeks [2]. For child development, negative effects of maternal mental health difficulties have been described in relation to cognitive and behavioural functioning, and attachment [3]. There is also growing evidence that infant sleep may be negatively impacted.

Infant sleep is important because it is a common concern for parents and infant sleep problems are a primary reason for seeking professional help [4]. Poor infant sleep is associated with several parental difficulties, such as limit-setting [5], and can disrupt family functioning, for instance, by awakening other family members [6]. Infant sleep has also been longitudinally associated with child outcomes in behavioural, cognitive, and socio-emotional domains [7]. For example, infant night wakings at 3 months have been prospectively related to internalising and externalising symptoms in toddlerhood [8], and severe, persistent sleep problems in the first year have been associated with an increased risk of meeting diagnostic criteria for an emotional disorder at age 10 years [9]. While infant sleep development can be influenced by complex interactions among physiological, environmental, and psychosocial factors [10], maternal mental health represents a key factor, potentially modifiable through intervention [11].

Maternal depression effects on infant sleep

Longitudinal studies of maternal depression have provided the most robust evidence for antenatal effects on infant sleep outcomes. In a large study, involving the Avon Longitudinal Study of Parents and Children (ALSPAC) in the UK (United Kingdom) and Generation R in the Netherlands, maternal antenatal depressive symptoms (measured at 32 gestational weeks in the ALSPAC and at 20 gestational weeks in the Generation

R) were associated with shorter sleep duration and a higher number of nighttime awakenings in children at the age of 18- and 24-months [12]. Effects were moderated by infant temperament and postnatal depression symptoms were controlled for. In a U.S. study, the infants of mothers with depression during pregnancy had shorter sleep duration at ages 1 and 2 years compared to mothers without [(0.36 and 0.38 hours fewer respectively) 13]. An earlier report from the ALSPAC study found that maternal depressive symptoms (measured at 18 and 32 weeks during pregnancy, with the Edinburgh postnatal depression scale cut-off of 12) were associated with broadly defined sleep problems at infant age 18 and 30 months but not with total sleep time [14]. Comparing women who did and did not meet depression diagnostic criteria during pregnancy, Galbally, Watson [15] reported differences in infant sleeping arrangements at 6 and 12 months, where mothers with depression were three times as likely to be sleeping on the same surface as their infants at six months, and twice as likely to be sharing a room at 12 months. However, depression did not predict maternal perception of infant sleep problems.

While the two previously mentioned studies with ALSPAC and Generation R participants [12, 14] used *postnatal* depression as a covariate in testing the effects of antenatal depressive symptoms, several studies have focused on postnatal depression or depression across the entire perinatal period. Findings on postnatal effects have been mixed. For example, in the high-income setting of New Zealand, postnatal depression status, or both antenatal and postnatal depression status, were not associated with nighttime awakenings (>2) or short sleep duration (<11 hours) at infant age of two years [16]. However, in a low-income, primarily ethnic minority US sample, higher postnatal depressive symptoms at five months were associated with increased night awakenings at nine months [17]. In a Brazilian sample, depression at any time in the perinatal period, from pregnancy or up to 3 months postnatally, was associated with reported shorter total sleep duration, longer sleep onset latency, but not total number of awakenings at 12 months [18]. A 2020 Australian study examined infant sleep problems, and using latent class analysis, reported on 5 trajectories of infant sleep patterns [19]. Membership of the trajectory group with persistent and severe infant sleep problems was predicted by the presence of both prepartum and postpartum maternal depression.

Maternal anxiety: effects on sleep may differ from that seen in depression

In addition to maternal depression, there is some evidence that maternal anxiety may also negatively impact infant sleep outcomes, with effects differing from that seen for depression. Maternal anxiety is proposed to impact worries about infant sleep, driving over-sensitivity to infant signals and increasing involvement during the night [20]. For example, while maternal anxiety symptoms during pregnancy were related to co-sleeping with parents at 3 months, maternal depression was associated with having an irregular sleep routine [21]. In the same study, both depression and anxiety symptoms were associated with long sleep onset latency. In Cook, Conway [19], mothers of infants with persistent and severe infant sleep problems were more likely to experience anxiety postnatally but not prenatally.

To date, studies examining how maternal mental health symptoms are associated with infant sleep have typically relied on one or two measurements during the perinatal period (but see also [22] for an example of more frequent perinatal symptom measures). With such an approach, most evidence has accumulated for antenatal depression being associated with negative outcomes for infant sleep. While many mothers experience depression *both* antenatally and postnatally, there is evidence for discontinuity of symptoms in some women, or emergence of symptoms only in the postnatal period [23]. Therefore, there may be different trajectories of symptoms, and resultant associations with infant sleep, that have not been described.

Our longitudinal study of maternal mental health symptoms and infant sleep had three main aims. First, we assessed *both* anxiety and depression symptoms in the same models, to examine their unique contributions to sleep, and given findings suggesting that depression and anxiety may impact infant sleep outcomes in diverse ways. We anticipated that both depression and anxiety would be associated with negative infant sleep outcomes, with anxiety, for example, related to greater reporting of infant awakenings, but depression related to duration-related sleep measures. Second, we examined how different trajectories of maternal symptoms, measured at five time points across the perinatal period, were associated with infant sleep. Finally, we tested

multiple domains of infant sleep outcome, using continuous variables to extend findings from existing studies, which have examined binary infant sleep variables [16, 18].

Methods

The present study uses data from the FinnBrain birth study, a population-based cohort recruited in southwest Finland (www.finnbrain.fi). The characteristics of the sample and a detailed description of the recruitment process are available elsewhere [24]. Briefly, recruitment of the initial sample took place between December 2011 and April 2015. Women attending maternal welfare clinics, during pregnancy ultrasound scans at gestational week 12 who would eventually be referred to give birth at Turku University Hospital in the Southwest Finland Hospital District and the Aland Islands in Finland were approached by a study nurse. The Ethics Committee of the Hospital District of Southwest Finland approved the study protocol. The study inclusion criteria were: sufficient knowledge of Finnish or Swedish and a normal ultrasound screening result. The representativeness of the sample is presented in detail elsewhere [25]. After initial recruitment to the study, attrition was higher in mothers with lower socioeconomic status and somewhat higher depression symptom levels, as reported in [25].

