Impact of Postpartum Depression on Infant Behavioral Outcomes at Age 12 Months: A Prospective Investigation

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ABSTRACT

Background: Postpartum depression (PPD) may negatively impact a woman’s ability to effectively care for her child, potentially leading to compromised developmental functioning in key areas, including cognitive functioning, sleep, and behavior. However, research investigating potential negative behavioral outcomes in infancy (birth through 12 months of age) is limited. Little is currently known regarding whether infants may be at risk for specific types of behavioral difficulties. Also unclear is whether the effects of PPD on behavioral adjustment may vary between boys and girls. Using data from a prospective cohort study, the current investigation examined the association between elevated PPD symptomatology and infant behavior problems (total, internalizing, and externalizing) at 12 months of age (n=248). We also examined whether the gender of the infant moderates these potential associations.

Methods: Participants were recruited from a postpartum floor of a single hospital in the northeastern United States and followed up to 12 months. At eight weeks postpartum, women completed a modified version of the Edinburgh Postnatal Depression Scale. Mothers reported on a range of infant behaviors at 12 months of age.

Results: Unadjusted models suggest that elevated PPD symptomatology is significantly related to an increased odds of infant behavior problems at 12 months of age, particularly total and externalizing behavior problems. However, adjusting for confounding factors (and a proxy of maternal mental health measured when outcomes were assessed) led to an attenuation of these associations. Elevated PPD symptomatology was found to be positively, but not statistically significantly, associated with infant behavior problems in the fully adjusted models (total: odds ratio [OR]=1.98, 95% confidence interval [CI]=0.90-4.37; internalizing: OR=1.49, 95% CI=
Findings further suggest the existence of gender differences in these associations. Girls who had mothers with elevated PPD symptomatology were more prone to internalizing behaviors than boys with this exposure (girls: OR=1.85, 95% CI=0.68-5.04; boys: OR=0.68, 95% CI=0.13-3.66); yet externalizing behavior problems were more common among exposed boys than among exposed girls (boys: OR=3.70, 95% CI=0.98-14.00; girls: OR=1.14, 95% CI=0.43-2.99).

Conclusions: Results indicate a possible trend association between elevated PPD symptomatology and infant behavior problems at 12 months of age. While much of the reported overall association may be due to residual or unmeasured confounding, findings suggest that the effect of PPD may differ for boys and girls. Important associations may be missed when analyses are not conducted separately by gender. Additional prospective studies with larger sample sizes are needed to more fully address these research questions, including questions of gender differences in the associations between PPD and infant behavior problems.
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INTRODUCTION

Maternal depression, particularly postpartum depression (PPD), constitutes a significant public health problem due to its high prevalence both in the United States and globally.[1] With its detrimental effects on maternal mood, PPD may compromise a woman’s ability to effectively care for her infant, potentially leading to compromised developmental functioning among children with this exposure and constituting it as an intergenerational health issue.[2] Yet it should be noted that it remains unclear as to whether PPD is a causal risk factor for infant/childhood developmental problems. Maternal depression tends to be accompanied by many adversities in the infant social environment that may explain previously observed associations between PPD and developmental deficits (e.g., marital/relationship distress, low socioeconomic status, minority group status, stressful life events).[3]

Research focusing specifically on potential negative behavioral outcomes among the infants of women with (vs. without) PPD is limited. For example, it is unclear when behavioral differences among the children of women with (vs. without) PPD first emerge. Additionally, although several studies point to PPD as a putative risk factor for total behavior problems,[4] little is currently known about whether exposed infants may be at risk for specific types of behavioral difficulties (e.g., internalizing versus externalizing behavior problems), as well as subgroups of infants (e.g., boys versus girls, those from lower versus higher socioeconomic status) that may be at particular risk for poor behavioral outcomes when exposed to PPD. This knowledge is critical to the planning of targeted intervention and supportive services aimed at improving the developmental functioning of children who have mothers with PPD.
The current study seeks to build upon previous research regarding PPD and early childhood behavioral outcomes by prospectively examining the association between PPD symptomatology, as measured at eight weeks postpartum, and infant behavior at 12 months of age. It has been suggested that the earlier in life a child is subjected to maternal depression, the more detrimental the effects,[5] thereby posing the first year of life as an important area of scientific investigation. However, few studies to date have examined outcomes associated with PPD during this pivotal developmental stage. For our primary aim (Aim 1), we prospectively examined the relationship between elevated PPD symptomatology and total behavior problems and investigated whether elevated PPD symptomatology was differentially associated with subtypes of problems: internalizing versus externalizing behavior problems.\footnote{Internalizing behavior problems are directed inward and are self-harming; externalizing behavior problems are manifested as outward behaviors directed toward the external environment.[6] During infancy and early childhood, internalizing behavior problems include depression, anxiety, withdrawal, extreme shyness, and separation distress. Externalizing behavior problems include hyperactivity, impulsivity/disruptive behavior, and anger.[7]} As a secondary aim (Aim 1.a), we examined the relationship between elevated PPD symptomatology and specific behavioral symptoms within the internalizing and externalizing subtypes (e.g., separation distress, hyperactivity, impulsivity/disruptive behavior, and anger). Gaining knowledge about specific deficits in early behavior problems that may be associated with elevated PPD symptomatology will help to inform the direction of future research as well as the design and implementation of targeted intervention programs. For our second major aim (Aim 2), we examined whether infant gender moderates associations between elevated PPD symptomatology and behavioral outcomes. Our study is well positioned to address key limitations in the literature because of its longitudinal design, the measurement of natural rather than laboratory-based infant behavior, and an ability to both control for critical potential
confounding factors and account for maternal mental health status at the time of the 12 month infant behavioral assessment.

Before detailing the methods and findings of the current study, we briefly review the literature relevant to our research questions. We first provide an overview of PPD and its potential impacts on maternal behaviors. This is followed by an overview of the measurement and classification of behavior problems in infancy and a review of prior investigations of the association between PPD and childhood (particularly infancy) behavior problems. This is not meant to serve as an exhaustive review but provide a motivation for our aims and hypotheses. In this literature summary we also seek to identify important limitations in the literature.

**Postpartum Depression: Overview**

PPD is a psychiatric disorder affecting approximately 10-20% of women in the United States subsequent to childbearing.[8] According to the fifth edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-V),[9] PPD is classified under the diagnostic criteria for Major Depressive Episode with Peripartum Onset. It is described as a period lasting at least two consecutive weeks occurring either during pregnancy or within four weeks of delivery during which one possesses five or more of the following symptoms, which are consistent with those of major depressive episode: (1) depressed mood; (2) loss of interest and pleasure in activities; (3) significant weight loss or decrease in appetite; (4) insomnia; (5) changes in psychomotor behavior; (6) fatigue; (7) feelings of worthlessness; (8) diminished ability to think, concentrate, make decisions; and (9) suicidal ideation.[9] To qualify for diagnosis, one of the five or more endorsed symptoms must include either depressed mood or a loss of interest and pleasure in activities. It is further required that the endorsed symptoms cause
significant distress or impairment in one’s life roles (e.g., social, occupational), and are not the psychological effects of substance use or a medical condition.[9]

Although many women may experience one or a few symptoms of PPD as a part of the normative experience of having a new baby (e.g., decreased energy, changes in sleep patterns),[10] the diagnosis attempts to identify women who are experiencing reactions that are atypical (longer lasting or more severe) and have a significant adverse impact on life functioning.[11] Additionally, self-report scales used to assess PPD, such as the Edinburgh Postnatal Depression Scale used in the current investigation, ask questions focusing on maternal mood rather than physical symptoms (e.g., “I have been so unhappy that I have had difficulty sleeping”) in an effort to differentiate between typical symptoms of new motherhood and PPD.[12]

The most robust predictors of PPD include previous psychiatric illness (e.g., previous history of major depression, anxiety during pregnancy);[13] lack of social support;[14] and minimal or no partner support.[15] Women of lower socioeconomic status[16] and those who experience pregnancy and delivery complications (e.g., hyperemesis, premature contractions, and birth to babies with major malformations)[17] have also been found to be at higher risk of PPD.

Many researchers, however, argue that DSM-based definitions of PPD are too stringent.[14] They further suggest that focusing research efforts solely on those women who meet clinical levels of PPD may lead to an underestimation of the potential negative childhood outcomes associated with this psychiatric problem. Critiques typically focus on two specific aspects of the PPD diagnosis: the restrictive period of onset (e.g., onset must occur within four weeks following childbirth) and the number of symptoms needed to qualify for diagnosis. For
example, accumulating evidence suggests that, for many women, PPD may not begin within four weeks of childbirth. In fact, it has been shown that PPD onset may occur up to a year following childbirth,[14, 18, 19] with prevalence of PPD varying throughout the first postpartum year.[20] Stowe et al. (2004) reported that a significant portion of women (nearly 25%) experience the onset of PPD after the first six weeks postpartum.[21] Additionally, accumulating evidence suggests that PPD beginning later than four weeks of postpartum[9] may present in a way similar to that of earlier onset PPD, with comparable child outcomes.[22] By restricting the period of onset for clinical diagnosis to four weeks postpartum, many women experiencing significant PPD may be overlooked.

A growing number of studies also suggests that many women experience meaningfully elevated levels of subclinical PPD that may have implications for their own functioning and the adjustment of their offspring.[23] Those with subclinical depression (but not those with normative transient low levels of symptoms experienced by many women after childbirth[10]) have been observed to have substantially more impairment in their lives as compared to those without elevated depressive symptoms,[24, 25] which may be comparable to the experience of those meeting full diagnostic criteria for PPD.[26, 27] Additionally, young children of mothers with psychiatric disorders not clinically classified as PPD have been observed to have impaired mother-infant relationships[28] and behavioral outcomes[29] comparable to those of mothers with clinical depression. This suggests that adverse child behavioral outcomes may occur in response to maternal distress in general, regardless of diagnostic status.

Postpartum Depression: Potential Effects on Maternal Behaviors

The maternal role is vital for ensuring the health and safety of an infant.[30] Given that maternal well-being is likely to impact a woman’s ability to care for her infant, prior studies
have sought to contrast the maternal caregiving,[31-35] parenting behaviors,[36-39] and mother-infant relationships[40, 41] of mothers with and without PPD. Most studies examining these associations suggest that PPD has an overall negative impact on maternal behaviors and, as a consequence, is a potential risk factor for compromised infant developmental outcomes.

