Published in final edited form as:

Infant Behav Dev. 2012 June ; 35(3): 489–498. doi:10.1016/j.infbeh.2012.04.005.

Parent-child interaction, maternal depressive symptoms and preterm infant cognitive function

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Abstract

Preterm infants are at risk for cognitive difficulties due to infant neurological immaturity and family social disadvantage, and this may be exacerbated by maternal depressive symptoms. This longitudinal study of infants born preterm (<35 weeks) or low birth weight (<2500 grams) (n=137) tests if maternal depressive symptoms at 4 months is associated with preterm children's cognitive function at 16 months. Additionally, we test if this association is mediated by the quality of parent-child interaction at 9 months, and if these associations differ by levels of maternal social support. Children's cognitive function was measured using the Bayley Scales of Infant Development, 2nd edition. Maternal depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale. Perceived social support was measured using the Maternal Support scale. The quality of parent-child interaction was measured using the Parent-Child Early Relational Assessment. Linear regression and structural equation modeling were used to test the research questions. Postnatal depression at 4 months is associated with lower cognitive function (mean difference=-5.22, 95% CI: [-10.19, -0.25]) at 16 months controlling for a host of socioeconomic characteristics. For mothers with fewer depressive symptoms, bolstering effects of maternal supports on children's cognitive function were evident. We find no evidence for effect mediation by quality of parent-child interaction. Early exposure to maternal depressive symptoms appears to have a negative influence on preterm children's later cognitive function. These findings suggest important policy and programmatic implications for early detection and intervention for families of preterm infants.

Keywords

postnatal depression; parent-child interaction; preterm birth; cognitive function

1.1 Introduction

Preterm birth (< 37 weeks) is associated with neurodevelopmental difficulties, including low cognitive function, which can persist throughout the lifecourse (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Board on Health Sciences Policy, Committee on Understanding Premature Birth and Assuring Healthy Outcomes, Institute of

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Medicine of the Academies, 2006). Predictors of low cognitive function among preterm infants include not only social and neurological characteristics of infants, but also the well-being of families (Msall, Sullivan, & Park, 2010; Wertlieb, 2003).

1.1.1 Theoretical Framework

Ecological theories (Bronfenbrenner, 1979; Sameroff & Fiese, 2000) and the lifecourse model of human development (Ben Shlomo & Kuh, 2002) informed the current study. These theoretical frameworks highlight the importance of early exposure to risk (e.g., neonatal morbidity, maternal psychosocial distress, and adverse socioeconomic environments) *and* resilience (i.e., protective factors in the face of adversity) in shaping neurodevelopmental trajectories of young children. In particular, the ecological framework highlights the importance of different contextual effects on children's development. For infants, parental and family influences are particularly relevant since infants are so dependent on parental provision of a wide variety of resources for growth and development.

1.1.2 Postnatal Depression

The association between postnatal depression and children's emotional and behavioral development has been well-documented in the full-term population (Seifer & Dickstein, 2000), but is less understood in the context of cognitive function, particularly in preterm infants (Hay, Pawlby, Sharp, Asten, Mills, & Kumar, 2001). Research with full-term infants suggests biological (e.g., altered frontal lobe activity) and social (e.g., less maternal contingency) pathways linking postnatal depression and lower cognitive function. These are likely exacerbated in the face of neurological immaturity and social risk associated with preterm birth (Seifer & Dickstein, 2000; Sohr-Preston & Scaramella, 2006). Elevated rates of postnatal depression in mothers of preterm versus full-term infants are common and socially disadvantaged mothers and younger children are particularly vulnerable (Aarnoudse-Moens, et al., 2009; Eisengrat, Singer, Fulton, & Baley, 2003; Poehlmann, Miller Schwichtenberg, Bolt, & Dilworth-Bart, 2009).

1.1.3. Dyadic Interaction

Ecological and lifecourse theoretical frameworks suggest the importance of conceptualizing risk and resilience as dynamic constructs that act additively and interactively. That is, early exposure to maternal depressive symptoms is likely to affect subsequent parent-infant interactions, which in turn compromises opportunities' for infants to explore, learn, and bolster foundations for later cognitive development, particularly in the context of developmental vulnerability associated with preterm birth. For example, in structured interactions with their infants, depressed mothers demonstrate more limited eye gaze, frequent perceptions that their infant is difficult to care for, and are more likely to be in a matched negative rather than positive state with their infants compared to non-depressed mothers (Seifer & Dickstein, 2000). There is growing evidence that similar patterns exist in unstructured dyadic interactions between mothers and their preterm infants [Poehlmann, et al., 2011a; Poehlman, et al., 2011b].