In the present study, participants comprised those responding to the sleep questionnaire items from the Brief Infant Sleep Questionnaire (BISQ) at either 6 months or 12 months (n=2137, responding to at least one item). From this initial sample, mothers with multiple births (twins, triplets, n=26) and infants with serious chronic illnesses or those affecting the central nervous system (n=13) were excluded. Examples of the excluded illnesses include epileptic syndromes, Down syndrome, Crouzon syndrome, Hirschsprung disease, or hereditary blindness, and severe congenital heart anomalies such as Tetralogy of Fallot.

Measures

Infant sleep

Sleep at 6 months and 12 months was measured using the BISQ [26]. The BISQ comprises 13 items about the duration of sleep, settling, night waking, and sleep arrangements. Four infant sleep variables were selected as outcomes: total sleep time in hours, nighttime awakenings (a count variable), sleep onset latency in minutes, and maternal sleep perception of the infant as having a sleep problem (with the possible responses as 'none', 'mild', 'severe'; BISQ variables reported in Table 1; histogram plots of the variable distributions see, S.Figure 1, see S.Figure 3 for a plot of the outcome correlations). For total duration of sleep, both daytime and nighttime sleep duration reports were required. The accepted range for the total sleep duration was 6-21 hours. There were two excluded cases at the age of six months and 2 at the age of 12 months, where less than 6 hours of sleep was reported. There were no exclusion criteria for the other sleep variables.

Maternal Anxiety and Depressive symptoms

Mothers completed the Edinburgh Postnatal Depression Scale (EPDS) and the Symptom Checklist –90 (SCL) anxiety subscale at three prenatal time points (first, second and third trimester, gestation weeks 14, 24 and 34) and two postnatal time points, 3 months, and six months. The EPDS, but not the SCL, was completed at 12 months. The EPDS is a widely used measure of both postnatal and prenatal depression [27] and consists of ten items rated from 0 to 3 (higher scores indicate more depressive symptoms). The anxiety subscale of Symptom Checklist 90 (SCL-90) is a reliable and valid measure of anxiety symptoms in both clinical and research settings [28-30] and consists of 10 items rated from 0 to 5. Table 2 presents the participants' depression and anxiety scores at the pre and postnatal measurement points, and the percentage of women with elevated symptom scores (for depression > above 12; for anxiety > 10). We controlled for covariates previously demonstrated to impact infant sleep, including infant birth weight (grams), maternal

breastfeeding (yes/no), infant sex (male, female) maternal smoking (yes/no) and maternal education level (i.e., three categories high school/vocational education, polytechnics/applied university, or university degree) [31].

Statistical Analysis

We used the maximum number of available datasets for the included variables. We performed multiple imputation to deal with missing predictor variables (e.g., EPDS, SCL). We did not impute BISQ infant sleep outcomes, because these were used as inclusion criteria for this study. We first investigated the patterns of missingness by comparing density plots for the key variables (EPDS and SCL scores at the six and five time points respectively, along with demographic variables), where the 12-month total sleep time was missing or available (see S.Figure 2). We then used deterministic regression imputation using the Multivariate Imputation via Chained Equations (MICE) R Package. In MICE, we used the predictive mean matching (pmm) imputation method, which finds matches among the observed data, and subsequently selects observed values to replace missing values [32]. We imputed data for all variables as they contained less than 40% missing data (Jakobsen et al., 2017) and we examined five possible imputed datasets. For the analyses focusing on postnatal symptoms, we used all five imputed datasets and pooled the posterior estimates to include the uncertainty due to the imputation process fully. For the analysis including symptom depression and anxiety symptom classes, we used the best fit of the imputed datasets, because it was not possible to use multiple imputed datasets in the latent class analysis. We selected the best fitting dataset by comparing the density plots of the original and the imputed datasets.

Postnatal symptoms and infant sleep

We examined whether maternal depression and/or anxiety symptoms at 6 and 12 months were associated with infant sleep at these respective time points. We fitted Bayesian regression models using the Stan modelling language (Carpenter et al., 2016) and the package *brms* (Buerkner, 2016). Four sampling chains

ran for 2000 iterations with a warm-up period of 1000 iterations for each model, yielding 4000 samples for each parameter tuple. Bayesian regression provides intuitive ways of pooling estimates across the datasets generated by multiple imputation. It enables more nuanced distributional modeling, thus allowing for better quantification of the uncertainty of the result than frequentist modelling (Schad et al., 2020). Model comparisons were carried out using Watanabe-Akaike information criteria (WAIC) and the associated stacking weights [33]. We included maternal breastfeeding, infant birth weight and maternal education, smoking, and infant sex as covariates. Next, we tested maternal EPDS and SCL scores separately, together, and including their interaction effect (EPDS*SCL), yielding a total of five models for each of the four outcome variables (See S. Table 1 for final models). We performed model quality checks for each model, including comparison to a model based on non-imputed data, and inspection of the model fit to the data, based on a posterior predictive distribution, described in the Supplementary materials (see Supplementary Materials Figure and table list). We also compared mothers with the highest symptom scores (10% highest EPDS scores: at 6 months 10-27; at 12 months: 10-23; SCL scores 8-29) and lowest symptom scores (10% lowest EPDS scores: 0 at both time points; SCL: 0), referred to as the "highest" and "lowest" symptom groups throughout.

Maternal trajectories and infant sleep

We used latent class mixed modelling to identify different trajectory groups, based on maternal symptom scores (EPDS, SCL) using the R-package *lcmm.* For this analysis, we selected the imputed dataset with the best fit of the 5 imputed datasets, as determined by density plots comparing the original and imputed dataset. EPDS and SCL symptom scores were the outcome variables, and measurement time point was the predictor variable. Measurement time was included as a random effect, and as the mixture term, by which each class should differ from each other. A linear link function model was estimated. We searched for up to 6 groups, starting with 1 group as a baseline and increasing by 1 group for each iteration. For model selection, indices of Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC) and Entropy (1 indicating higher confidence in classification) were evaluated. Further, posterior probabilities of class membership

(certainty and group size) were considered. Where the indices did not give a clear choice, theoretical interpretability guided the final model selection [34]

The resulting classes were used as predictors of four infant sleep measures, nighttime awakenings (a frequency count of the number of awakenings), sleep onset latency (SOL, in minutes), total sleep time (TST, in hours) and parental perception of sleeping problems (None, Mild, Severe). Eight mixed effect models were compared in each analysis, including either EPDS, SCL, neither or both, and interacting with each other or sleep measurement time, neither or both. All models included covariates and the sleep measurement time point. We used Bayesian regression for model estimation and Watanabe-Akaike information criteria for model selection.