PPD, which may lead a woman to experience heightened and prolonged impairment of cognitive processes (e.g., concentration, decision-making) and reductions in energy,[9] may have significant negative impacts on a mother’s caregiving behaviors, including difficulties with infant handling,[31] reduced odds of breastfeeding continuation,[35] undesirable sleep practices (e.g., placing the infant in non-recommended positions),[32] seeking fewer preventative healthcare services,[33] and reduced in-home safety precautions (e.g., lowering water temperature).[34]

It has been suggested that mothers with PPD have difficulties with expressions of pleasure[31] and emotional responsiveness[37] with their infants, which may be associated with negative parenting styles[39] and impairments in the mother-infant relationship.[41] There is empirical evidence to suggest that PPD may impair mother-infant interactions through two negative maternal behavior patterns: intrusiveness (e.g., hostility, over-stimulation[37, 42]) and withdrawal (e.g., disengagement, under-stimulation[37, 42]).[36] Characteristics of both intrusive (e.g., threatening, anger, negative facial expressions and gestures)[38] and withdrawn (e.g., ignoring, lack of interact, neglect)[38, 39] parenting behaviors have been found to be associated with maternal depression in general. Overall, mothers with (versus without) depression tend to use less positive interactive behaviors with their infants, displaying less maternal warmth and affection, potentially disrupting the ability to create a synchronous mother-child relationship.[40]
**Infant Behavioral Development and the Identification of Behavioral Problems**

Within the first year of life, infant behavioral development follows a typical trajectory. Two important domains of infant behavioral development are social engagement and emotional regulation. Normative social engagement is important as it allows infants to develop the skills necessary for communicating, forming social relationships, and functioning within the social world.[43] At the time of birth, infant social engagement skills are restricted to preference for viewing human faces.[44] By the third month of life, infants begin to develop abilities to function successfully in synchronous face-to-face interactions with their parents.[45] By the time an infant reaches 12 months of age, infant social engagement has developed dramatically, with infants displaying reciprocal interactions with their parents,[45] demonstrating intentional actions and a sense of subjective self.[46] In addition, by the end of an infant’s first year of life, the ability to regulate distress becomes developed. This is accompanied by a reduction in typical infantile stress reactions (e.g., fussing, crying) that attempt to gain the attention of a caregiver, and is replaced with more active methods to cope with stressful situations (e.g., turning away, manipulating objects).[47]

Yet there is much variation within this typical trajectory, making it challenging to identify infants who have meaningful deficits in age-related behavioral functioning. Behavior at this developmental stage can be unstable and difficult to measure using available research instruments. As such, the assessment of behavior problems in young children has traditionally been met with controversy[48] and research regarding risk factors for negative outcomes in the first year of life is limited.

More recently, however, tools have been developed to improve opportunities to reliably examine infant and early childhood behavior and identify those with meaningful behavioral
deficits. For example, the Achenbach System of Empirically Based Assessment consists of assessment tools to diagnose problems in children as young as 1½ years across various behavioral domains (including the internalizing and externalizing domains), each with DSM-Oriented Scales to assess for diagnostic criteria.[49] Additionally, the Infant-Toddler Social and Emotional Assessment (ITSEA) was specially designed as a method of identifying behavior problems emerging in infants aged 12 months to 35 months, 30 days, acting as a tool to improve early identification.[50] The ITSEA in particular has been shown to validly measure behavior problems in infants and young children,[51, 52] presenting a valuable opportunity to measure behavior problems in children as early as 12 months of age. Yet our literature review identified only one study using this measure to address questions pertaining to the association between PPD and infant behavioral outcomes.[53] (This study suggested that much of the association between PPD and infant behavioral outcomes is due to the confounding effects of maternal and family characteristics).

The identification of infants with behavior problems using these tools usually involves comparisons of individual children to expected norms derived from age-matched peers in terms of the frequency, intensity, and/or duration of behavioral symptoms.[54] For example, failure to display the expected level of social engagement (e.g., acting shy, withdrawn) or distress regulation (e.g., excessive crying, anger) at 12 months may be indicative of underlying behavioral problems.

**Postpartum Depression: Putative Effects on Infant /Early Childhood Behavior**

Over the past few decades, researchers have sought to examine the potential effects of PPD on early childhood behavior. Overall, results from existing studies suggest a correlation between maternal depression and adverse behavioral outcomes in young children. However, little is
known about whether these behavioral outcomes begin to arise or are evident in the first year of life. The primary aim of the current study is to help address this gap in the literature. As it has been observed that behavioral effects are larger in magnitude when children are exposed to maternal depression at younger ages,[5, 55, 56] it is important to investigate exposures and outcomes occurring during the first year of life.

Given that reports focusing specifically on the association between PPD and infant outcomes are rare, we expanded our review of the literature in several important ways in order to provide an adequate background to inform our hypotheses. First we expanded the scope of our literature review to include studies of children older than 12 months, up to five years of age. Given this, the term “child” will henceforth be used to refer to those studies focusing on children older than 12 months. The term “infant” will be strictly used when referring to the period from birth to 12 months of age. Secondly, given that studies looking at specifically PPD in relation to child behavioral outcomes are limited, we expanded our review to include studies that measure maternal depression occurring later than the first year of life (but within early childhood). As such, the term “PPD” will only be used in reference to maternal depression occurring within the first 12 months postpartum, with “maternal depression” referring to depressive episodes occurring outside of this timeframe.

Although existing studies generally suggest an association between maternal PPD and total behavior problems in early childhood, there are some inconsistencies in the literature. A meta-analysis by Beck (1998) reviewed studies published between 1978 and 1995 and found small but statistically significant associations between PPD and general behavior problems (in children ranging from 1 to 14 years of age) when controlling for factors including concurrent maternal depression.[57] The included studies that assessed children under two years of age
reported substantially impaired quality of mother-infant interactions in association with PPD.[58, 59] (However, these early childhood studies did not specifically measure behavior problems; they made inferences about such behaviors based on mother-infant interactions.) Conversely, more recent prospective studies suggest that deficits in young children’s behavior may not be due to the lingering effects of maternal PPD status.[53, 60, 61] In these studies, once potential confounding factors,[53] current maternal depression,[60] or other current maternal psychopathology[61] was accounted for in analyses, there was no longer a significant association between PPD and childhood behavior problems.

Knowledge regarding how PPD may be differentially associated with various subtypes of behavior is limited.[56] Although it has been noted that the strength of association between PPD and child behavior problems may vary across the internalizing versus externalizing subtypes,[56] this has not been well studied. This is an important area of inquiry because studies that focus only on total behavior problems (which are calculated as a sum of internalizing and externalizing behaviors) may potentially miss important associations. ² For example, a cross-sectional study found a significant association at 21 months of age between maternal depression and internalizing behavior problems, but not for total or externalizing behavior problems, when controlling for contextual risk factors (including family environment, stress, and maternal interpersonal support).[62] Had the researchers included only a measure of total behavior problems an important association would have been missed.

² Internalizing and externalizing behavior problems are two categories falling under the umbrella term of “total behavior problems.” As such, scores evaluating total behavior problems are calculated as a sum of scores from the internalizing and externalizing behavioral domains. By determining a total behavior score in such a way, it is possible that important observations could be missed. For example, if an infant’s internalizing problems score was highly elevated, but their externalizing problems score was substantially below average, combining these two scores together would create a total behavior problems score that would appear average.
The few studies that have examined possible differences in the effect of PPD across the internalizing and externalizing behavior problem domains in infants/young children tend to be cross-sectional in design. This presents difficulties with drawing temporal links between PPD and infant behavioral outcomes, making it unclear whether PPD influences infant developmental delays or vice versa. For example, while PPD may negatively influence a mother’s parenting abilities, leading to detrimental infant behavioral development, it is also possible that infantile emotional and behavioral problems may also trigger PPD in mothers due to stress and feelings of guilt.[63] This begs the need for prospective studies in order to assess the temporality of these possible associations.

Results appear to consistently suggest associations between PPD and various types of internalizing behavior problems in early childhood (e.g., shyness and sadness,[64-66] fear and distress[40, 64]). However, it appears that associations between PPD and externalizing problems may further differ depending on the specific externalizing behavior symptoms examined (e.g., activity level,[67, 68] impulsivity/disruptive behavior,[69-71] anger[72, 73]). Results are discussed below.

Internalizing Behavior Problems

Internalizing behavior problems in infancy and early childhood manifest as anxiety and depression, fears, withdrawal, shyness, inhibition, and separation distress.[7] Although experiencing low levels of some of these behaviors during infancy and early childhood is normative, elevated levels in comparison to age-matched peers are not.[54] Such emotional disturbances during infancy and early childhood have been much less studied as compared to externalizing behavior problems. This is mainly due to the fact that young children are unable to communicate their emotions, and that it is difficult to establish what constitutes “normal”
emotional responses (e.g., tantrums, crying).[48] However, the field of child mental health has made advances in recent years to assess developmental behavior in infants and young children, and to subsequently categorize that behavior as potentially problematic.[74] Although it has been estimated that severe internalizing behavior problems have low prevalence in young children,[75] any elevation of psychopathological symptoms in young children is significant as behavior problems acquired early in life tend to persist,[7] potentially affecting functioning later in life. For example, a study by Murray et al. (1999) found that infants exposed to PPD tended to be rated by their mothers at age five as being more neurotic as compared to their non-exposed peers.[72]

Studies that have sought to examine associations between PPD and internalizing behaviors specifically in infancy or early childhood usually involve direct observation of infant behavioral symptoms that may indicate underlying internalizing behavior problems (e.g., shyness and sadness,[64-66] fear and separation distress[40, 64]). Two meta-analyses have reported positive associations between PPD and risk of internalizing behavior problems.[55, 56] Yet only one of these meta-analyses[56] included studies measuring behavioral outcomes in the period of infancy. The majority of included infancy studies focused on infants under four months, utilizing observations of social engagement during mother-infant interactions[76-79] and play[80] to rate internalizing behavior problems. Those investigations of infants 8 to 12 months of age found infants of mothers with PPD to more asocial (e.g., unresponsive, passive, withdrawn)[42, 81, 82] and had a more negative mood[42, 64] during interactions with mothers. The existence of associations during early infancy and early childhood begs the need for further investigation of infants at 12 months of age.
To more fully understand potential associations between PPD and internalizing behavior problems, there is a need to examine how PPD may impact specific internalizing behaviors. Low levels of surgency (e.g., shyness, sadness) are a possible manifestation of internalizing behavior problems in infants and young children.[66] Studies suggest that experiencing PPD may place youngsters at risk for such behavioral difficulties. For example, a cross-sectional study of young children (21 months of age) reported an association between elevated negative mood (e.g., increased negative facial expressions and responses) and maternal depression.[64] Additionally, preschool children of mothers with a history of depression have been found to exhibit heightened levels of negative emotionality.[65]

Excessive fear and separation distress during infancy and early childhood (indicated by greater than normal crying, fretting), especially during separation from one’s mother, is also an expression of internalizing problems.[66, 83] Separation distress is of particular interest to the current study as this is what is captured in our measure of internalizing behavioral problems. While emotions such as joy and interest are exhibited during the first six months of life, fearful reactions toward strangers and unfamiliar objects do not begin to emerge until later,[84] suggesting 12 months to be an appropriate age at which such behaviors may be studied. Cross-sectional, laboratory-based studies have observed heightened adverse reactions during fear paradigms[40] and more quick, intense reactions to maternal separation in the presence of a stranger[64] among infants (9-10 months old) of mothers with (versus without) depression.

Overall, cross-sectional findings suggest an association between PPD and multiple manifestations of infant internalizing behaviors.[40, 64] However, it should be noted that studies using specific behavior observations to indicate internalizing behaviors (e.g., shyness

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3 The fear paradigm in this study involved an experimenter interacting with an infant while wearing a series of masks (e.g., clown, animal, ghost) in order to elicit a fear response in the infant.
and sadness,[64-66] fear and distress[40, 64]) are often laboratory-based[40, 64] and may not be generalizable to real-life situations. Additionally, since many existing studies focus on childhood outcomes (rather than infancy), there remains a gap in knowledge regarding at what point these behaviors begin to emerge (e.g., are they evident at 12 months?) and whether associations are upheld after controlling for confounding factors.