1.1.4. Maternal Supports

Although preterm infants, on average, experience less optimal cognitive development compared to full-term infants (Bhutta, Cleves, Casey, Cradock, & Anand, 2002), there is significant within-group variability. It is important to examine protective factors that foster *resilience* in preterm infants (Masten, 2001). For example, preterm children of depressed mothers reporting high social support have more optimal cognitive outcomes than those whose mothers report lower levels of support (McManus & Poehlmann, forthcoming). A hypothesized mechanism explaining this finding is that maternal supports foster

environments that shape learning and cognitive development, particularly for low-income families (Lee, Holditch-Davis, & Shandor Miles, 2007; Klebanov, Brooks-Gunn, McCarton, & McCormick, 1998; Stein, Malmberg, Sylva, Barnes, Leach, & the FCCC team, 2008).

In the present study we explore risk (i.e., maternal depressive symptoms) and resilience factors (i.e., maternal supports) to test their cumulative and interactive influence on parent-infant interactions and preterm infant's cognitive development. This has the potential to make an important contribution to the literature. Previous studies investigating parental attributes and provision of developmentally supportive environments (Klebanov, et al., 1998; Stein, et al., 2008) only considered maternal responsiveness and quantity of learning opportunities (e.g., books) rather than quality of the parent-child interaction and only one (Klebanov, et al., 1998) studied preterm, low birth weight infants. Parenting quality and infant emotional/behavioral regulation, particularly in the context of varying maternal supports, may be a more sensitive measure of children's early cognitive experiences.

The purpose of this study is to 1) investigate the effect of early exposure to maternal depressive symptoms on later child cognitive function, 2) determine if this association is mediated by the quality of the child-parent social interaction, and 3) evaluate if these associations differ by levels of maternal social support. We hypothesize that in the presence of greater maternal supports, maternal depressive symptoms will have a less adverse influence on parent-infant interactions and children's cognitive function.

1.2 Materials and Methods

1.2.1 Study Sample

The study sample includes 181 mother-infant dyads. During 2002–2005, staff at 3 newborn intensive care units (NICU) in Wisconsin recruited 186 mother-infant pairs and of those, 181 (97%) participated. Families were invited to participate in the study if they met the following criteria: 1) infants were born at 35 weeks gestation or less or weighed less than 2,500 grams at birth, 2) infants had no known congenital malformations or prenatal drug exposure, 3) mothers were at least 17 years of age, 4) mothers could read English, and 5) mothers self-identified as the infant's primary caregiver. Infants and their families were followed up at 6 timepoints: prior to NICU discharge, 4 months, 9 months, 16 months, 24 months, and 36 months. There was 15% attrition rate between hospital discharge and 16 months of age. The present sample is drawn from 157 mother-infant dyads for whom social support information was collected as part of an ancillary study. These 157 families did not differ from the original 181 on depression scores, socioeconomic characteristics, neonatal risk factors, or attrition rate. Of the 157 children, 20 were missing data on covariates of interest (i.e., 10 for maternal employment and 10 for marital status). Sensitivity analyses including these latter cases with missing data had no discernible effect on the results. We restrict our analysis to 137 children with complete data.

1.2.2 Outcome Measure

At 16 months, the Bayley Scales of Infant development (BSID), 2nd edition, Mental Development Index (Bayley, 1993) was used. The study collected cognitive function data at all study timepoints except hospital discharge and 4 months postterm. The 16-month cognitive function scores were chosen for these analyses to allow for a temporal investigation of early exposure to maternal depressive symptoms, dyadic interaction, and cognitive function. The 16 month timeframe was deemed to be early enough to validly measure cognitive function without being too distal to the exposures of interest. Moreover, use of the BSID at 16 months postterm is consistent with the Infant Health and Development Program (Klebanov, et al., 1998), which allows for comparability.

The BSID is a widely used assessment of cognitive function appropriate for children ages 1 to 42 months. The Mental Developmental Index of the BSID measures concept formation, visual permanence, and sensorimotor development. Completed items are summed for an overall score and compared to a standardized distribution (mean=100, SD=15). The BSID, Mental Developmental Index has excellent reliability ($\alpha=.91$), moderate to high concurrent validity ($r=.59-.79$) (Bayley, 1993). In the current study, BSID scores are based upon postterm age (i.e., adjusted for prematurity).