Results

Demographic characteristics of the sample are presented in Table 2. Most mothers did not smoke during pregnancy (86.5%, n = 1848, 8.5% smoked early in pregnancy, 5% smoked late in pregnancy). Most women were first-time mothers (n=1136, 53.2% or had one previous infant, n=708, 33%). The average number of rooms in the home at the first study assessment point was 3.6 (*SD* = 1.5).

Infant total sleep time (TST)

At six months, the best model included maternal depression scores (EPDS), while adding anxiety scores (SCL) did not improve the model. The results indicate a small but certain, negative effect of depression symptoms on infant TST, where higher depression symptom scores were associated with reduced infant sleep time. For every standard deviation increase in EPDS score (4.15), the average expected infant TST decreased by 4.2 minutes (CI: 4.4 – 4.1; Figure 1a, S. Table 2, 3, S. Figure 4-6). For mothers with the lowest EPDS scores, their infants were predicted to sleep for an average total of 13.73 hours. For mothers with the highest EPDS scores, their infants were predicted to sleep for a total of 13.4 hours, a difference of 20 minutes compared to the lowest symptom group. At 12 months, the best model included depression scores,

which were negatively associated with infant TST, and the effect was slightly stronger than at six months. For every standard deviation increase in EPDS score (4.08), expected infant TST decreased by 6.92 minutes (CI: 7.13 – 6.61). At either end of the EPDS symptom scores, infants of mothers with the lowest depression symptoms had an average sleep time of 12.91 hours, while infants of mothers with the highest depression symptoms had an average sleep time of 12.43 hours, almost half an hour less (Figure 1a, S. Table 2, 3, S. Figure 4-6).

1*Sleep Onset Latency*

At six months, the best model included maternal depression symptom scores (EPDS) and anxiety (SCL) scores, but symptom effects were extremely small. For each standard deviation increase in EPDS score (4.15), SOL increased minimally by 1.32 minutes (CI: 0.35 – 1.94; Figure 1b, S. Table 4, S. Figure 7). SCL scores had a slightly weaker effect than EPDS scores. For every standard deviation increase in SCL (3.93), SOL increased by 1.10 minutes (CI: 0.27 – 1.65) (Figure 1c, S. Table 4, 5, S. Figure 7-9). The difference in SOL for the infants of mothers with the highest and lowest EPDS scores was about 6 minutes (lowest EPDS: 24.7 minutes, CI: 1.7 - 70.8; highest EPDS: 30.6 minutes, CI: 3.29 - 79.6). For the SCL scores, there was about 5 minutes of a SOL difference between infants of mothers in the highest SCL score group (SCL 8-29; 30.5; CI: 3.11 - 79.2) compared to the lowest SCL score group (scores of 0; 25.4; CI: 1.84 - 71.8). At 12 months, the best model included maternal depression scores, as for the 6-month data ~~but not SCL scores.~~ For every standard deviation increase in EPDS scores (4.08), SOL increased by 1.61 minutes (CI: 0.31 – 2.73) (Figure 1b, S. Table 4, 5, S. Figure 7-9). Further, the difference in infant SOL between mothers with the lowest EPDS scores versus the highest was around 7 minutes (21.4 min, CI: 0.79-71.3, vs 28.0 min, CI: 2.06 - 82.0). Note, however, that the inference had a high uncertainty level and considerable unexplained variance.

2Nighttime awakenings

At six months, the best model included maternal depression scores (EPDS), but not anxiety scores (SCL). For every standard deviation increase in EPDS (4.15), nighttime awakenings increased by 0.23 (CI: 0 – 0.45;

Figure 1d, S. Table 6, 7, S. Figure 10-12). For mothers with the lowest EPDS scores, their infants were predicted to wake an average of 2.17 times per night. For mothers with the highest EPDS scores, their infants were predicted to wake 3.18 times per night. At 12 months, we found a similar pattern for EPDS scores but with smaller effect sizes. For each standard deviation increase in EPDS (4.08), nighttime awakenings increased by 0.14 (CI: 0 – 0.34; Figure 1d, S. Table 6). Examining mothers with the lowest EPDS scores, their infants were predicted to wake an average of 1.48 times per night, which differed only minimally from infants of mothers with the highest EPDS scores, who were predicted to wake 2.06 times per night. The uncertainty in estimates of predicted nighttime awakenings from EPDS at both six months and 12 months was high, with substantial unexplained variance (see Figure 1d, S. Table 6, 7; S. Figure 10-12).

Parental Perception of infant sleep

The best model fit at six months included maternal depression scores, where higher depression symptoms were associated with an increased probability of infant sleep being perceived as a problem. For every standard deviation increase in mothers' EPDS scores (4.15), there was an increased probability of mothers' perceiving infant sleep as a slight problem (an increase of 5.92%; CI: 5.67 – 6.02) or a severe problem (2.68% (CI: 1.54 – 4.07) (Figure 1e, S. Table 8, 9, S. Figure 13-15). Mothers with the lowest EPDS scores, generally rated their infants as having no problem with sleep (84% probability of being rated as 1, "no sleep problem"), and only occasionally as having a slight problem with sleep (16% probability), and rarely as having a severe problem with sleep (1%). In contrast, mothers with the highest EPDS scores, had a 45% probability of rating their infants as having no problem with sleep, a 44% probability of rating their infants as having a slight problem and a 10% probability of rating sleep as a severe problem.