Externalizing Behavior Problems

Externalizing behavior problems in infancy/early childhood include aggression, hyperactivity, impulsivity, and inattentiveness,[7] and are typically referred to as disruptive, or “acting-out,” behaviors.[48] Again, some evidence of these types of behaviors during infancy and early childhood are normative, but problematic levels are indicated when behavioral symptoms are displayed with excessive frequency and/or intensity.[54]

Longitudinal studies have suggested these early childhood problems frequently persist into adolescence and beyond (e.g., violent behavior, anger management problems),[85] thereby making it advantageous to identify potential externalizing behaviors early on in order to prevent later behavioral difficulties. Meta-analyses have found maternal depression to have a small but statistically significant association with externalizing behavior problems in children through age 20.[55, 56] Only one of these meta-analyses[56] included infants 12 months of age and under; only two studies were identified that had measures of infant behavior. These outcomes were limited to observations of infantile fussiness and expressions of anger during interactions with mothers.[86, 87] Evidence suggests the existence of associations between PPD and externalizing behavior problems during later childhood, but additional research is needed to comment on whether a relationship exists for externalizing problems at 12 months of age.
Yet in reviewing the evidence, it appears that PPD may not similarly impact all types of externalizing behavior. Our measure of externalizing behavior taps into hyperactivity, impulsivity/disruptive behavior, and anger, so studies examining these outcomes will be focused on here. Although some studies have not found associations between maternal depression and overall externalizing behavior problems,[62] it has been suggested that such findings may arise because certain externalizing behavioral symptoms may be more impacted than others (e.g., activity level[67, 72, 85, 88] versus impulsivity/disruptive behavior[69-71] versus anger[73, 88]), as will be discussed below. This underscores the importance of looking at specific externalizing symptoms, not just the overall domain scores.4

Studies observing infants and young children in natural environments have not reported a clear trend regarding the association between PPD and hyperactivity. In fact, PPD may have differential impacts on activity level according to age of the child, with children experiencing suppressed activity level during infancy, and hyperactivity in later childhood. For example, studies of the association between PPD and activity levels early in infancy (one using motion detectors at 6 weeks of age[88] and another utilizing observations of mother-infant interactions at 2 months of age[89]) did not reveal any difference in activity level across mothers with and without PPD, suggesting differences in activity level in association with PPD may not arise this early in infancy. Yet a cross-sectional study of 3-6 month old infants found that infants of mothers with (versus without) PPD had overall lower levels of physical activity.[67] Interestingly, PPD appears to be associated with hyperactivity[85, 90] and increased levels of physical play[72] in school-aged children. As no studies have examined activity level in infants

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4 Screening tools for behavior problems in infancy/early childhood, such as the ITSEA,[50] determine an overall externalizing behavior problem score by summing together ratings of different behavior subtypes (e.g., hyperactivity, impulsivity/defiance, and aggression). Therefore if any one of these subtypes were not elevated, the entire externalizing score would be lowered.
at 12 months in association with PPD, the current analyses aims to determine whether infants at this time exhibit a behavioral profile resembling that of earlier infancy (e.g., decreased activity level[67]) versus childhood (e.g., hyperactivity[85, 90]).

Impulsivity, disruptive behavior, and anger during infancy and early childhood (indicated by difficult temperament (e.g., anger and frustration,[66, 83] food refusal and fussiness[48])) rise to the level of externalizing behavior problems[83] when exhibited at heightened levels beyond what is normative compared to peers. Studies assessing these specific behaviors in infants and young children have consistently reported increased defiance[69-71] and increased anger[73, 88]) in association with PPD. Mothers with depression tend to rate their infants as being less compliant,[71] more disruptive,[70] and more difficult to care for than mothers without depression.[69, 70] Interestingly, observations of mother-infant interactions by outsiders of mother-infant interactions have found infants of mothers with PPD are no different from those of non-depressed mothers in terms of compliance,[70] suggesting potential instrument biases to exist with subjective maternal reports.

Overall, cross-sectional associations seem evident between maternal depression and elevated infant impulsivity/disruptive behavior[69-71] and anger.[73] However, studies have found that associations with activity level varies by age (lower activity levels in early infancy[67] versus hyperactivity in older children[72, 85, 90]). It is therefore unclear what to expect with infants at 12 months of age. (In keeping with the pattern of findings from studies of younger infants, we hypothesized that infants of mother with (versus without) PPD would have a decreased odds of hyperactivity at 12 months of age.) Additional research is required to examine how PPD longitudinally impacts specific subtypes of infant externalizing behaviors at 12 months of age.
Possible Gender Differences

Not all infants and young children of mothers with PPD display behavior problems. We are interested in evaluating potential gender differences in associations between PPD and infant behavioral outcomes (total, internalizing, and externalizing). Various theoretical orientations hypothesize why differences by gender may arise in the experience of behavior problems associated with PPD. For example, evidence suggests that mothers with depression may act differently toward their infant depending on the gender of the child.[4] The duration of the depressive episode may also vary depending on child gender,[5] potentially increasing the infant’s exposure time to PPD. It has also been suggested that girls may more often display internalizing behavior problems due to gender-specific social encouragement of girls to display more depressive symptoms than boys.[91]

Theories based on biological sex differences have also been proposed to explain how PPD may differentially impact boys and girls. For example, it has been suggested that infant boys, who tend to be less emotionally mature than girls via biological mechanisms, may require increased maternal sensitivity to regulate their emotions, causing them to be more distressed by the decreased sensitivity that may accompany PPD.[92] Additionally, PPD may be a manifestation of female genetic liability to depression,[91, 93] so elevated internalizing (versus externalizing) behavior problems among girls may also be a manifestation of genetic liability.

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As briefly described in this section, both socially-based and biologically-based theories have been proposed to explain why PPD may differentially affect boys and girls. Although there are potential biological sex differences that may explain differing associations between PPD and behavioral outcomes for boys and girls, the term “gender” is used in the current study. Due to the fact that we have no way of measuring and controlling for infant sex differences (e.g., hormone levels) and the fact that our outcome measure is dependent on subjective maternal reports (which are likely to be influenced by socially constructed gender expectations), we believe that the use of the term “gender” (rather than “sex”) more appropriately matches our socially-based perspective for the difference between boys and girls in the current analyses.[90]
Differences in the association between PPD and infant behavioral outcomes have sometimes, but not always, been reported in the literature according to infant gender. A literature review by Grace et al. (2003) suggested that, overall, boys tend to have greater risk of poor behavioral development in association with PPD as compared to girls.[4] Boys of mothers with PPD have also been found to have a significantly increased risk of insecure attachment as compared to girls.[59] A recent study found that internalizing behaviors were more common among the girl children but not the boy children of mothers with PPD,[48] consistent with the theory that daughters of mothers with depression may be at greater risk for depressive symptoms than sons of mothers with depression.[91] More varied findings exist for externalizing problems. While school-aged boys have been found to have an increased risk of hyperactivity in relation to PPD,[90] a meta-analysis by Goodman et. al (2011) concluded that the PPD and externalizing behavior problems association in young children is not gender specific.[56] These gender-specific inconsistencies within the literature require further investigation.

Intervention for PPD

The relationship between PPD and subsequent infant behavioral outcomes is important to clarify in the literature. If there is indeed an association, the early identification of women with PPD may have important implications not only for improving maternal health status but in preventing potential adverse effects on infant/child behavioral development. PPD often goes undiagnosed and untreated in spite of the availability of effective treatment options.[94] As detailed in the discussion section, reasons for under-diagnosis and under-treatment are varied (e.g. trouble recognizing symptoms, inadequate screening for PPD, limited access to care).
Effective treatment methods for maternal depression include pharmacological approaches (e.g., antidepressants), psychotherapy, and mood induction interventions (e.g., message, music therapy). However, treatments for PPD aimed at exclusively treating maternal depressive symptoms may provide only limited benefits to the infants themselves. Interventions targeting the mother-infant dyad, rather than the mother in isolation, have shown strong positive effects on infant health and development. For example, “interaction coaching,” which focuses on teaching mothers with PPD positive interaction styles, has been found to be effective at yielding changes in mother-infant interactions and improving behavioral outcomes in infants ages 6-36 months.

**Current Study**

There exists only a small body of research examining possible adverse associations between PPD and behavioral outcomes in infancy. Prior studies have found PPD to be associated with a range of infant internalizing behavior problems. The association between PPD and externalizing behavior problems, however, shows less consistency, with suggestions of differences across varied externalizing behavioral symptoms (e.g., activity levels, impulsivity/disruptive behavior, anger).

There is a lack of prospective, naturalistic studies examining specifically infants in the first 12 months of life. Study designs tend to be cross-sectional, making it difficult to draw temporal conclusions. The few longitudinal studies that have been conducted tend to focus on later childhood (rather than infancy). Existing prospective studies often lack important measures of maternal mental health at the time of child assessment, making it unclear as to whether identified associations are due to persisting effects of PPD versus current maternal depression. Additionally, studies often implement subjective measures of...
maternal depressive symptomatology and infant outcomes,[62, 69-73, 88] which may be biased due to the negative outlook that accompanies maternal depression.[56, 107, 108] Conversely, studies that do utilize direct researcher observations of infant behavior tend to utilize constructed situations in laboratory settings,[40, 64, 65] which may not be generalizable to all life situations. Information is also lacking regarding how the effects of PPD on infant behavioral outcomes may differ depending on infant gender.

The proposed study seeks to address some of these limitations by: (1) utilizing a longitudinal study design; (2) using data on infant outcomes that were collected in their natural environment (their homes), rather than a laboratory setting; (3) accounting for current maternal mental health at the time of infant assessment; and (4) examining whether associations between elevated PPD symptomatology and infant behavioral outcomes differ for boys and girls. We were motivated to address two major research questions: (1) Are there prospective associations between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age? (2) Are there gender differences in the associations between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age?

The specific aims and hypotheses were as follows:

**AIM 1**: To prospectively examine the associations between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age (total, internalizing, and externalizing).

- We hypothesized that infants of mothers who exhibit elevated PPD symptomatology at eight weeks postpartum would show significantly higher odds of total, internalizing, and externalizing behavior problems at 12 months of age as compared to infants of mothers without elevated PPD symptomatology.
We hypothesized that these associations would remain statistically significant, but be attenuated, when controlling for important confounding factors and mother’s mental health status at the time of the 12 month infant assessment.

**Aim 1.a:** A secondary aim of the current investigation was to examine whether associations exist between elevated PPD symptomatology and specific behavioral symptoms (separation distress, hyperactivity, impulsivity/disruptive behavior, and anger).

- We hypothesized that we would find consistent associations across all internalizing behavioral symptoms (which all measure separation distress).
- Infants of mothers with elevated PPD symptomatology were not anticipated to have a uniformly increased odds of all symptoms of externalizing behavior problems. Based on the literature, we expected that infants of mothers with elevated PPD symptomatology would exhibit a significantly increased odds of impulsivity/disruptive behavior and anger, but a decreased odds of hyperactivity as compared to infants of mothers without elevated PPD symptomatology.

**AIM 2:** To examine whether the associations between elevated PPD symptomatology and infant behavioral outcomes differed between boys and girls.