1.2.3 Maternal Depressive symptoms

Maternal depressive symptoms were measured at 4 months using the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977). Mothers reported, on a 4-point scale (0=rarely/none of the time to 3=all of the time), their frequency of symptoms for 20 scale items. Higher scores indicate more depressive symptoms with scores greater than 16 indicating clinically depressive symptoms. The CES-D has been used extensively in epidemiologic studies of postnatal women. In the larger study maternal depressive symptoms were measured at 4 months, 9 months, 16 months, and 24 months and reliability was good ($\alpha=.85$) across all timepoints. For these analyses, we utilized the 4-month CES-D score to test the hypothesis that early exposure to maternal depressive symptoms influenced subsequent infant cognitive function. To increase interpretability and clinical meaningfulness, we dichotomized (<16 or ≥ 16) continuous CES-D scores.

1.2.4 Neonatal and Socioeconomic Characteristics

Child's race and ethnicity was categorized as white, non-Hispanic or not (due to small numbers within minority sub-groups). Yearly family (i.e., household) income was measured in US dollars and grouped as $<\$10,000$, $\$10,000$ to $\$30,000$, $\$30,000$ to $\$60,000$, and greater than $\$60,000$. Maternal education was categorized as high school or less, some college, college degree, and graduate degree. We also measured maternal and paternal employment status (employed versus unemployed), parity (primiparous versus multiparous), child's sex, presence of a partner (married/cohabitating versus not married/not cohabitating), maternal smoking (present/former or never), birthweight (in grams), gestational age in weeks, child's chronological age at hospital discharge, and mother's age at child's birth in years. All neonatal socioeconomic covariates (Table 1) with the exception of maternal employment (measured at 4 months) were collected at hospital discharge.

1.2.5. Maternal Social Support

Maternal perceived social support was measured at 4 months using the Maternal Support scale (Poehlmann et al., 2009) – an index of emotional, informational, household, child care, financial, respite, and other support – collected about the baby's father, mother's parents, in-laws, and extended family. A total score was calculated by summing each type of support (7) across the four sources resulting in a range from 0 to 28. The internal consistency reliability of maternal support scale scores ranged from .73 to .87 across 4 timepoints (hospital discharge, 4, 9, and 16 months postterm). Test-retest correlations for maternal report of support between the child's birth and 4, 9, 16, and 24 months ranged from .55 to .86. The maternal support scale also significantly correlated with the intimate relationship satisfaction and family satisfaction scales of the Social Support measure of Crnic, Greenberg, Ragozin, Robinson, and Basham's (1983) Inventory of Parent's Experiences administered at 16 months (correlations ranged from .26 to .37, $p < .01$). An analysis (Poehlmann et al., 2009) utilizing the maternal support scale showed that, in each hierarchical linear model assessed, maternal support was significantly and negatively associated with maternal depression scores, indicating that within persons, as maternal support increased (or decreased) over time, depression correspondingly decreased (or increased). Moreover, the scale has been used to provide evidence in support of hypotheses

that more maternal support buffers social and biological associated with health and neuodevelopmental outcomes (McManus & Poehlmann, forthcoming) thereby demonstrating its predictive and construct validity. For these analyses, total support was categorized as high (more than 1 SD above the mean), low (less than -1 SD below the mean), and otherwise middle to increase interpretability and meaningfulness.

1.2.6 Parent-Child Interaction

Parent-child interaction was measured at 9 months using the Parent-Child Early Relational Assessment (PCERA) (Clark, 1985). The PCERA measures parent's and child's affect and behavioral characteristics during a 5-minute play observation using 29 parent items across 3 sub-scales of *parenting quality* (positive affective involvement and verbalization; negative affect and behavior; and intrusiveness, insensitivity, and inconsistency) and 28 child items across 3 sub-scales of *infant emotional/behavioral regulation* (positive affect, communicative, and social skills; quality of play, interest, and attentional skills; and dysregulation and irritability). Reliability across parent ($\alpha=.86$ to $.91$) and child ($\alpha=.83$ to $.87$) sub-scales is excellent. Previous psychometric analyses (Clark, 1999) indicate that PCERA items are a valid measure of parent quality and child emotional and behavioral regulation. For the present study, we utilized scores for the 3 parent and 3 child sub-scales. Sub-scale cores ranged from 1 (negative relational quality) to 5 (positive relational quality). Ten percent of the sample was independently coded by at least two trained research assistants. Interrater reliability ranged from $.83$ to $.97$, with a mean of $.88$.