At 12 months, the best model included depression scores, but with a slightly smaller effect than at six months. With every standard deviation increase in mothers' EPDS scores (4.08), there was an increased probability of mothers' perceiving infant sleep as a slight problem (increase of 5.39% (CI: 4.86 – 5.65), or as a severe problem (increases of 1.62% (CI: 0.98 – 2.53) (Figure 1e, S. Table 8, S. Figure 13). Mothers with

the lowest EPDS scores, generally rated their infants as having no problem with sleep (81% probability), only occasionally as having a slight problem with sleep (18% probability), and rarely as having a severe problem with sleep (1%). As for the 6-month data, mothers with the highest EPDS scores, had a 52% probability of rating their infants as having no problem with sleep, a 41% probability of rating their infants as having a slight problem and a 7% probability of rating sleep as a severe problem (see S. Figure 14, 15; S. Table 9).

Maternal classes from prenatal and postnatal depression and anxiety symptom scores

The fit indices from the latent class mixed models are presented in Table 3. Assessing EPDS classifications, the 5 and 6 class solutions contained groups with less the 1% of the sample and were therefore excluded [35]. Of the remaining models, Model 4 had the best AIC and BIC indices but had low entropy. Model 4 had two almost identical classes and was therefore judged to be less interpretable compared to Model 3 (S. Figure 16). The posterior probabilities of class memberships in Model 3, were all above 0.8 and therefore acceptable [36] (Table 3). The first group was characterised by consistently low/absent EPDS symptoms (86%). The second group had consistently increasing symptoms, particularly after birth ("postnatal symptoms", 4%), and the third group had elevated symptom scores during pregnancy, and decreasing scores postnatally (10%, "prenatal symptoms") (Figure 2). For the SCL classifications, we excluded the 3, 4, 5 and 6 class solutions due to empty groups. Of the remaining two models, the 2-class solution had the best BIC and AIC indices, high entropy and had posterior probabilities for class membership above 0.9, indicating certainty in the groupings (Model 2, Table 3). The first group can be characterised as having "consistently low/absent SCL symptoms" (92%), and the second group have "increasing anxiety symptoms", which have a pronounced increase after birth (8%, see Figure 2).

Maternal Symptom class and Infant Total Sleep Time

We modelled the associations between infants' TST and mothers' depression and anxiety symptom trajectory groups. The best model of infant sleep time included EPDS class, while adding SCL class or an interaction

effect with time of sleep measurement did not improve the model. Both classes of mothers with postnatal and prenatal depression symptoms reported lower TST in their infants relative to mothers with no depressive symptoms. The mothers with prenatal (class 3) or postnatal depression symptoms (class 2) had comparable infant sleep times (Figure 3a, S. Table 10, S. Figure 17). At six months, TST was estimated to be 13.67 hours (CI: 13.56 - 13.77) for infants of mothers with stable and low symptoms (class 1), but at 13.41 hours (CI: 13.18 - 13.65) for infants of mothers with postnatal symptoms (class 2), and 13.43 hours (CI: 13.26 - 13.61) for infants of mothers with prenatal symptoms (class 3).

At 12 months, again, infants of mothers with low and stable symptoms slept the longest (class 1; 12.78 hours; CI: 12.67 – 12.88), whereas infants of mothers with postnatal symptoms slept for 12.52 hours (class 2; CI: 12.29 - 12.76), and infants of mothers with prenatal symptoms for 12.55 hours (class 3; CI: 12.37 - 12.72), (Figure 3a, S. Table 10, S. Figure 17). In summary, at both 6 and 12 months, infants of mothers with postnatal or prenatal depression symptoms (classes 2 and 3) did not differ from each other but both differed from infants of mothers with low and stable symptoms (class 1).

Maternal Symptom Class and infant Sleep Onset Latency (SOL)

For infant SOL, the best model included EPDS class, interacting with time of sleep measurement. Adding SCL class did not improve the model. Postnatal (class 2) and prenatal depression symptoms (class 3) were both related to longer SOL measures compared to those with no depression (class 1). At six months, the postnatal symptom group was associated with the largest effect size (class 2), while at 12 months, the prenatal symptom group was associated with the largest effect (Figure 3b, S. Table 11, S. Figure 18). At six months, infant SOL was estimated to be 23.16 minutes (CI: 21.90 - 24.48) for infants of mothers in class 1), 27.85 minutes (CI: 24.04 - 32.10) for class 2, and 25.29 minutes (CI: 22.76 - 28.07) for class 3. At 12 months, infant SOL was estimated to be 19.92 (CI: 18.79 - 21.09) for infants of mothers in class 1, 22.53 minutes (CI: 19.11 - 26.18) for class 2, and 25.75 minutes (CI: 23.22 - 28.49) for class 3.

Maternal Symptom Class and Infant Nighttime awakenings

For infant nighttime awakenings, the best model included EPDS symptom class. Adding SCL class improved the model fit only marginally and the interaction effect with time did not improve the model fit. At six months, infant nighttime awakenings were estimated to be 2.09 (CI: 1.95 – 2.23) for mothers with low and stable depression symptoms (class 1), 2.60 (CI: 2.23 – 3.06) for maternal postnatal symptoms (class 2), and 1.96 (CI: 1.75 – 2.19) for maternal prenatal depression (class 3). That is, postnatal symptoms were associated with infant nighttime awakenings to a small degree, but prenatal symptoms were not. At 12 months, the pattern was similar, but with a lower number of awakenings overall, at 1.49 (CI: 1.39 – 1.60) for mothers with low and stable depression symptoms (class 1), 1.87 (CI: 1.59 – 2.19) for postnatal depression symptoms (class 2), and 1.40 (CI:1.25 – 1.57) for prenatal symptoms (class 3; Figure 3c, S. Table 12, S. Figure 19).

Maternal anxiety symptoms (SCL class 2) were related to slightly increased estimates of nighttime awakenings. At six months, infant nighttime awakenings were estimated to be 2.09 (CI: 1.95 – 2.23) for infants of mothers with no anxiety (class 1) and 2.24 (CI: 1.99 – 2.52) for infants of mothers with postnatal symptoms (class 2). At 12 months, there were subtle effects, with infants of mothers with no anxiety estimated to awaken 1.49 times (CI: 1.39 – 1.60) and 1.60 times for infants of mothers with postnatal symptoms (class 2; CI: 1.42 – 1.81; Figure 3d, see also S.Table 12, S.Figure 19).