- We anticipated that the associations between elevated PPD symptomatology and behavioral outcomes (total, internalizing, and externalizing) would differ by infant gender. More specifically, it was hypothesized that internalizing behavior problems would be more commonly observed among girls exposed to elevated PPD symptomatology than among exposed boys. Conversely, we expected that total and externalizing behavior problems would be more commonly observed among exposed boys than exposed girls.
METHODS

Study Design and Participants

The current study is a secondary data analysis of a prospective cohort study conducted between 2005 and 2008. The study methods are described in detail in Dagher and Shenassa (2012).[109] The original study recruited new mothers from a single hospital postpartum floor in a moderately-sized city in the northeastern United States. Criteria for eligibility included being at least 18 years of age and English-speaking. 662 of 932 approached women (71%) signed a consent form and completed an in-person interview at the hospital within 24 hours of childbirth. Additional data were also obtained from the hospital’s labor and delivery records. Data collected at this initial assessment included personal characteristics of the mothers (e.g., age, race/ethnicity, education level, prenatal smoking behavior) and infants (e.g., gender, birth weight). At eight weeks postpartum, a questionnaire-based in-person interview was conducted in the participant’s home, with a participation rate of 79% (n=526). At this time a modified version of the Edinburgh Postnatal Depression Scale (EPDS) was administered.[12] A third wave of data collection occurred at 12 months postpartum, with a participation rate of 49% (n=256) of the second wave. The extensive questionnaire administered aloud to mothers contained an adapted version of the Infant-Toddler Social and Emotional Assessment (ITSEA). Detailed information on infant behavioral functioning was collected as part of the ITSEA. Information regarding current maternal mental health functioning was also collected at this time.
Comparison of non-participants and participants of the 12 month follow-up revealed no meaningful between-group differences\(^6\) on important baseline characteristics, including mean infant birth weight (participants: 3428.3 ounces, non-participants: 3413.6 ounces) and mean maternal age (participants: 28.3 years, non-participants: 27.4 years). Small differences were found for male infant gender (participants: 47.5%, nonparticipants: 54.9%), non-Hispanic white maternal race (participants: 74.1%, nonparticipants: 67.3%), and high maternal education level (at least some college; participants: 57.9%; nonparticipants: 51.9%). Mean depression score differed somewhat between those who did and did not participate in the 12 month follow-up (participants: 4.6, nonparticipants: 5.4). Taken together, these differences suggest there is little concern for differential loss to follow-up. However we will address these issues further in the limitation section of the discussion. The sample at 12 months remained largely representative of the original population in terms of important characteristics of the mothers (age, race/ethnicity, education level, PPD symptomatology score) and infants (birth weight, gender).

Of the 256 women who participated in the 12 month follow-up, 8 were excluded for missing 2 or more items from the internalizing scale, thus leaving 248 in the overall analytic sample. All recruitment and interviewing was completed by a single research assistant. The original study had Institutional Review Board (IRB) approval from Brown University and the participating hospital; current analyses were approved by the Brandeis University IRB.

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\(^6\) Formal tests of statistical interaction were not performed. Relying on statistical significance to determine if the participating sample at 12 months remained representative of the original cohort was problematic. Due to our limited sample size, large meaningful differences between groups may not attain statistical significance. We instead looked at the distribution of important covariates across participants and non-participants. If the participating group at 12 months remains representative of the original sample, means and percentages should be very similar on these variables.
Measures

Maternal PPD Symptomatology

The Edinburgh Postnatal Depression Scale (EPDS) was administered to mothers at the eight week follow-up. While this assessment falls outside of the four week postpartum window required by the DSM criteria for PPD,[9] this requirement has been criticized for being too stringent. Research has found that most women (nearly 70%) experience PPD onset within the first several months postpartum,[21] and that onset later than four weeks may have similar child consequences to that of earlier onset PPD.[22] This suggests that eight weeks postpartum is an appropriate exposure window for the assessment of PPD symptoms.

The EPDS consists of ten short statements regarding the mother’s moods during the previous 7 days, asking mothers to rate their degree of agreement with each.[12] These statements tap into symptoms included in the DSM-V PPD diagnosis (e.g., depressed mood, loss of interest in activities, insomnia). Sample items include “I have felt sad or miserable,” “I have looked forward with enjoyment to things,” and “I have been so unhappy that I have had difficulty sleeping.”[9] The original study excluded the tenth item of the scale, which asks about suicidal ideation. This item was excluded given recent research suggests self-harm to be a factor independent of other EPDS items.[109]

The scale was scored using a response range from 0 to 3 (0=not at all; 1=not much; 2=sometimes; 3=often), and items were summed to indicate PPD symptomatology scores for each woman. Based on these scores women were classified into one of two groups: women with scores ≥9 (range 0-13) were considered to have elevated PPD symptomatology; women scoring 0-8 were considered to have non-elevated PPD symptomatology. This choice of threshold level was informed by a review of the literature.[110-113] (Further information about how the EPDS
was used in the current analyses can be found in Appendix 1 and Appendix 3.) Although this cut-point is lower than the clinical threshold of ≥13,[114] research has shown that subclinical levels of depression may have significant implications on both maternal functioning[23-27] and infant outcomes[23, 28, 29] that are comparable to that of clinical depression.

Infant Behavior Problems at 12 Months of Age

As noted above, infant behavioral outcomes were assessed as a part of the third wave questionnaire using an adapted version of the ITSEA. (See Appendix 1 for further detail on the behavioral assessment and the variables included in the current analyses.) The ITSEA screener has previously been shown to be a valid and reliable assessment tool for children 12 months of age to 35 months, 30 days of age.[115] The ITSEA is useful in the identification of children in this age range in need of further evaluation for potential behavioral disorders.[115]

In the current study, the adapted Parent Form of the ITSEA was administered as a self-report questionnaire to the mothers. Internalizing behaviors were assessed utilizing four out of six items from the separation distress subscale: (1) cries when mothers leaves; (2) gets upset with new babysitter; (3) gets upset with familiar person; (4) hangs onto mother/wants to be in lap. An additional similar item was also included: (5) looks for mother when she leaves.

The six items in the externalizing domain relate to hyperactivity, impulsivity/disruptive behavior, and anger, and include: (1) gets hurt often; (2) restless and can’t sit still; (3) gets wound up/silly when playing; (4) constantly moving; (5) very loud/ screams a lot; (6) goes from toy to toy quickly. Items were scored on the basis of a 0-2 scale in the original study (0=not true/rarely; 1=somewhat true/sometimes; 2=very true/often). This type of Likert scale[116] is a common method utilized on psychological surveys and have been shown to be reliable measures of respondent attitudes.[117]
If subjects were missing only one item on either the internalizing (n=80) or externalizing (n=9) subscales, mean imputation utilizing the scores on the remaining items was used to fill in the missing value. Mean imputation is a common method for addressing missing data in public health research.[118] Due to the modest analytic sample size, we felt that this method was favorable over excluding these subjects altogether. Internalizing and externalizing scores were then calculated by separately summing the items within each scale. Total scores were calculated as the sum of all internalizing and externalizing items. The mean total behavior problem score was 8.3 (SD=3.7). The mean scores for the internalizing and externalizing behavior problem domains were 3.8 (SD=2.4) and 4.5 (SD=4.2), respectively. The Cronbach’s alpha reliabilities of the scales (internalizing: 0.71; externalizing: 0.53; total: 0.67) were comparable to those found in the literature.[115]

Scores on each scale were not normally distributed as anticipated based on prior research.[115] Some levels of internalizing and externalizing problems are anticipated at this age as part of the normal course of development.[54] So it is common for many children to have low levels, but not extreme maternal endorsement of symptoms. Therefore we sought to identify children on extremes of these distributions as this will help ensure we are focusing on less normative levels of behavior. We considered infants to have behavior problems if they scored within the top 30% of the sample on the respective scale score. This is comparable to cut-points used on similar child behavior assessment tools to identify those with suspected behavior problems.[50] (As discussed below and in Appendix 3, we examined whether findings were influenced by our selected cut-points to identify infant behavior problems).

We also performed an item-level analysis for each statement on the internalizing and externalizing subscales of the adapted ITSEA. While all items on the internalizing scale
measure separation distress, items on the externalizing scale measure differing aspects of externalizing behavior problems. More specially, the externalizing items restless and can’t sit still, constantly moving, and goes from toy to toy quickly reflect infant hyperactivity; the items gets hurt often and gets wound up/silly when playing tap into areas of impulsivity/disruptive behavior. Finally, the item is very loud/ screams a lot was used as a measure of infant anger.

For these analyses, scores on each individual item were collapsed into a dichotomous rating, indicating the presence or absence of a particular behavior problem. Infants were considered to possess the problem if their mother reported it to be “very true” (as opposed to “somewhat true” or “not true”). We found that many of the behaviors were too common among the infants when combining the “very true” and “somewhat true” response categories, often yielding higher percentages of infants with than without the specific behavior problem. (See Appendix 2.) Therefore, we felt that the more stringent categorization used here was more indicative of an underlying behavior problem.

Potential Confounding Factors

Potential confounding factors were identified from the literature and include: infant gender,[4] infant birthweight,[119] maternal age at time of birth,[16, 120] maternal race/ethnicity,[121] maternal education[16, 122], maternal marital/relationship status,[14] and maternal smoking during pregnancy.[109] Infant gender was coded from hospital records. Given that literature on this topic typically focuses on whether boys have increased vulnerability compared to girls, infant gender was coded with girls as the reference group (1=boy, 0=girl). Birth weight (measured in ounces) was obtained from medical records. Maternal race/ethnicity was dichotomized as non-Hispanic white in comparison to all other options. This was done due to the low prevalence of many of the other racial/ethnic groups. The
most commonly endorsed other categories were: Hispanic or black (22.6%) and non-white other (2.4%). As in a previous publication with this cohort,[109] maternal education level was coded as <college (less than high school, high school graduate/GED, or trade or technical school) or ≥some college (some college, college graduate, or graduate degree). Maternal marital/relationship status was coded as single (single, divorced/separated, or widowed) versus partnered (engaged, married). As part of the hospital interview, mothers also reported whether they smoked during pregnancy (coded as 1=ever smoked during pregnancy, 0=never smoked during pregnancy). Other factors were also considered for inclusion as potential confounders, including premature birth and serious infant health problems, but their prevalence was low in this sample (<10%) so they were not included. Data were not available for other factors which we would have liked to include (e.g., maternal use of alcohol/drugs during pregnancy, infant birth defects). However, since these factors are uncommon in the population, failure to control for these factors is not likely to greatly influence findings. Issues of potential unmeasured or residual confounding are discussed in the limitations section of the discussion.

Assessment of Maternal Mental Health at the 12 Month Follow-up

At the 12 month follow-up, the assessment of current maternal mental health was limited to questions regarding parenting stress. Elevated parenting stress has been shown to be associated with maternal depression.[122] This measure was used in the current analyses as a proxy measurement of current maternal depressive symptomatology. (See Appendix 1 for further detail.) Our main rationale for controlling for the presence of current maternal mental health was to ensure that analyses were examining prospective associations between earlier maternal PPD symptomatology and later infant behavioral outcomes. We fully recognize that parenting stress is only a proxy measure of the true construct for which we would have liked to have
controlled. Yet, prior studies have shown that PPD is related to higher levels of parenting stress and more negative experiences of parenting,[123] suggesting that parenting stress may indeed be a marker of concurrent maternal depression. Women who responded “strongly agree” to the statements “I feel stress by the responsibility of being a parent” and “It can be difficult to balance all of my responsibilities because of my child(ren)” were coded as having elevated parenting stress.

The Analysis Plan

Firstly, we examined the distribution of variables in the overall analytic sample, and by elevated versus non-elevated PPD symptomatology (Table 1). Numbers and percentages are reported for binary variables, and means and standard deviations for continuous variables. Differences in variables were examined across the maternal PPD symptomatology groups to identify potential confounding variables in the current study. Chi-square tests for binary variables and t-tests for continuous variables were used. Associated 2-tailed p-values are also reported.

Secondly, we examined the relationship between elevated maternal PPD symptomatology and infant behavior problems (Table 2). Three logistic regression models were run separately for each outcome examined (total behavior problems, internalizing behavior problems, and externalizing behavior problems). In Model 1, we examined the unadjusted association between elevated maternal PPD symptomatology and each infant behavioral outcome (total, internalizing, and externalizing). In Model 2, the association was examined with adjustment for potential confounding factors identified in part one above. In Model 3, the association was examined with full adjustment for the same covariates as in Model 2 plus elevated parenting stress at the time of the infant assessment. Odds ratios (ORs) and 95% confidence intervals
(CIs) are reported. In evaluating results from these models, we not only focused on statistical significance, but on the direction and size of the estimated effects and their precision (e.g., width of confidence intervals). In commenting on the role of confounding in the estimated associations, we also focused on the magnitude of change in the effect estimates as models were adjusted for potential confounders and our marker of current maternal mental health at 12 months.