1.3 Theory and Calculation

1.3.2 Analytic Strategy

To answer our research questions we used linear regression and structural equation modeling (SEM) (Bollen, 1989). Structural equation modeling is a family of analytic techniques that estimates a *measurement model* - the association between PCERA sub-scale scores and the latent constructs (infant emotional/behavioral regulation and parenting quality) and a *structural model* - the inter-relationships between maternal depressive symptoms, covariates, latent constructs, and child's cognitive function (Figure 1). SEM explicitly models measurement error, which allows more precise estimation of complex inter-relationships in a conceptual model (Figure 1).

First, linear regression tested the association between maternal depressive symptoms at 4 months on child's cognitive function at 16 months controlling for infant's race and ethnicity, parity, infant's sex, maternal education categories, family income categories, and presence of a partner. Preliminary analyses revealed that maternal and paternal employment, maternal smoking, child's age, and mother's age had small, insignificant effects on children's cognitive function. Therefore, we excluded these covariates. Gestational age was highly collinear ($r=.70$) with birth weight, so we include only birth weight. However, birth weight had small insignificant effect (mean difference=0.001, 95% CI: -0.002, 0.005) and we excluded birth weight.

The second linear regression model additionally included maternal perceived social support at 4 months and a third linear regression model additionally included an interaction term between maternal perceived social support and maternal depressive symptoms. The third (i.e., interaction) model tested if the effect of maternal depressive symptoms on children's cognitive function is uniform across levels of levels of social support. For the linear regression models, we report the mean difference (and 95% CI) in child's cognitive function for each covariate.

For the measurement model, we report the factor loadings (i.e., the strength of the association between the PCERA sub-scale score and the underlying parent or child latent construct) and three fit statistics -- the comparative fit index (CFI), the root mean square of approximation (RMSEA), and the standardized root mean square residual (SRMR). Values of CFI greater than .95 and values of RMSEA and SRMR less than .06 are considered acceptable and indicate that the model fits the data structure well (Hu & Bentler, 1999).

In the structural model, we test if the inter-relationships between maternal depressive symptoms, infant emotional/behavioral regulation and parenting quality, and cognitive function (Figure 1) differ for varying levels of maternal perceived social support (i.e., effect modification). To test for effect modification, we constrained the structural model (i.e., path analysis) to equality across groups characterized by levels of social support (i.e., high, middle, and low). We tested for differences between the constrained and unconstrained model using chi-square test of differences. A significant deterioration in model fit between the models indicates that the associations between maternal depressive symptoms, parent-child interaction, and children's cognitive function are *different* for varying levels of social support. Finally, we tested if the constructs of infant emotional/behavioral regulation and parenting quality mediated the association between maternal depressive symptoms and children's cognitive function, separately, by level of social support.

To test for mediation, we calculated the overall indirect effects and 95% confidence interval between the exposure (maternal clinical depressive symptoms), mediators (infant emotional/behavioral regulation and parenting quality), and outcome (child's cognitive function) separately for each social support category using methods described by Hayes (2010) and Vanderweele (2010). Linear regression models were conducted in SAS v9.2 (SAS Institute Inc., Cary, NC, USA, 2002–2003) and SEM analyses were conducted in Mplus v6 (Muthen & Muthen, 1998–2007). The Institutional Review Board at all participating institutions approved this study. All parents provided written consent to participate.

1.4 Results

In Table 2, Model 1 suggests that maternal depressive symptoms were associated with lower child cognitive function (mean difference=−5.22, 95% CI: [−10.19, −0.25]), conditional on a host of child and family socioeconomic characteristics. Being female (mean difference=4.50, 95% CI: [0.82, 8.18]) and in a household with a family income greater than \$60,000 (mean difference=11.21, 95% CI: [0.68, 21.74]) was associated with higher cognitive function.