Parental Perception of infant sleep

For parental perception of infant sleep, the best model fit included both EPDS and SCL class, each interacting with time of sleep measurement. Postnatal depression symptoms (class 2) were associated with a high probability of rating ~~of~~ infant sleep as being a problem, while low and stable symptoms (class 1) and prenatal symptoms (class 3) were not (Figure 3e, S. Table 13, S. Figure 20). At six months, mothers with low and stable symptoms (class 1) had a high probability of rating their infant's sleep as not a problem (83.1%;

CI: 79.4 – 86.8) and were less likely to rate their infant's sleep as being a slight problem (16.7%; CI: 13.2 – 20.4) or an extreme problem (0.14%; CI: 0.06 - 0.28). The prenatal symptom group had a similar pattern of probabilities compared to the low and stable group: with probability of perceiving sleep as being no problem (86.5%; CI: 80.2 – 91.3), a slight problem (13.4%; CI: 8.6 – 19.5), and a severe problem (0.09%: CI: 0.03 – 0.23). However, for postnatal symptoms (class 2), mothers were more likely to rate their infants as having a slight problem with sleep (32.3%; CI: 21.7 – 43.7) and were also less likely to say that their infants had no problem with sleep (67.0%; CI: 54.7 – 78.0).

At 12 months, mothers with low and stable symptoms had a high probability of rating their infants as having no problem with sleep (80.0%; CI: 75.8 – 84.0), and a lower probability of rating the infant as having either a slight problem with sleep (19.81%; CI: 15.9 – 23.9) or a severe problem (0.20%; CI: 0.10 - 0.39). For mothers with prenatal symptoms, the distribution of probabilities was like that for mothers with low and stable symptoms (no problem: 81.1%; CI: 73.2 – 87.4; slight problem: 18.8%; CI: 12.5 – 26.4; severe problem: 0.18%; CI: 0.06 - 0.45). However, for the postnatal symptom group (class 2), mothers were more likely to rate their infants as having a slight problem with sleep (27.5%; CI: 16.8 – 40.0) and were also slightly less likely to say that their infants had no problem with sleep (72.1%; CI: 58.8 – 83.0).

Maternal anxiety symptoms (SCL class 2) were also related to infant sleep being perceived as a problem compared to the no-symptom group (Figure 3f, S. Table 13, S. Figure 20). At six months, mothers with no anxiety symptoms (class 1), had a high probability of rating their infants as having no problem with sleep (83.1%; CI: 79.4 – 86.8), and a lower probability of rating their infants as having a slight problem with sleep (16.7% probability; CI: 13.2 – 20.4), and rarely saw sleep as a severe problem with sleep (0.14%; CI: 0.06 - 0.28) (group 3). In contrast, mothers with some anxiety symptoms were more likely to rate their infants as having a slight problem with sleep (23.6%; CI: 16.3 – 31.8) compared to mothers with no symptoms. At 12 months, there were minor differences in probabilities across the symptom compared with the no symptom group. Mothers with no symptoms had a 19.8% (CI: 15.9 – 23.9) probability of rating their infant as having a

slight problem with sleep, whereas mothers with anxiety symptoms had a somewhat higher probability, at 29.9% (CI: 21.5 – 39.2).

Discussion

Using data from a large birth cohort in Finland, we examined the relation between maternal depression and anxiety symptoms and mother-reported infant sleep at 6 and 12 months. Across the four infant sleep outcomes included, we found small but certain effects for concomitant depression symptoms, but almost no additional effects for anxiety symptoms beyond that already accounted for by depression. Our clearest associations between depression and infant sleep were concerning maternal reporting of infant sleep as a problem, where higher symptoms were related to more probable reporting of at least a mild sleep problem. This marked tendency to perceive sleep as problematic is of interest, given the small effects on duration-based measures of infant sleep (total sleep time, sleep onset latency) and frequency of nighttime awakenings. For two of these outcomes, total sleep time, and frequency of nighttime awakenings, our effects were strongest for mothers with the highest levels of depressive symptoms, where there were pronounced effects. We found clear negative effects for infants of mothers reporting the highest level of depressive symptoms, relative to mothers reporting no symptoms. For sleep duration, the difference was circa 20 minutes at 6 months and 30 minutes at 12 months. To contextualize a 20-minute difference, a large RCT to improve infant sleep reported 25 and 22 minutes of extra nocturnal sleep in the intervention group relative to the control group at 16 and 40 weeks [37].

Across all infant sleep outcomes, much of the variance was not explained by either depression or anxiety symptoms, or indeed the covariates included. Several large-scale studies have described the substantial naturally occurring variance in infant sleep [6, 38, 39]. There is also evidence for robust environmental contributions to sleep [e.g., 40], and household variables such as level of physical organization or chaos [41], and transient variables such as teething [42] or infections have been implicated in infant sleep outcomes. We suggest that much of the unexplained variance here is attributable to the normative variation in infant sleep,

or environmental factors not assessed here because only a small component could be explained by maternal postnatal mood symptomology.

Symptom Trajectories: depression

We also examined whether mothers' symptom trajectories, from prenatally into the postnatal period, are associated with infant sleep. As for the concomitant symptom analyses, the most robust effects emerged for depression symptoms over anxiety symptoms. For total sleep time, higher maternal depression symptoms, whether they occurred prenatally or postnatally, were associated with a lower infant sleep time at both 6 and 12 months compared to mothers with low symptoms (~15 mins). For sleep onset latency, an outcome which was challenging to model, there were effects of postnatal depression symptoms particularly at six months, and of prenatal symptoms at 12 months. For both symptom groups, infant sleep onset latency was approximately five minutes longer compared to infants of low-symptom mothers. However, credibility intervals were wide and overlapping for these analyses. For both nighttime awakenings and perception of sleep as a problem, effects were apparent only for *postnatal* depression symptoms, and not for prenatal symptoms. Anxiety symptoms had marginal effects on the reported numbers of nighttime awakenings and on parental perception of sleep as a problem, but to a smaller extent than that seen for depression symptoms.