Thirdly, we examined the relationship between PPD and individual, specific behavioral symptoms using logistic regression models. Reported models are fully adjusted for confounding factors and current maternal mental health at 12 months (Table 3). (These analyses are referred to as “item-level” analyses.)

Fourthly, we examined potential gender differences in the PPD-behavioral outcomes associations in fully adjusted models by separately calculating associations for boys and girls (Table 4). ORs and 95% CIs are reported for analyses stratified by infant gender. Again, in evaluating these results we focused on the size of the estimated effects, rather than just statistical significance.

Lastly, as explained briefly in the results section and in detail in Appendix 3, a set of additional analyses were conducted to test assumptions made when coding our exposure and outcome variables.

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7 Formal tests of statistical interaction were not conducted. Due to the limited sample size and the fact that tests of interaction are known to be underpowered, no statistically significant interactions were anticipated.
RESULTS

Sample Characteristics

Characteristics of the analytic sample are displayed in Table 1. The majority of women were non-Hispanic white (75.0%), with an average age of 28.4 years (SD=4.5); 41.1% (n=102) were not educated beyond the high school or technical school level; 12.5% of women (n=31) reported elevated levels of parenting stress at the 12 month follow-up. The average number of PPD symptoms was 4.5 (standard deviation[SD]=4.4), with 14.5% of the sample (n=36) meeting our threshold (≥9 symptoms) for elevated PPD symptomatology. Thresholds for behavior problems aimed to identify approximately the top 30% of the sample distribution for each category yielded 29.0% for total (n=72), 25.4% for internalizing (n=63), and 28.6% for externalizing (n=71) behavior problems.

Characteristics According to Depression

Differences in characteristics were examined among women with elevated (n=36) versus non-elevated (n=212) PPD symptomatology to identify potential confounders. Potential confounders were those characteristics found to be associated with PPD at a liberal p-value of ≤0.10. This methodology helped ensure that we identified the most important potential confounders while allowing us to be parsimonious in our covariate selection given the moderate sample size. Women who had girl infants, were a race/ethnicity other than non-Hispanic white, were single, and had smoked during pregnancy were markedly more likely to have elevated PPD symptomatology at eight weeks postpartum. We thus included these four variables as covariates in our adjusted models.
Aim 1: Associations between PPD Symptomatology and Infant Behavior Problems

Our first aim was to prospectively examine the associations between elevated PPD symptomatology and infant behavior problems (total, internalizing, and externalizing) at 12 months of age. Table 2 presents these results. In the unadjusted model, elevated PPD symptomatology was statistically significantly associated with about a 3-fold increased odds of total infant behavior problems (OR=2.93, 95% CI=1.42-6.10). This association was somewhat attenuated (and no longer statistically significant) when controlling for infant gender, maternal race/ethnicity, marital/relationship status, and smoking during pregnancy (OR=2.14, 95% CI=0.98-4.67). The estimated effect was further reduced when also controlling for elevated parenting stress (OR=1.98, 95% CI=0.90-3.50). The estimated size of the effect of PPD on infant total behavioral problems in the unadjusted model was reduced to about half the size (48.0%) following full adjustment, suggesting that much of the original association was due to confounding or due to concurrent mental health problems.

Elevated PPD symptomatology was associated with a somewhat increased odds of infant internalizing behaviors at 12 months of age, although this association was not statistically significant (OR=1.83, 95% CI=0.87-3.88). It was also attenuated when controlling for covariates in Model 2 (OR=1.58, 95% CI=0.71-3.50). Controlling for parenting stress in Model 3 further reduced the association (OR=1.49, 95% CI=0.65-3.28). The magnitude of the unadjusted estimated effect of PPD on infant internalizing behavior problems was reduced (by 22.8%) after controlling for all factors.

Infants of mothers with elevated PPD symptomatology had a statistically significant increased odds of externalizing behavior problems at 12 months of age (OR=2.28, 95% CI=1.11-4.72). However, this association was reduced and no longer statistically significant
when controlling for covariates (OR=1.78, 95% CI=0.83-3.82). The association was further reduced when controlling for elevated parenting stress (OR=1.65, 95% CI=0.76-3.57). The estimated effect size of PPD on infant externalizing behavior problems was attenuated (by 38.2%) from the unadjusted to the fully adjusted model.

Boys and infants of non-Hispanic white race/ethnicity were found to have a significantly reduced odds of behavior problems (total, internalizing, and externalizing) in the adjusted models. All other covariates were associated with increased odds of behavior problems with the exception of maternal smoking during pregnancy. Maternal smoking during pregnancy was associated with reduced odds of internalizing behaviors in the adjusted models, although associations should be interpreted cautiously as findings were not statistically significant.

Aim 1.a: Item-Level Analysis of Specific Behavioral Symptoms

In addition to examining the associations between elevated PPD symptomatology and infant total, internalizing, and externalizing behavior problems, as a secondary aim we examined associations with specific behavioral symptoms. To do so, we examined the distributions of each specific behavior problem across categories of maternal PPD symptomatology and fit fully adjusted models. Results are displayed in Table 3.\(^8\) We focus on the overall pattern of findings and interpret these findings with caution due to the relatively low prevalence of some of the items.

Results suggest that elevated PPD symptomatology was consistently associated with internalizing behavioral symptoms reflecting separation distress. Large between-group

\(^8\) Note that denominators on which percentages are based vary due to missing data on some items.
differences\(^9\) were found for the item *looks for mother when she leaves* (80.6% elevated PPD symptomatology; 45.3% non-elevated group). Maternal PPD symptomatology was found to be associated with increased odds of problematic reports on items *gets upset when left with a new babysitter* (OR=1.70, 95% CI=0.68-4.26), *gets upset with familiar person* (OR=3.03, 95% CI=0.49-3.91), and *hangs onto mother/wants to be lap* (OR=1.76, 95% CI=0.79-3.91) and *looks for mother when she leaves* (OR=4.81, 95% CI=1.95-11.83). Only the item *looks for mother when she leaves* reached statistical significance. The limited power of our analyses is particularly apparent in the wide confidence interval for this item.

Analysis of specific externalizing behavioral symptoms (hyperactivity, impulsivity/disruptive behavior, and anger) suggests infants of mothers with elevated PPD symptomatology do not have a uniformly increased odds of all types of externalizing behavior problems. Among items relating to hyperactivity, there were some inconsistencies in the findings: elevated PPD symptomatology was positively related to *restless and can’t sit still* (OR=2.22, 95% CI=0.92-1.14) and *goes from toy to toy quickly* (OR=1.90, 95% CI=0.65-5.57), while an inverse association was observed for *constantly moving* (OR=0.74, 95% CI=0.33-1.66). For the two items relating to impulsivity, both showed positive effects (*gets hurt often*: OR=2.65, 95% CI=0.24-29.2; *gets wound up/silly when playing*: OR=1.42, 95% CI=0.66-3.07). It may be that infants of mothers with (versus without) elevated PPD symptomatology are less likely to display anger at 12 months (*very loud/screams a lot*: OR=0.81, 95% CI=0.32-2.06). However, each of these results were not statistically significant and therefore are indicative only of possible trends.

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\(^9\) Due to limited sample size and low prevalence on some items, statistical significance was not expected to be achieved. So in addition to tests of statistical significance, we identified substantial between-group differences to be at the magnitude of \(\geq 20\%\) across groups.
Aim 2: Gender Differences in the PPD-Infant Behavioral Outcomes Associations

The second aim of this research was to examine whether the associations between PPD and infant behavioral outcomes differed between boys and girls. Fully adjusted models for the associations between elevated maternal PPD symptomatology and infant behavior problems are displayed in Table 4, separately for boys (n=117) and girls (n=131). After accounting for covariates, exposed boys were found to have a slightly higher odds than exposed girls of total behavioral problems (boys: OR=2.23, 95% CI=0.56-9.19; girls: OR=1.93, 95% CI=0.73-5.09). However, the associations were not statistically significant.

Between-group differences were observed for the internalizing and externalizing domains. Girls exposed (versus unexposed) to elevated maternal PPD symptomatology had a higher odds of internalizing behavior problems at 12 months of age (girls: OR=1.85, 95% CI=0.68-5.04). In contrast, boys exposed (versus unexposed) to elevated PPD symptomatology showed a decreased odds of later internalizing behavior problems (boys: OR=0.68, 95% CI=0.13-3.66). There appears to be some separation of effects, as the point estimate for boys is at the lower end of the confidence interval for girls. This suggests that the differences between boys and girls may be meaningful and not just due to random variation.

Decreased internalizing behavior problems in exposed boys is coupled with substantially elevated odds of externalizing behavior problems in association with maternal PPD. Although exposed girls show moderately elevated odds of externalizing behavior problems, it is not as high as that of exposed boys (boys OR=3.70, 95% CI=0.98-14.00; girls OR=1.14, 95% CI=0.43-2.99). Again, some separation of effects is apparent, as estimated effect for boys falls outside of the range of the confidence interval for girls. (Note that none of these relationships are statistically significant.)
Additional Analyses

Our models made many assumptions about appropriate cut-points for elevated PPD symptomatology (≥9 symptoms) and infant behavior problems (top 30%). We conducted additional analyses (detailed in Appendix 3) to examine whether the overall pattern of our findings would remain following changes in our definitions of elevated PPD symptomatology and infant behavior problems.

The associations between elevated PPD symptomatology and infant behavioral outcomes were re-examined using varying thresholds for classifying women as having elevated PPD symptomatology. In addition to using the EPDS as a continuous variable, more stringent (≥13 symptoms) and more liberal (≥5 symptoms) cut-points were used in these supplemental analyses. Similar patterns of results to those presented here were found when treating maternal PPD as a continuous variable and when using the alternate cut-points to indicate elevated PPD symptomatology.

Additionally, the associations between elevated PPD symptomatology and infant behavioral outcomes were also re-examined after altering the threshold used to indicate infant behavior problems to the top 20% of the sample distribution. Using this more stringent threshold for infant behavior problems also produced comparable findings (but confidence intervals tended to be slightly wider, suggesting further decreased precision in our estimated effects).

Given our limited sample size, we were also interested in whether utilizing a covariate sum score\textsuperscript{10} in place of adjustment for each individual covariate factor would yield narrower confidence intervals. This method yielded only slightly tighter confidence intervals and, since

\textsuperscript{10} In creating this score, participants received a point for each individual covariate factor present: boy infant gender, other maternal race/ethnicity, “single” maternal marital/relationship status, maternal smoking during pregnancy, and elevated parenting stress.\textsuperscript{[124]}
the overall message did not change, we therefore opted to present the original models as it allows us to see the relationships between each covariate and infant behavioral outcome.

**DISCUSSION**

This study prospectively examined the associations between elevated PPD symptomatology at eight weeks postpartum and multiple infant behavioral outcomes at 12 months of age. After adjusting for both potential confounding factors (infant gender, maternal race/ethnicity, marital/relationship status, and smoking during pregnancy) and a proxy measure for current maternal mental health status, we found small-to-moderate positive, but not statistically significant, associations between elevated PPD symptomatology and infant behavior problems (total, internalizing, and externalizing). The effect appears to be modified by infant gender, with exposed girls experiencing heightened internalizing behavior problems compared to exposed boys, and exposed boys more likely to experience externalizing behavior problems than exposed girls.