In Table 2, Model 2 additionally included categories maternal support. Maternal support at 4 months is not significantly associated (i.e., no mean effect) with cognitive function at 16 months, after accounting for socioeconomic characteristics and maternal depressive symptoms. Model 3 (Figure 2) additionally included an interaction term between maternal depressive symptoms and maternal perceived social support. This interaction term was statistically significant (F test, $p < .01$) indicating that the influence of maternal symptoms of clinical depression on children's cognitive function is not uniform across varying levels of maternal perceived social support. Rather, there appears to be a maternal support gradient in infants' cognitive function for mothers with fewer depressive symptoms. That is, among mothers with fewer depressive symptoms, more maternal supports are associated with higher cognitive function. Among mothers with elevated depressive symptoms, the maternal support slope is relatively flat. That is, more maternal supports appear to be associated with relatively no change in cognitive function. Moreover, the statistically significant difference in slopes (i.e., between mothers with elevated versus non-elevated depressive symptoms, Figure 2) stems from disparity in cognitive function within the high maternal support group.

This is, among mothers with lower depressive symptoms, highest perceived maternal support is associated with particularly high cognitive function.

Table 3 presents the factor loadings for the PCERA sub-scale scores and the two latent constructs -- infant emotional/behavioral regulation and parenting quality. All factor loadings were greater than .30 indicating a strong relationship with the underlying constructs (Howard, Tinsley, & Tinsley, 1987). The model fit statistics (CFI=.998, RMSEA=.041, SRMR=.039) indicate acceptable model fit suggesting that a measurement model with two factors fit the data well.

We then tested the hypothesis that the structural model (i.e., path analysis) differed by level of maternal perceived social support. The results of the chi-squared test for differences between models ($\chi^2_3 = 8.0$, $p < .05$) suggests that the inter-relationships depicted in the structural model differ significantly in the presence of varying levels of maternal perceived social support.

Within the high social support group, we found evidence for statistically significant inverse associations between postnatal clinical depressive symptoms and infant emotional/behavioral regulation (coefficient=-.11, s.e.=0.04) as well as between the parenting quality and child's cognitive function (coefficient=-2.64, s.e.=.87). However, these effect estimates should not be interpreted in isolation. That is, parent-infant effect estimates from the mediation-modification analyses (i.e., effect modification by levels of maternal support and mediation by parent-infant interaction) must consider the effect estimate of maternal support when estimating cognitive function across sub-groups of parent-infant interaction and maternal supports. However, since we found no evidence for statically significant indirect effects (mediation) of parent-child interaction, we present cognitive function scores for maternal support sub-groups (i.e., statistically significant effect modification without parent-infant interaction) in Figure 2.

1.5 Discussion

The results of these analyses suggest that early exposure to maternal depressive symptoms predicts preterm children's later cognitive function, above and beyond a host of socioeconomic characteristics. This association appears to vary substantially by maternal perceived support levels, yet we find no evidence that quality of parent-child interaction mediates the association between maternal depressive symptoms and children's cognitive function.

The findings from this study differ from previous literature suggesting a null effect of maternal depression (measured prenatally) on full-term children's cognitive function (Tse, Rich-Edwards, Rifas-Shiman, Gilman, & Oken, 2010). However, mothers of preterm infants demonstrate more severe psychosocial distress (Eisengrat, et al., 2003) and caregiving difficulties (Sohr-Preston & Scaramello, 2006), which appear to be exacerbated by preterm children's medical fragility, neurological immaturity, and interactional difficulties (Board on Health Sciences Policy, 2006; Msall, et al., 2010). Our results are consistent with our a priori hypothesis regarding the association between children's early exposure to maternal depressive symptoms and their later cognitive function. However, it should be noted that this study only investigated the association between maternal depressive symptoms at 4 months postterm and infant cognitive function at 16 months postterm. It is possible that these associations may differ earlier or later in infancy and childhood. Indeed, depressive symptoms among mothers of preterm infants are dynamic during the first 24 months postterm (Poehlmann, et al., 2009). Previous research with this sample (McManus & Poehlmann, 2010) suggests that the role of maternal depressive symptoms appears to be most influential for early (i.e., 16 months postterm) versus later cognitive function (i.e., 36

months postterm). Thus, the current study adds to a growing body of literature suggesting the influence of early exposure to maternal depressive symptoms on later infant cognitive function, but the results should be interpreted with appropriate caution.