Prenatal and postnatal effects

Our findings align with a small number of studies indicating postnatal depression effects on different infant sleep outcomes [17, 18, but see also Kim et al., 2020]. The trajectory models used here allow us to differentiate effects associated with depression symptoms occurring primarily during pregnancy or postnatally. While prenatal symptoms were associated with more negative outcomes for total sleep time, and sleep onset latency, only postnatal symptoms were associated with negative outcomes across all four infant outcomes. We interpret these findings as potentially relating to the different mechanisms underlying associations between maternal postnatal and prenatal depression and child outcomes [43]. Prenatal depression exposure may be associated with alterations to duration-based sleep outcomes only, whereas

postnatal depression may also impact parental cognitions around infant sleep, reflected in the perception of sleep as being problematic. More negative perceptions of infant sleep are consistent with models of interpretation biases in depression [44], whereby depressive symptoms are associated with negative interpretations of ambiguous information. Postnatal symptoms may also impact perception of infant nighttime awakenings, possibly via the disturbances to mothers' own sleep, which often characterize depression[45].

Maternal depression is often conceptualized in terms of negatively impacting parental quality via reduced sensitivity or responsiveness to infant cues [46]. Maternal anxiety, while also described as disrupting parental sensitivity, has been described in terms of heightened vigilance to infant cues [47], and might therefore plausibly be related more strongly to reporting nighttime awakenings in infants. Indeed, previous work has shown that maternal separation anxiety has been previously associated with objectively recorded infant nighttime awakenings at 10 months [48]. While we found associations between mothers' trajectories of anxiety symptoms and reported awakenings, for maternal symptoms occurring at the time of infant sleep rating, depression symptoms had greater explanatory power than anxiety symptoms. Our overall findings are consistent with previous work indicating that maternal anxiety was more relevant for infant crying and feeding, whereas maternal depression was more related to infant sleeping issues [49].

Study limitations: Low levels of depression and anxiety and self-reported infant sleep

Why have some studies reported pronounced effects of antenatal maternal depression on even later infant developmental time points than tested here [e.g., 3.5 years; 22]? One explanation may be related to the prevalence and severity of mood symptoms reported in the present sample compared to other studies. For example, in the Toffol et al. study, 12% of mothers had clinically significant depression symptoms, compared to just 6% of the current sample who had elevated depression or anxiety symptoms. Negative outcomes for the child seem to be particularly pronounced where maternal mood disruption is persistent or recurrent [43], with low socioeconomic support [50]. In addition to a low prevalence of elevated, chronic

symptoms, the sample tested were from a Finnish cohort and are relatively advantaged from a socioeconomic perspective [25]. These socioeconomic conditions limit the generalizability of our findings to less homogenous sociocultural settings, or to conditions of socioeconomic disadvantage. Furthermore, attrition in this sample was related to maternal symptom levels [for full profile of the sample, see 25], such that there may be dilution of the observed effects.

In addition to a low-symptom group, a further limitation here is that the data analyzed here are based solely on parent-reported questionnaires. Ideally, infant sleep would be measured using both self-reports and actigraphy measures. Parent reports often provide different estimates of infants' sleep compared to actigraphy [51] and indeed, recent work has reported that mothers' emotion symptoms are correlated with their infants' self-reported sleep, but not their infants' actigraphy-recorded sleep [52]. It is not surprising that if mothers are experiencing depressive symptoms, they are concomitantly more likely to rate their infants' sleep as problematic. However, parents' perceptions of their infant's sleep are important because these perceptions influence the likelihood of help-seeking, or indeed parents' experience of their own stress and parenting competences. We further point to the size of the effects as important: much of the variance in self-reported infant sleep outcomes is not explained by concomitant or longitudinally measured maternal mood symptoms.

Given the type of data reported here, several variables presented challenges for our statistical modelling, because of parents' tendency to report units of time in whole or half units, rather than as a pure continuous time dimension. This meant that our data had peaks and valleys. We accordingly chose to rely on a flexible Bayesian statistical framework with a well-established diagnostic workflow to ensure assumptions are explicitly stated and tested and the inference process is checked for robustness [53]. Bayesian modeling highlighted convergence issues for some models, which would not have been evident in more traditional analyses. The issues could be remedied by adding noise to the data in some instances and using beta correction in others (see S.Table 2 for details).

Conclusion

Our primary finding is that mothers with depression symptoms occurring in the postnatal period are more likely to perceive their infant's sleep as problematic compared with mothers with lower or no symptoms. Where we found effects on duration-based infant sleep outcomes, these were small, and clearest for depressive symptoms over anxiety symptoms. This is consistent with a body of literature suggesting effects of maternal depression in the perinatal period on infant sleep [e.g., 12, 21, 22, 54]. We draw these conclusions from a large population sample, with multiple measures of gestational and postnatal symptoms, and data from infant age six months and 12 months, across different infant sleep outcomes.

Data availability

The data cannot be made openly available due to restrictions by national law and local ethical permissions. Data sharing is possible via formal material transfer agreements for which interested investigators should contact the senior author.