**Aim 1: Associations between PPD Symptomatology and Infant Behavior Problems**

In the unadjusted model, we found elevated PPD symptomatology to be positively associated with infant behavior problems. The associations were statistically significant for PPD symptomatology and total and externalizing, but not internalizing, behavior problems. When adjusting for confounding factors (infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy), the observed associations were substantially attenuated and no longer statistically significant, suggesting that much of these associations may be due to confounding. Additional adjustment using a proxy measure for current maternal mental health attenuated the effects even further, indicating that there does not
appear to be much of a lingering effect of PPD at eight weeks postpartum on subsequent behavior problems at 12 months of age. Due to the limited sample size (n=248), it is possible that we lacked adequate statistical power achieve statistically significant effects. But even if there were statistically significant associations, the effects are likely to only be small-to-moderate in magnitude.

Aim 1.a: Item-Level Analysis of Specific Behavioral Symptoms

In addition to examining total, internalizing, and externalizing behavior problems, we examined the associations between elevated maternal PPD symptomatology and specific behavioral symptoms (separation distress, hyperactivity, impulsivity/disruptive behavior, and anger) (Table 3). We were interested in evaluating whether the associations with PPD were uniformly distributed across the entire behavioral domain. It was hypothesized that exposed infants would show consistently elevated behavior problems across items in the internalizing domain,[40, 64, 66, 83] but show differences according to specific subtypes of externalizing behavior problems (activity level,[67, 68] impulsivity/disruptive behavior,[69-71] and anger[73, 88]).

All internalizing items used in the current analyses relate to separation distress. Prior cross-sectional research has consistently suggested that infants of mothers with (versus without) PPD are more likely to have heightened fear[40] and separation distress.[64] As hypothesized, exposed infants were observed to have an overall increased odds of stranger fear (e.g., gets upset with new babysitter) and separation anxiety from their mothers across various situations (e.g., looks for mother when she leaves, hangs onto mother/wants to be in lap), although the associations were not statistically significant. This finding supports previous research.[40, 64] While we observed positive associations between PPD symptomatology and all items except
cries when mother leaves, it is possible that this particular item is too regularly observed in children at 12 months of age to reliably measure problem behaviors.

Given previous research, we hypothesized that within the externalizing domain, infants of mothers with PPD symptomatology would exhibit increased odds of anger[73, 88] and impulsivity/disruptive behavior,[69-71] but decreased odds of hyperactivity[67] as compared to unexposed infants. In contrast to previous research,[73, 88] our results did not support such hypothesized association regarding infant anger. However, the original researchers for this cohort study only included one item related to anger in the externalizing domain, and therefore we may be limited in our ability to capture this domain. Yet, these results preliminarily suggest that infants of mothers with elevated PPD symptomatology have increased odds of displaying impulsive/disruptive behaviors (e.g., gets hurt often, gets wound up/silly when playing). This is in step with the literature, which suggests infants of mothers with PPD tend to be more defiant and disruptive during play compared to infants of mothers without PPD.[69-71] (But our results again should be interpreted cautiously as they are not statistically significant.)

While some research has suggested that offspring of mothers with depressive symptomatology have lower levels of physical activity during early infancy,[67] our observations did not fully support this conclusion. We observed evidence of a positive association between PPD and infant hyperactivity on some activity level items (restless and can’t sit still, goes quickly from toy to toy), but not all (constantly moving). This difference between the literature and observed results could be due to the age group examined. Our review of the literature identified one cross-sectional study regarding PPD and activity level in infants at 3-6 months, which reported reduced levels in exposed (versus unexposed) infants.[67] Conversely, other research focusing on school-aged children have reported hyperactivity in
association with exposure to PPD.[72, 85] We found that infants at 12 months of age exhibited a profile on activity level paralleling neither younger nor older children; they exhibited an intermediate profile. Future studies with repeated assessments of items tapping activity level would be helpful in examining how associations between maternal PPD and activity level may change over time.

**Aim 2: Gender Differences in the PPD-Infant Behavioral Outcomes Associations**

We hypothesized that exposed boys would be more likely to have total and externalizing behavior problems[90] as compared to exposed girls, with internalizing behaviors more commonly observed among exposed girls than among exposed boys.[48, 91] Although the association between elevated PPD symptomatology and total behavior problems was slightly higher among boys than girls, the differences were not marked (boys: OR=2.23, 95% CI= 0.56-9.19; girls: OR=1.93, 95% CI=0.73-5.09). (Neither finding was statistically significant.) Given our limited statistical power, it is not possible to comment on whether these difference are truly meaningful, as suggested in some previous research reporting boys to be more prone to the adverse effects of PPD than girls.[4, 59, 90] It is possible that this apparent discrepancy between the literature and our observations could be due to the age group under examination. For example, while it has been suggested that gender differences observed in young children may be due to an underlying biological maturational advantage in girls, which acts as a protective factor to the adverse social effects of maternal depression,[4] it is possible that 12 months of age may be too soon for advantage to have arisen. Additionally, as the infant behavior assessment was a subjective questionnaire completed by mothers, it is possible that mothers may differentially regard what is considered to be “normal” behavior when assessing infants of different genders
(e.g., there may be different baseline ideas of what is considered loud or restless for girls versus boys).

When examining gender differences across the internalizing and externalizing domains, we found evidence suggesting differential associations. Elevated PPD symptomatology was found to place girls at a higher risk of internalizing behavior problems than boys, but place boys at a higher risk of externalizing behavior problems than girls (Table 4). Effects did not reach statistical significance. However, point estimates for boys on both internalizing and externalizing behavior problems fell outside (or on the boundary) of the confidence intervals for girls, suggesting a meaningful separation of effects. These observations are in keeping with previous findings that PPD has a greater effect on internalizing behavior problems among girls than boys.[56, 91] This supports previous observations suggesting heightened externalizing behavior problems in boys compared to girls.[90]

**Strengths**

Our secondary data analysis was well poised to investigate the association of elevated maternal PPD symptomatology and broader (total, internalizing, and externalizing) as well as specific (separation distress, hyperactivity, impulsivity/disruptive behavior, and anger) infant behavioral outcomes at 12 months of age. The study design and execution was able to address many limitations of previous studies. Typically, questions about PPD symptomatology and infant behavioral outcomes are addressed with cross-sectional designs.[69-71, 73, 88] Therefore, this study’s longitudinal design is an advantage as it gives us an opportunity to establish temporal ordering. Furthermore, the few longitudinal studies in the literature tend to examine behavioral outcomes in school-aged children,[72, 85] so this study adds important data regarding prospectively assessed behavioral outcomes at 12 months of age.
Studies within the literature tend to involve infant observations within experimentally constructed situations; these may not be generalizable to real life contexts.[40, 64, 65] Assessment of real-life infant behavior in the current analyses is thus an advantage over these constructed situations.

In this study we were able to control for both various confounding factors (infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy) and for current maternal mental health at the time of the 12 month follow-up. Additionally, prior prospective studies within the literature frequently lack measures of maternal depression at the time of child behavioral assessment,[72] thereby making it unclear whether the observed associations are due to the residual effects of PPD or due to current maternal depressive status.

Another strength of this study is the investigation of potential gender differences in associations between PPD and infant behavioral outcomes. There is limited existing literature exploring how the effects of PPD symptomatology on childhood behavior may differ by gender, [4, 48, 59, 90, 91] specifically during infancy. We also included multiple indices of infant behavior problems (total versus internalizing versus externalizing, and specific behavioral symptoms) to examine whether associations differed for different types of behavioral outcomes.

**Limitations**

There are several important limitations that must be considered when interpreting these findings: limited sample size, assessment of exposure and outcomes variables, and residual confounding. First of all, analyses are limited by the sample size (n=248). Of course it is unknown whether statistical significance would have been achieved with a larger analytic sample. But findings do suggest that any real associations between elevated PPD
symptomatology and infant behavioral problems at 12 months of age are likely to be only small-to-moderate in magnitude. Moreover, less than half of the baseline sample participated in the 12 month follow-up, raising concerns of differential loss-to-follow-up. However, when examining the remaining versus lost participants, no substantial differences were found between groups on important covariates. This diminishes concerns that the final sample was not representative of the original cohort.

Several potential limitations of this study result from the methodology used to assess maternal PPD symptomatology. PPD symptomatology was assessed by a single, self-reported measure administered at eight weeks postpartum. We acknowledge that it would have been beneficial to administer multiple measures of PPD over time. The utilization of multiple PPD measures would increase the likelihood that women were correctly classified as having elevated versus non-elevated PPD symptomatology. Although misclassification may be likely, it has been noted that the majority of women (nearly 70%) experience PPD onset within the first six weeks postpartum,[21] suggesting that many women experiencing PPD symptomatology were correctly identified in this study. While many women experience physical symptoms similar to those of PPD as a part of a normative reaction following childbirth (e.g., reductions in energy, changes in sleep pattern), elevated PPD symptomatology in the current analyses is assessed using a measure that focuses on maternal mood rather than strictly physical symptoms.[12] It is also important to note that, as a self-report measure, the EPDS is subject to error. Although the EPDS does not offer a clinical diagnosis of depression, it has been shown to have high sensitivity for identifying women with PPD.[125] Additionally, the EPDS is advantageous given that self-report surveys are less time-consuming than interview-based diagnostic
methods,[125] and have been found to be important for identifying subclinical levels of depression.[126, 127]

As behavior at this developmental stage is unstable and difficult to measure, our measurement of infant behavior problems is not without limitation. Since infant behavior may be inconsistent, it would have been beneficial to have multiple assessments, rather than a single assessment. Utilizing only a single measure at a single point in time may increase the likelihood of misclassifying infants. Additionally, the infant behavioral assessment was based solely on maternal reports. It has previously been noted that mothers with depression may over-report child behavior problems,[56, 107, 108] leading to an overestimation of the harmful effects of PPD on offspring behavioral outcomes.

It is unclear whether the lack of statistically significant associations observed in the current analysis is due to a true lack of association at 12 months, or due to the measurement tool used (an adapted version of the ITSEA). Whether the specific items selected for inclusion by the original study investigators are tapping into the correct behaviors for this age group is a critical question that we cannot directly answer. Yet, our item-level analysis of individual behavioral symptoms offers some insight into this issue. While some specific behavioral symptoms were observed in association with PPD (Table 3), some observations were inconsistent. For example, the items restless and can’t sit still and constantly moving both address activity level in infants, but yielded highly contrasting results in association with PPD. This suggests that activity level within infants at 12 months may not be stable enough to reliably measure, or that perhaps this type of maternal report questionnaire may not be well-suited for assessing activity level in infants at this age. Furthermore, we observed that many specific behavioral symptoms were highly prevalent within this age group (see Appendix 1). For example, over 80% of mothers
reported the items *looks for mother when she leaves* and *constantly moving* to be at all true regarding their infants (Table A3.1), providing evidence that these items may too closely resemble normal infant behavior at 12 months of age to reliably identify problems.

We aimed to control for important confounding factors. Yet it is possible that we did not control for all important confounding factors of the associations between PPD and infant behavioral outcomes, leading to unmeasured confounding. For example, our analyses lacked data on factors such as drug usage during pregnancy, genetic predispositions to PPD, maternal history of other psychopathological conditions, and infant birth defects and serious medical conditions. It is possible that such factors may simultaneously make women more prone to exhibiting elevated PPD symptomatology and contribute to adverse infant developmental outcomes, thereby (partially) accounting for observed associations. Other factors were also considered for inclusion as potential confounding, including premature birth and serious infant health problems, but their prevalence was low in this sample (<10%) so they were not included. For those confounding variables we did measure, some were only proxies of the true underlying construct, leading to residual confounding. (For example, maternal education is only a of socioeconomic status).