Our finding that maternal perceived social support is an important correlate of maternal depressive symptoms is consistent with previous research (Poehlmann, et al., 2009) suggesting a dynamic, influential relationship between maternal support and maternal symptoms of clinical depression. In the present study, we further explore if maternal depressive symptoms on children's cognitive function is particularly harmful for children whose mothers report low perceived social support. Clinically depressed mothers often struggle to provide optimal physical and social environments for their children (Seifer & Dickstein, 2000; Sohr-Preston & Scaramella, 2006), and this appears to be exacerbated when social support resources (i.e., financial, emotional, instrumental, informational, etc) are sparse. The results of the current study suggest an interesting association between maternal supports and children's cognitive function whereby additional supports appear to be most helpful for mothers with fewer depressive symptoms. Moreover, for mothers with elevated depressive symptoms, additional supports appear to have a negligible effect on children's cognitive function. This suggests areas of future research to better understand the role of maternal supports on buffering risk and promoting resilience among families with a preterm infant. For example, we chose a measure of social support inclusive of seven different types of support because we had no a priori hypothesis about which may be most germane and the full scale would be most reliable from a statistical standpoint. However, we acknowledge that understanding how specific types of social support influence postnatal depression and children's cognitive function would facilitate more optimal implementation of interventions and future research should explore the social support sub-scales. For example, previous literature (Campbell & Cohn, 1997) has suggested the importance of emotional and instrumental support on mitigating maternal depression among mothers of full-term infants. Future research should test this hypothesis in mothers of preterm infants. Moreover, the current study focused on the perceived quantity of maternal supports. It is possible that despite similar quantities of maternal supports, the quality differs. This may be particularly salient for mothers with elevated depressive symptoms and suggests the importance of future research to explore which support interventions might be most helpful for subgroups of mothers of a preterm infant.

We hypothesized that the quality of the parent-child interaction would mediate the relationship between maternal symptoms of clinical depression and children's cognitive function, yet we found no evidence for this. A dearth of previous studies with related research questions limits comparisons. However, our finding differs from the results of a mediational analysis (Klebanov, et al., 1998) using a preterm, low birth weight sample where the quality of the home environment partially explained the inverse association between socioeconomic status and children's cognitive function. In the present study, the lack of statistically significant mediation effects appears to stem from a relatively weak association between maternal depressive symptoms and parent-child interactions. This finding is consistent with a previous study (Boyd, Zayas, & McKee, 2005) of socially disadvantaged mothers of full-term infants where clinical postnatal depression had little effect on parent-child interaction quality. Rather, positive and negative life events (e.g., moving, losing a job, finding new friends, trouble at work, illness, etc) had a more meaningful influence than postnatal depression per se, on parent-child interactions. Although this suggests the potential importance of understanding the contribution of mothers' broader social context to the parent-infant interaction and perhaps children's cognitive function, the current study did not measure positive or negative life events.

We acknowledge the study's limitations. The relationships that we describe might be biased by unmeasured confounders. For example, we have no measure of current child health status. We investigated the influence of several measures of neonatal morbidity –gestational age, birth weight, days on mechanical ventilation, and days hospitalized in the NICU – and found, consistent with previous research (Poehlmann, et al., 2009) using this sample, that none had a meaningful influence on the associations under study. However, it is possible that these measures neglect to capture other aspects of children's current health, which may influence maternal depression and children's cognitive function. We also have no information on prenatal depression. Understanding postpartum depressive symptoms in the context of a continuum of depressive symptoms (i.e., preexisting) across the lifecourse has important implications for appropriately screening women and tailoring clinical interventions for women and their infants. Future research should include multiple measures of depression (e.g., prior to, during, and post pregnancy) to better inform clinical and population health practice.

Moreover, our measure of postnatal depressive symptoms is collected via maternal report. This has the potential to introduce bias if mothers differentially report depressive symptoms in ways that coincide with children's cognitive function. Clinical diagnoses of depression were not ascertained in this study nor did we include a measure chronicity of maternal depressive symptoms in the current study. Moreover, we did not include a measure of maternal anxiety, which future research should explore.

Families lost to follow-up were somewhat more likely to be socially disadvantaged. This is of particular relevance given that socially disadvantaged families are more likely to experience postnatal depression and lower child cognitive function. Therefore, this introduces bias to our results, but likely in the direction of underestimating the true association between maternal depressive symptoms and children's cognitive function.

The sample was derived from a region of one mid-Western state and was homogenous with regard to socio-economic characteristics. The lack of racial, ethnic, and social diversity may have contributed to lack of statistical significance with regard to parent-infant interaction. Moreover, the patterns observed in this study with regard to maternal supports may differ across racial and ethnic sub-groups. Future research should include larger, more diverse samples to better understand potential social disparities in cognitive function that may stem from parent-infant interaction and/or differing maternal supports.