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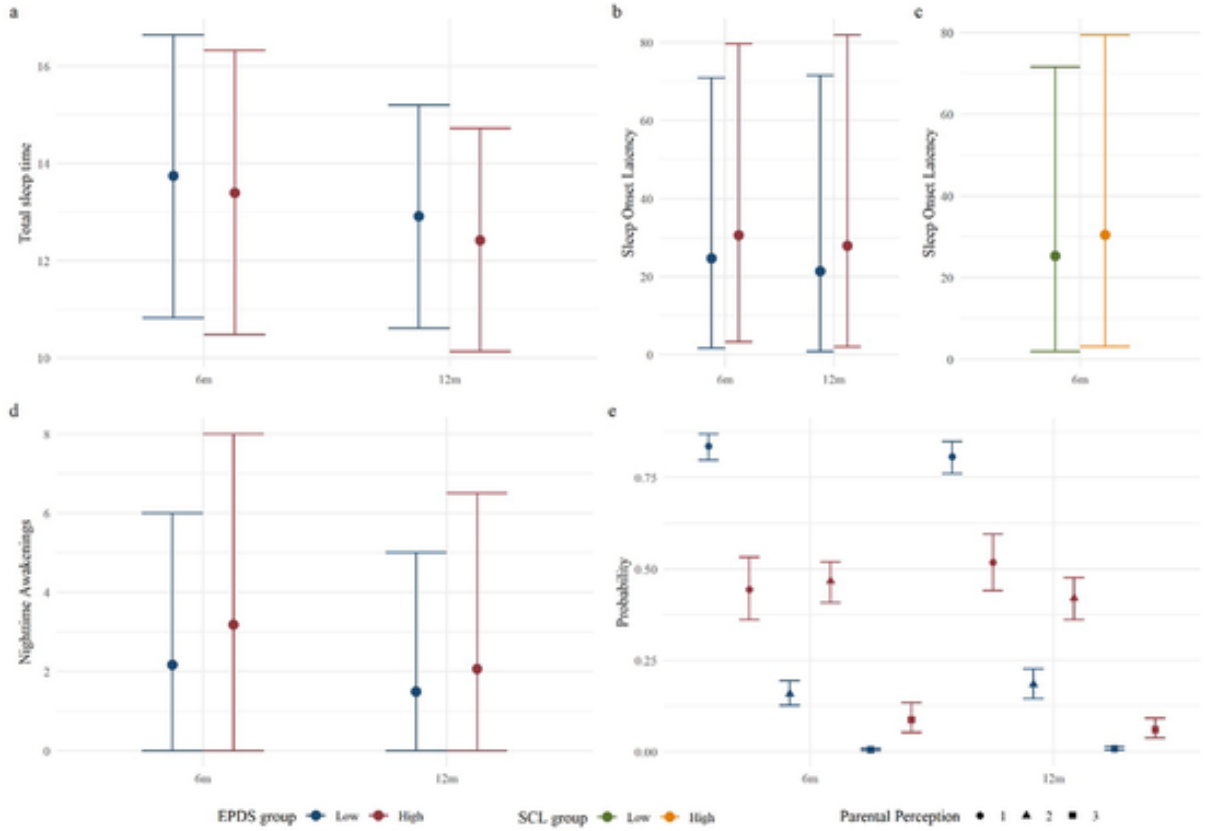

Figure 1. Estimates of sleep outcomes for the infants of mothers with the lowest (blue) and highest (red) 10% EPDS scores at six months and 12 months. a. Total sleep time b. Sleep onset latency (EPDS) c. Sleep onset latency for the SCL lowest and highest scores d. nighttime awakenings e. parental perceptions of infant sleep (1 being no problem, 2 slight problem, 3 severe problem). Error bars indicate credible intervals.

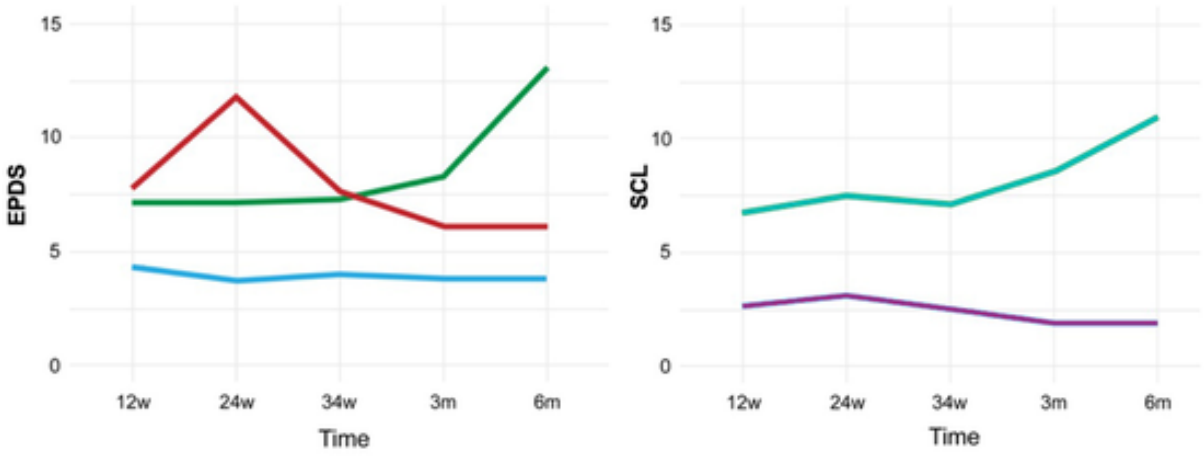

Figure 2: The selected latent class models for depression symptom trajectories with three classes (EPDS, left) and for anxiety symptom trajectories with two classes (right). For EPDS, Blue = class 1 (low and stable symptoms), Green = class 2 (postnatal symptoms), Red = class 3 (prenatal symptoms). For SCL, Purple = low and stable (class 1) and Turquoise = class 2 (postnatal symptoms).