Finally, we acknowledge that we only had a proxy measure for current maternal mental health, elevated parenting stress (see Appendix 2), rather than a true assessment of maternal depression. This limitation arises from the original study design, emphasizing a challenge of secondary data analysis. It is possible that this proxy measurement may not adequately control for current maternal depressive symptoms.
Future Research Directions

Future studies should implement various methodological improvements to address the limitations of the current project. First of all, a larger sample size is needed to adequately power the study to explore not only overall associations, but also to test for gender differences. A larger sample would have yielded more subjects falling into the extremes on the distributions of maternal PPD symptomatology and infant behavioral problems, allowing for the examination of those more likely to be true population outliers.

Investigations should also include multiple assessments of both maternal depressive symptomatology and infant behavioral outcomes into their designs. Follow-up with additional outcome measurements over time would allow for the examination of whether a critical window exists for identifying associations between PPD and behavior problems from infancy into later childhood. Additionally, including outside raters of both maternal depressive symptomatology and infant behavioral outcomes would be useful. Such expert raters would reduce bias arising from subjective self-reports, improving the likelihood of correct classifications. It would also be helpful to see if similar or different patterns in findings emerge when comparing maternal behavioral ratings to those of other caregivers (e.g., fathers).

Finally, future studies should examine a wider range of potential effect modifiers. The current study looked at only infant gender. Various social determinants of health have been suggested to accompany PPD (e.g., low socioeconomic status, marital/relationship distress, minority group status, stressful life events)[3] and may moderate the effect of exposure to PPD on behavioral outcomes. For example, some researchers suggest that maternal socioeconomic status (SES) may modify these associations. Heightened adverse behavioral outcomes in association with PPD have been observed among infants and young children of low (versus...
high) SES families,[56, 70, 72, 90, 128] suggesting high SES may act as a buffer of the adverse effects of PPD.[70] Future studies should stratify results based on SES and other social determinants of health (e.g., race/ethnicity) in order to explore how such characteristics may modify the association between PPD and infant behavioral outcomes.

**Implications for Intervention and Policy**

Research regarding (a) the extent of the impact of PPD on infant behavior, (b) the stage at which specific deficits in behavior begin to arise, and (c) the identification of factors that may place exposed youngsters at heightened risk for poor outcomes is important for informing intervention and treatment strategies. Identifying mothers with significant levels of PPD symptomatology, and thus at-risk infants, is critical. Developmental problems acquired early in life often persist over time.[7] Cost-benefit analyses have shown that intervention during early childhood improves social, emotional, and behavior skills enabling labor force and economic growth contributions in the future.[129] Programs targeting the mother-infant relationship have been found to be effective at improving both maternal and infant mental and behavioral health.[101-106]

Yet new mothers are unlikely to seek treatment for their depression,[94] often due to lack of knowledge and fear of stigma.[130] There are also structural barriers influencing access to care (e.g., no source of regular care, lack of health insurance).[131] Effective initiatives aimed at increasing the number of women with PPD who receive treatment include community level interventions and efforts within healthcare settings.

Because new mothers are expected to be happy and overcome with joy at the birth of their child, mothers with depression often feel shame and guilt regarding their negative mood.[132] Mothers may not seek treatment for PPD symptomatology due to an inability to recognize
symptoms, a fear of disclosing feelings, and a doubt that health professionals may provide help.[130] Therefore, outreach programs have been suggested to increase awareness and destigmatize PPD.[129] Specifically, these programs may provide education regarding the prevalence of PPD, how to recognize its symptoms, and its potential impacts on infant and early childhood outcomes.[129] Information about where to receive screening and treatment should also be distributed to communities.[129] Furthermore, as it has been found that parents often do not seek mental health services for their young children due to structural barriers (e.g., costs, travel, lack of knowledge of where to go) and perceptions of services (e.g., stigma, previous negative experience),[133] PPD community outreach programs should also educate families regarding supportive services for the mental and behavioral health of infants and young children. Implementing such community-level interventions, particularly in high-risk areas (e.g., low socioeconomic status areas), could help ensure that women have the knowledge and tools to recognize PPD symptomatology.

Expectant and new mother interact frequently with a variety of healthcare providers (e.g., obstetricians/gynecologists, genetic counselors, pediatricians), providing opportunities for women to receive routine PPD screening and support, and treatment referral (if appropriate).[129, 134] For this reason, implementation of systematic screening and referrals for various health conditions, including PPD, in the pediatric primary care setting would be beneficial.[12, 131] It has been suggested that public health organizations should implement PPD educational workshops within healthcare organizations and provide informational materials to providers in order to strengthen understanding of mental and infant mental health.[129] By placing the knowledge and tools for PPD screening into the hands of pediatric
physicians, the burden for seeking PPD treatment would be taken out of the hands of the mother and restructured as a routine obligation of healthcare professionals.

Conclusions

Overall, this study suggests that much of the association between elevated PPD symptomatology and infant behavior problems at 12 months of age can be attributed to confounding influences and/or to the effects of current mental health concerns (rather than the lingering effects of PPD). After accounting for these factors, only a small-to-moderately sized association between elevated PPD symptomatology and infant behavior problems at 12 months of age remained. (Results from fully adjusted models were not statistically significant). Yet our findings also suggest that the effects of PPD may be modified by infant gender, with exposed girls tending to experience heightened internalizing behavior problems while exposed boys are more likely to experience externalizing behavior problems.

Although this secondary data analysis is limited by the assessment tools used in the original cohort study, strengths lie in its prospective design and ability to control for concurrent maternal mental health, allowing us to comment on the temporal association between PPD symptomatology and infant behavioral outcomes. Further research is needed to determine appropriate behavioral symptoms at 12 months of age in order to identify underlying behavior problems. It is also of interest to further investigate factors in the infant social environment (e.g., family, home, neighborhood, community) in order to examine the multidimensional pathway between PPD and adverse infant behavioral outcomes.
REFERENCES


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Table 1: Characteristics of overall analytic sample and by maternal PPD symptomatology

<table>
<thead>
<tr>
<th></th>
<th>Overall Analytic Sample (n=248)</th>
<th>Elevated PPD Symptomatology (n=36)</th>
<th>Non-Elevated PPD Symptomatology (n=212)</th>
<th>χ² (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maternal PPD Symptomatology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal PPD symptoms, mean (SD)</td>
<td>4.5 (4.4)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elevated depressive symptomatology¹</td>
<td>36 (14.5)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Infant Behavior Problems at 12 Months of Age²</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>72 (29.0)</td>
<td>18 (50.0)</td>
<td>54 (25.5)</td>
<td>8.99 (0.03)*</td>
</tr>
<tr>
<td>Internalizing</td>
<td>63 (25.4)</td>
<td>13 (36.1)</td>
<td>50 (23.6)</td>
<td>2.55 (0.11)</td>
</tr>
<tr>
<td>Externalizing</td>
<td>71 (28.6)</td>
<td>16 (44.4)</td>
<td>55 (25.9)</td>
<td>5.16 (0.02)*</td>
</tr>
<tr>
<td><strong>Potential Confounders</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant gender (boys vs. girls)</td>
<td>117 (47.2)</td>
<td>11 (30.6)</td>
<td>106 (50.0)</td>
<td>4.67 (0.03)*</td>
</tr>
<tr>
<td>Birth weight, mean ounces (SD)</td>
<td>3432.9 (448.9)</td>
<td>3437.4 (453.7)</td>
<td>3407.2 (425.2)</td>
<td>t=0.03 (p=0.71)</td>
</tr>
<tr>
<td>Maternal age, mean (SD)</td>
<td>28.4 (4.5)</td>
<td>28.1 (5.4)</td>
<td>28.5 (5.5)</td>
<td>t= 0.4 (p= 0.68)</td>
</tr>
<tr>
<td>Maternal race/ethnicity (non-Hispanic white vs. other)</td>
<td>186 (75.0)</td>
<td>23 (63.9)</td>
<td>163 (76.9)</td>
<td>2.78 (0.10)*</td>
</tr>
<tr>
<td>Maternal education (&lt;college vs. ≥some college)</td>
<td>102 (41.1)</td>
<td>17 (47.2)</td>
<td>85 (40.1)</td>
<td>0.65 (0.42)</td>
</tr>
<tr>
<td>Maternal marital/relationship status (single vs. engage/married)</td>
<td>101 (40.7)</td>
<td>19 (52.8)</td>
<td>82 (38.7)</td>
<td>2.53 (0.11)</td>
</tr>
<tr>
<td>Maternal smoking during pregnancy</td>
<td>85 (34.3)</td>
<td>18 (50.0)</td>
<td>67 (31.6)</td>
<td>4.62 (0.03)*</td>
</tr>
<tr>
<td><strong>Current Maternal Mental Health at 12 Month Assessment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated parenting stress³</td>
<td>31 (12.5)</td>
<td>7 (19.4)</td>
<td>24 (11.3)</td>
<td>1.86 (0.17)</td>
</tr>
</tbody>
</table>

¹ Elevated PPD symptomatology based on score of ≥9 on modified version of Edinburgh Postnatal Depression Scale at eight weeks postpartum.
² Infant behavior problems based scores within the top 30% of sample on the adapted version of Infant Toddler Social Emotional Assessment at 12 months of age on each respective scale.
³ Women considered to have elevated parenting stress if reported (1) feeling stressed by parenting responsibility and (2) having difficulty balancing parenting responsibilities at the 12 month follow-up.

*p<0.10
Table 2: Associations between elevated PPD symptomatology and infant behavior problems, unadjusted and adjusted models

<table>
<thead>
<tr>
<th></th>
<th>Model 1&lt;sup&gt;1&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 2&lt;sup&gt;2&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 3&lt;sup&gt;3&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Behavior Problems</strong>&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated PPD symptomatology&lt;sup&gt;5&lt;/sup&gt;</td>
<td>2.93 (1.42-6.10)*</td>
<td>2.14 (0.98-4.67)</td>
<td>1.98 (0.90-4.37)</td>
</tr>
<tr>
<td>Infant gender (boys vs. girls)</td>
<td>0.46 (0.25-0.84)*</td>
<td>0.41 (0.22-0.77)*</td>
<td></td>
</tr>
<tr>
<td>Maternal race/ethnicity (non-Hispanic white vs. other)</td>
<td>0.42 (0.21-0.82)*</td>
<td>0.43 (0.22-0.84)*</td>
<td></td>
</tr>
<tr>
<td>Maternal marital status (single vs. engaged/married)</td>
<td>1.92 (0.98-3.79)</td>
<td>2.10 (1.05-4.21)*</td>
<td></td>
</tr>
<tr>
<td>Maternal smoking during pregnancy</td>
<td>1.42 (0.71-2.84)</td>
<td>1.44 (0.71-2.91)</td>
<td></td>
</tr>
<tr>
<td>Elevated parenting stress&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td>2.32 (0.96-5.61)</td>
<td></td>
</tr>
<tr>
<td><strong>Internalizing Behavior Problems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated PPD symptomatology</td>
<td>1.83 (0.87-3.88)</td>
<td>1.58 (0.71-3.50)</td>
<td>1.49 (0.65-3.28)</td>
</tr>
<tr>
<td>Infant gender (boys vs. girls)</td>
<td>0.68 (0.37-1.26)</td>
<td>0.63 (0.34-1.78)</td>
<td></td>
</tr>
<tr>
<td>Maternal race/ethnicity (non-Hispanic white vs. other)</td>
<td>0.44 (0.23-0.86)*</td>
<td>0.45 (0.23-0.87)*</td>
<td></td>
</tr>
<tr>
<td>Maternal marital status (single vs. engaged/married)</td>
<td>1.82 (0.91-3.66)</td>
<td>1.98 (0.97-4.04)</td>
<td></td>
</tr>
<tr>
<td>Maternal smoking during pregnancy</td>
<td>0.64 (0.31-1.33)</td>
<td>0.63 (0.30-1.33)</td>
<td></td>
</tr>
<tr>
<td>Elevated parenting stress</td>
<td></td>
<td>2.08 (0.89-4.87)</td>
<td></td>
</tr>
<tr>
<td><strong>Externalizing Behavior Problems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated PPD symptomatology</td>
<td>2.28 (1.11-4.72)*</td>
<td>1.78 (0.83-3.82)</td>
<td>1.65 (0.76-3.57)</td>
</tr>
<tr>
<td>Infant gender (boys vs. girls)</td>
<td>0.55 (0.30-0.98)*</td>
<td>0.50 (0.28-0.92)*</td>
<td></td>
</tr>
<tr>
<td>Maternal race/ethnicity (non-Hispanic white vs. other)</td>
<td>0.74 (0.38-1.45)</td>
<td>0.76 (0.38-1.49)</td>
<td></td>
</tr>
<tr>
<td>Maternal marital status (single vs. engaged/married)</td>
<td>1.79 (0.92-3.49)</td>
<td>1.95 (0.99-3.86)</td>
<td></td>
</tr>
<tr>
<td>Maternal smoking during pregnancy</td>
<td>1.32 (0.68-2.58)</td>
<td>1.33 (0.68-2.63)</td>
<td></td>
</tr>
<tr>
<td>Elevated parenting stress</td>
<td></td>
<td>2.20 (0.94-5.12)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Model 1: unadjusted association between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age.