Finally, our measure of perceived social support asked only about the presence rather than the quality of various types of social support. Thus, our findings may underestimate the true association between perceived social support, maternal depressive symptoms, and children's cognitive function. Understanding what types of supports are most helpful to mothers of preterm infants will assist in developing appropriate interventions.

Despite these limitations, this study has strengths. We utilized a combination of ordinary least squares regression and structural equation modeling to answer our study questions. Moreover, we utilized methods to empirically test indirect effects while controlling for measured confounders. We used multiple methods, including standardized assessment, self-administered questionnaires, review of infant health records, and videotaped observations of infant-parent interactions.

1.6 Conclusions

Infants born preterm and their mothers are vulnerable because of pathways linking early social and biological risk with later neurodevelopment difficulties. This study extends previous research on the determinants of cognitive function among children born preterm by

highlighting family correlates of importance including maternal clinical depressive symptoms and perceived social support. The findings have important implications for policy and programmatic efforts for early screening and treatment of maternal postnatal depression, bolstering family supports, and early intervention to improve children's cognitive function.

Acknowledgments

The first author acknowledges funding from the Robert Wood Johnson Health and Society Scholars Program at University of Wisconsin-Madison. The second author acknowledges funding from the National Institutes of Health (R01HD44163) and the University of Wisconsin-Madison. The authors wish to thank Daniel Bolt, PhD for his review of the statistical analyses in this study. The authors are grateful to the families who dedicated their time to participate in this study.

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Highlights

- Early exposure to maternal depressive symptoms appears to have a negative influence on preterm children's later cognitive function.
- For mothers with fewer depressive symptoms, bolstering effects of maternal supports on children's cognitive function were evident.
- We find no evidence that the quality of the parent-child interaction explains the association between maternal depressive symptoms and preterm children's later cognitive function.

Figure 1.
Conceptual model of direct and indirect effects of postpartum depression (PPD) at 4 months on child's cognitive function at 16 months

Figure 2.

Adjusted* Mean differences in Cognitive Function at 16 months postterm Among a Sample (n=130) of Preterm Infants, by Category of Maternal Depressive Symptoms and Levels of Maternal Supports

*Adjusted for non-white race, maternal high school education, family income <\$10,000, not married, being male,

Postnatal depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale (CES-D). Maternal perceived social support was measured at 4 months using the Maternal Support scale. Children's cognitive function was measured (at 16 months) using the Bayley Scale of Infant Development, Mental Developmental Index.

Table 1

Characteristics of study sample (n=137) of preterm, low birth weight infants born in Wisconsin in 2003–2005.

Child and Family Characteristic	n(%)
Child's race and ethnicity	
White, non-Hispanic	112 (81.8)
Other race/ethnicity	25 (18.3)
Maternal Education	
High school or less	45 (32.9)
Some college	26 (19.0)
Bachelor's degree	42 (30.7)
Graduate degree	24 (17.5)
Family income	
Less than \$10,000	9 (6.6)
\$10,000 to less than \$30,000	19 (13.9)
\$30,000 to \$60,000	42 (30.7)
Greater than \$60,000	67 (48.9)
Maternal smoking	
Current or former	33 (24.1)
Never	104 (75.9)
Mom employment status	
Employed	95 (69.3)
Unemployed	42 (30.7)
Father's employment status	
Employed	121 (88.3)
Unemployed	16 (11.7)
Parity	
Multiparous	73 (53.3)
Primiparous	64 (46.7)
Partner status	
Married or cohabitating	111 (81.0)
Not married or cohabitating	26 (19.0)
Child's sex	
Male	68 (49.6)
Female	69 (50.4)
Birth weight category	
< 1500 grams	43 (33.1)
1500 grams	87 (66.9)

Child and Family Characteristic	n(%)
Maternal depressive symptoms ^A	
CESD < 16	109 (79.6)
CESD ≥ 16	28 (20.4)
Maternal social support ^B	
Low (< -1 SD below mean)	21 (15.3)
Middle (between -1 and 1 SD from mean)	91 (66.4)
High (> 1 SD above mean)	25 (18.3)
Mean (SD), range	
Child's Cognitive Function ^C	88.6 (11.3), 50–122
Maternal depressive symptoms ^A	8.8 (6.8), 0–28
Birth weight (grams)	1772 (599), 490–3328
Family income (\$)	69, 682 (58,801), 3000–500,000
Maternal age at child's birth	32.6 (5.8), 20–44
Gestational age	32 (3), 24–37
Child's age at hospital discharge (days)	32 (28), 3–132

^A Postnatal depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale (CES-D). The CES-D asks mothers to report, on a 4-point scale (0=rarely/none of the time to 3=all of the time), their frequency of symptoms for 20 scale items. Scores of 16 or greater indicate symptoms of clinical depression.