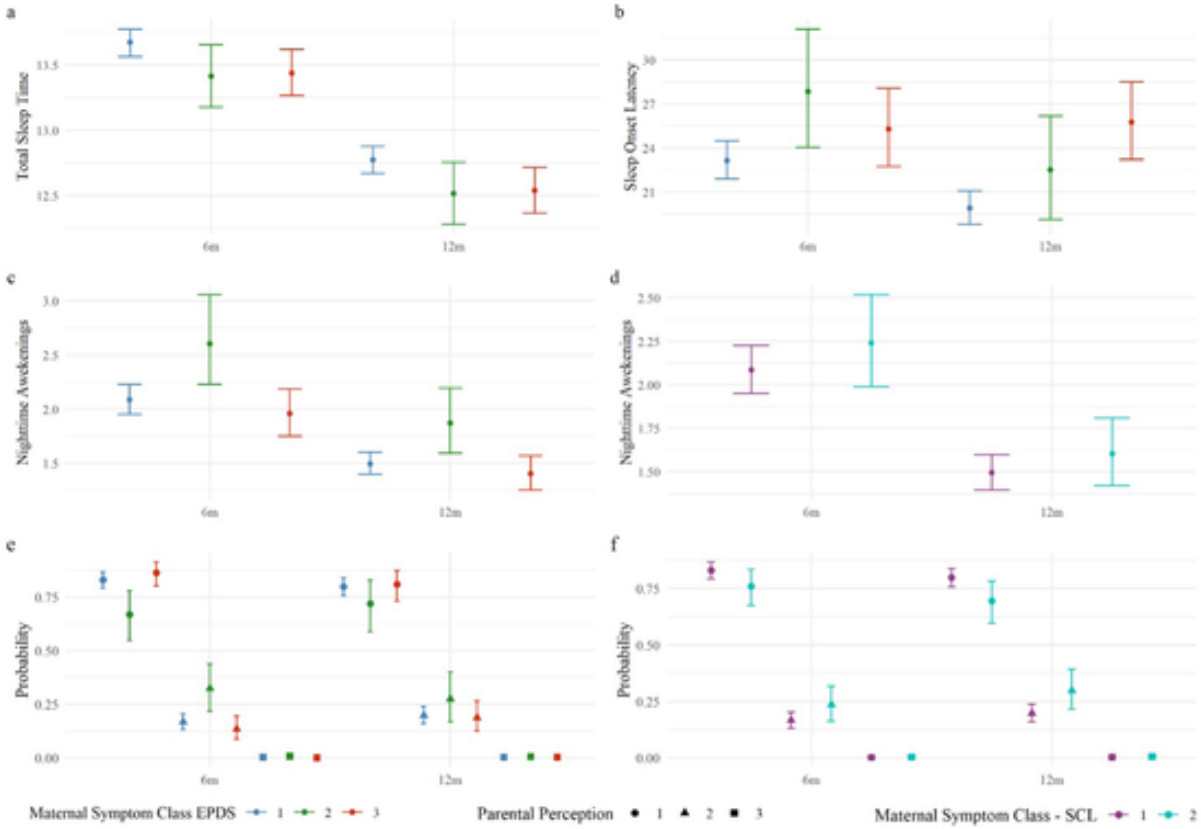

Figure 3. Estimating the conditional effect of mothers' EPDS symptom grouping at six months and 12 months (a – e) and mothers' SCL symptom grouping (f): a. Total sleep time b. Sleep onset latency c. Nighttime awakenings EPDS d. Nighttime awakenings SCL e. Perceptions of infant sleep (probability of sleep being perceived as: 1= no problem, 2 = slight problem, 3 = severe problem) f. Perceptions of infant sleep. Error bars indicate 95% credible intervals.

Table 1. BISQ variables for Total Sleep Time (TST), Sleep Onset Latency (SOL), nighttime awakenings and reporting of infant sleep as a problem (parental perception).

	n	M	SD	Min	Max
6-month TST	1907	13.66	1.41	6	21
12-month TST	1604	12.76	1.07	6.5	16
6-month SOL	1920	25.45	20.32	0	180
12-month SOL	1619	21.81	20.88	0	300
		Median		Min	Max
6-month nighttime awakenings	1882	2		0	15
12-month nighttime awakenings	1565	1.5		0	13.5
		None	Mild	Severe	
6-month, “Infant sleep as a problem”*	1936	66.5%	24.2%	1.8%	
12-month, “Infant sleep as a problem”*	1636	53.7%	22.5%	1.9%	

* missing data means that proportions do not add to 100%

Table 2. Sample demographic characteristics. EPDS and SCL scores at the pre- and postnatal time points. ‘Elevated’ indicates the percentage of participants with scores above a threshold indicating potential clinical significance (SCL>10; EPDS>12).

Timepoint	n	Mean	SD	Elevated score %	Min	Max
	EPDS					
Gw. 14	1973	4.99	3.97	6.84	0	27
Gw. 24	1997	4.78	4.04	6.91	0	25
Gw. 34	1967	4.72	3.98	6.35	0	26
3 m. postnatal	1920	4.28	3.78	5.1	0	21
6 m. postnatal	1867	4.53	4.15	6.27	0	27

Timepoint	n	Mean	SD	Elevated score %	Min	Max
12 m postnatal	1566	4.91	4.07	7.15	0	23
	SCL					
Gw.14	1972	3.19	3.92	7.1	0	33
Gw.24	1995	3.83	4.32	9.97	0	30
Gw.34	1962	3.1	3.91	7.34	0	33
3 m. postnatal	1917	2.56	3.51	5.48	0	24
6 m. postnatal	1869	2.78	3.96	6.47	0	29

Variable	*N*	*Mean*	*SD*	*Min*	*Max*
Mother's age	2094	30.68	4.38	18	45
Number of rooms	1975	3.65	1.5	1	16
Birthweight	2064	3556.52	525.97	460.00	5470
Number of siblings					
	1921	1 (Median)	0.96	0	9
	N			%	
Breastfeeding	2048			95.5% (reporting "Some" breastfeeding)	
Primiparious – yes	1110			53%	
Education level – post primary					

Variable	*N*	*Mean*	*SD*	*Min*	*Max*
Mid & low (1-5 years)	650			31%	
High/Vocational (6)	597			28.5%	
High (7-9)	752			35.9%	
Smoking during pregnancy - yes	283			13.5%	

Table 3. Results of the EPDS and SCL model comparisons

Class	AIC	BIC	Entropy	Proportion	Posterior Probability
1	54293	54412	1	100	1
2	53969	54121	0.81	14/86	0.87/0.96
3	**53580**	**53766**	**0.88**	**86/4/10**	**0.96/0.88/.87**
4	53403	53623	0.85	9/81/3/6	0.85/0.94/0.9/.81
5	53672	53926	0.44	15/3/81/0/0	0.76/0.88/0.61/NaN/NaN
6	53669	53957	0	16/4/80/0/0/0	0.73/0.82/0.34/NaN/NaN/NaN

Class	AIC	BIC	Entropy	Proportion	Posterior Probability
1	52454	52573	1	100	1
2	**51555**	**51708**	**0.95**	**92/8**	**0.99/0.93**
3	51567	51754	0.58	91/9/0	0.81/0.91/NaN
4	51116	51336	0.62	6/87/7/0	0.87/0.76/0.91/NaN
5	51018	51272	0.61	6/5/0/89/0	0.91/0.9/NaN/0.78/NaN

Class	AIC	BIC	Entropy	Proportion	Posterior Probability
6	51175	51463	0	5/6/89/0/0/0	0.88/0.88/0.48/NaN/NaN/NaN

NaN= not a number, empty cells