^B Maternal perceived social support was measured at 4 months using the Maternal Support scale – a multidimensional index of emotional, informational, household, child care, financial, respite, and other support – collected about the baby's father, mother's parents, in-laws, and extended family. A total perceived social support score was calculated by summing the scores of each type of support (7) across the four sources resulting in a range from 0 to 28.

^C Children's cognitive function was measured (at 16 months) using the Bayely Scale of Infant Development, Mental Developmental Index.

Table 2

Mean difference [95% CI] in children's cognitive function^A from adjusted linear regression models describing the association of maternal depressive symptoms (Model 1) at 4 months and additionally, the interaction between maternal symptoms of clinical depression and maternal perceived social support at 4 months (Model 2) among a sample (n=137) of infants born preterm in Wisconsin.

Child and Family Characteristic	Mean difference [95% CI]	
	Model 1	Model 2
Intercept	74.41 [64.45, 84.39]	73.92 [63.36, 84.49]
Child's race and ethnicity		
White, non-Hispanic	-2.43 [-7.68, 2.82]	-2.47 [-7.77, 2.83]
Other race/ethnicity	Reference	Reference
Maternal Education		
High school or less	Reference	Reference
Some college	2.23 [-3.51, 7.99]	2.20 [-3.60, 8.00]
Bachelor's degree	1.76 [-3.83, 7.37]	1.61 [-4.12, 7.35]
Graduate degree	5.63 [-0.62, 11.89]	5.41 [-1.11, 11.91]
Family income		
Less than \$10,000	Reference	Reference
\$10,000 to less than \$30,000	8.71 [-0.80, 18.21]	8.61 [-1.09, 11.91]
\$30,000 to \$60,000	7.02 [-2.93, 16.97]	7.01 [-3.13, 17.16]
Greater than \$60,000	11.21 [0.68, 21.74]	11.29 [0.61, 21.98]
Partner status		
Married or cohabitating	-0.63 [-6.54, 5.28]	-0.76 [-6.78, 5.26]
Not married or cohabitating	Reference	Reference
Child's sex		
Male	Reference	Reference
Female	4.50 [0.82, 8.18]	4.45 [0.72, 8.18]
Maternal depressive symptoms ^B		
CESD < 16	Reference	Reference
CESD ≥ 16	-5.22 [-10.19, -0.25]	-5.15 [-10.19, -0.11]
Maternal social support ^C		
Low (<-1 SD below mean)		Reference
Middle (between -1 and 1 SD from mean)		0.86 [-4.92, 6.63]
High (> 1 SD above mean)		0.97 [-5.97, 7.90]

^AChildren's cognitive function was measured (at 16 months) using the Bayley Scale of Infant Development, Mental Developmental Index.

^BPostnatal depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale (CES-D). The CES-D asks mothers to report, on a 4-point scale (0=rarely/none of the time to 3=all of the time), their frequency of symptoms for 20 scale items. Scores of 16 or greater indicate symptoms of clinical depression.

^CMaternal perceived social support was measured at 4 months using the Maternal Support scale – a multidimensional index of emotional, informational, household, child care, financial, respite, and other support – collected about the baby’s father, mother’s parents, in-laws, and extended family. A total perceived social support score was calculated by summing the scores of each type of support (7) across the four sources resulting in a range from 0 to 28.

Table 3

Measurement Model: Unstandardized Factor Loadings (SE) of Parent Child Early Relational Assessment subscale scores on Child and Parent Constructs

Parent Child Early Relational Assessment Item	Factor Loading (SE)
Infant emotional/behavioral regulation	
Infant positive affect, communicative style, and social skills	0.47 (0.05)
Infant quality of play, interest, and attentional skills	0.50 (0.04)
Infant dysregulation and irritability	0.45 (0.05)
Parenting Quality	
Parental positive affective involvement and verbalization	0.59 (0.05)
Parental negative affect and behavior	0.57 (0.05)
Parental intrusiveness, insensitivity, and inconsistency	0.60 (0.04)

Model Fit: CFI= .998 RMSEA= .041 SRMR=.039