<sup>2</sup> Model 2: association between elevated PPD symptomatology and infant behavioral outcomes adjusted for infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy.

<sup>3</sup> Model 3: Model 2 plus additional adjustment for elevated maternal parenting stress at the 12 month assessment.

<sup>4</sup>p<0.05
Table 3: Associations between elevated PPD symptomatology and specific behavioral symptoms

<table>
<thead>
<tr>
<th></th>
<th>Elevated PPD Symptomatology (n=36)</th>
<th>Non-Elevated PPD Symptomatology (n=212)</th>
<th>Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>N (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internalizing Behavior Problems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Items Relating to Separation Distress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cries when mother leaves</td>
<td>9 (25.0)</td>
<td>54 (25.5)</td>
<td>0.74 (0.30-1.82)</td>
</tr>
<tr>
<td>Gets upset with new babysitter</td>
<td>9 (25.0)</td>
<td>28 (13.2)</td>
<td>1.70 (0.68-4.26)</td>
</tr>
<tr>
<td>Gets upset with familiar person</td>
<td>2 (5.6)</td>
<td>4 (1.9)</td>
<td>3.03 (0.49-18.90)</td>
</tr>
<tr>
<td>Hangs onto mother/ wants to in lap</td>
<td>13 (36.1)</td>
<td>47 (22.2)</td>
<td>1.76 (0.79-3.91)</td>
</tr>
<tr>
<td>Looks for mother when she leaves</td>
<td>29 (80.6)</td>
<td>96 (45.3)</td>
<td>4.81 (1.95-11.83)*</td>
</tr>
<tr>
<td><strong>Externalizing Behavior Problems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Items Relating to Hyperactivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restless and can’t sit still</td>
<td>11 (30.6)</td>
<td>27 (12.7)</td>
<td>2.22 (0.92-1.14)</td>
</tr>
<tr>
<td>Constantly moving</td>
<td>25 (69.4)</td>
<td>152 (71.7)</td>
<td>0.74 (0.33-1.66)</td>
</tr>
<tr>
<td>Goes from toy to toy quickly</td>
<td>7 (19.4)</td>
<td>15 (7.1)</td>
<td>1.90 (0.65-5.57)</td>
</tr>
<tr>
<td>Items Relating to Impulsivity/Disruptive Behavior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets hurt often</td>
<td>1 (2.8)</td>
<td>3 (1.4)</td>
<td>2.65 (0.24-29.2)</td>
</tr>
<tr>
<td>Gets wound up/ silly when playing</td>
<td>16 (44.4)</td>
<td>64 (30.2)</td>
<td>1.42 (0.66-3.07)</td>
</tr>
<tr>
<td>Items Relating to Anger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very loud/ screams a lot</td>
<td>8 (22.2)</td>
<td>38 (17.9)</td>
<td>0.81 (0.32-2.06)</td>
</tr>
</tbody>
</table>

*p<0.05
Table 4: Adjusted\(^1\) associations between elevated maternal PPD symptomatology and infant behavior problems, stratified by infant gender

<table>
<thead>
<tr>
<th></th>
<th>Boys (n= 117)</th>
<th></th>
<th>Girls (n= 131)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds Ratio</td>
<td>(95% Confidence Interval)</td>
<td>Odds Ratio</td>
<td>(95% Confidence Interval)</td>
</tr>
<tr>
<td>Total behavior problems</td>
<td>2.23 (0.56-9.19)</td>
<td></td>
<td>1.93 (0.73-5.09)</td>
<td></td>
</tr>
<tr>
<td>Internalizing behavior problems</td>
<td>0.68 (0.13-3.66)</td>
<td></td>
<td>1.85 (0.68-5.04)</td>
<td></td>
</tr>
<tr>
<td>Externalizing behavior problems</td>
<td>3.70 (0.98-14.00)</td>
<td></td>
<td>1.14 (0.43-2.99)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Association fully adjusted for maternal race/ethnicity, maternal marital/relationship status, maternal smoking during pregnancy, and elevated parenting stress at the 12 month follow-up.
APPENDIX 1: MATERNAL PPD AND CURRENT MENTAL HEALTH ASSESSMENTS

Elevated PPD Symptomatology Threshold

There is a sizable variation within the literature regarding how the Edinburgh Postnatal Depression Scale (EPDS) is used in analyses. EPDS scores range from a minimum value of 0 to the maximum value of 30.[125] Within the literature, continuous scores from the scale are seldom used.[135] Women are often classified into groups based on a depression threshold score. EPDS scoring guidelines note that scores of 10-12 indicate “possible depression,” while scores ≥13 indicate “likely depression.”[114] Various studies have implemented a total score of 12 or higher as their depression cut-point,[136,137] and interview follow-ups have been recommended for women who score 10-12.[110]

Some studies have implemented cut-points at slightly lower scores,[112] including use of ≥9 as the threshold for identifying elevated PPD symptomatology.[113] As women scoring in the 6-8 range have been observed to indicate significant signs of PPD symptomatology,[111] some researchers have found it important to consider this important subclinical range in studies. A study by Nadel et al. categorized groups by calling scores of 0-5 non-depressed, with higher scores indicating PPD.[138] Other researchers have implemented 3-level categorical variables in order to account for subclinical levels of PPD. For example, Skotheim et al. scored 0-5 as non-depressed, 6-12 as subclinical, and 13 and higher as clinically depression.[139] Lagerberg et al. (2011) evaluated the sensitivity and specificity of the EPDS at various thresholds, finding cut-offs above 11 to yield very low sensitivity and overall recommending lower cut-off scores to be utilized.[111] The rationale for our selected cut-point (score of ≥9) is further explained in Appendix 3.
**Current Maternal Mental Health**

In order ensure that our analyses were longitudinally examining the association between elevated maternal PPD symptomatology (measured at eight weeks postpartum) and later infant behavioral outcomes (measured at 12 months of age) we needed to control for maternal depressive symptomatology at the 12 month follow-up. We originally sought to use the adapted 10-item Center for Epidemiologic Studies Depression Scale (CES-D)[140] that was included in the 12 month assessment. But while the CES-D is designed to ask about mood within the past week, the instrument as used in the current study covered mood during the past year. Because this scale referenced a timeframe that included the period covered by the original PPD assessment, this scale provides no way of differentiating between postpartum and current maternal mental health at 12 months.

Our aim was therefore to have a proxy measure for current maternal mental health as assessed at the 12 month follow-up. The questionnaire at this time included subsections regarding mood and various categories of stress (work stress, perceived stress, parenting stress, and acute stress). Most of these scales were not useful for our analysis because they were not querying women about current feelings of stress. For example, sections regarding life events stress (adapted from the Perceived Stress Scale)[141] as well as work stress asked women about their experiences within the past five years.

For the current analyses, we chose to use measures of parenting stress to derive our proxy measure of current maternal mental health. Mothers who continue to experience symptoms of depression throughout the first 12 months following delivery have been observed to report higher levels of parenting stress and more negative experiences of parenting,[123] suggesting that parenting stress may be an indicator of concurrent maternal mental health.
The scale used to measure parenting stress in the original cohort was comprised of three statements adapted from the Parental Stress Scale[142] and asks mothers to rate their agreement with each on a 5-point scale (1=strongly agree, 2=agree, 3=neither agree nor disagree, 4=disagree, 5=strongly disagree). In creating our dichotomous indicator of elevated parenting stress, we excluded the statement “I am happy in my role as a parent” because no women disagreed with this statement. (It is not likely a reliable measure of one’s parenting stress.) The remaining 2 items used to derive our elevated parenting stress variable were: “I feel stress by the responsibility of being a parent” and “It can be difficult to balance all of my responsibilities because of my child(ren).” Seeing as these statements coincide with normal feelings regarding new parenthood, we felt that agreement of any kind would be too lenient threshold to identify those with abnormal stress reactions. We therefore chose to consider only women answering “strongly agree” as having the elevated stress symptom indicated by that particular item (1=strongly agree, 0=other). Our elevated parenting stress scale thus had a range of 0-2. In order to identify extremes in the distribution, we considered scores of two to be our threshold for determining elevated parenting stress.

The frequencies and percentages of women classified as having elevated parenting stress are displayed in Table A2.1. 12.5% of the total analytic sample was classified as having elevated parenting stress. There were no significant between-group differences according to maternal PPD symptomatology status as measured at eight weeks postpartum.
Table A1.1: Frequencies and percentages of women characterized as having elevated parenting stress, overall and by maternal PPD symptomatology group

<table>
<thead>
<tr>
<th>Total Analytic Sample (n=248) N (%)</th>
<th>Distribution Parenting Stress According to Maternal PPD Symptomatology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Analytic Sample (n=248) N (%)</td>
</tr>
<tr>
<td>Elevated parenting stress</td>
<td>31 (12.5)</td>
</tr>
<tr>
<td>Non-elevated parenting stress</td>
<td>217 (87.5)</td>
</tr>
</tbody>
</table>
APPENDIX 2: INFANT BEHAVIORAL ASSESSMENT

Adapted Version of Infant-Toddler Social and Emotion Assessment

As discussed in Dagher and Shenassa (2012),[109] infant behavioral outcomes were assessed as a part of the 12 month follow-up using an adapted version of the Infant-Toddler Social and Emotional Assessment (ITSEA). The ITSEA has previously been shown to be valid and reliable for identifying children 12 months of age to 35 months, 30 days in need of further evaluation for potential behavioral disorders.[115] The ITSEA is designed to evaluate four broad behavior domains: internalizing, externalizing, dysregulation, and competencies. Each behavior domain is broken down in specific subscales. The internalizing scale is comprised on the depression/withdrawal, general anxiety, separation distress, and inhibition to novelty scales. The externalizing scale includes the activity/impulsivity, aggression/defiance, and peer aggression scales. The dysregulation scale includes the sleep, negative emotionality, eating, and sensory sensitivity scales. The competence scale includes the compliance, attention, imitation/play, mastery motivation, empathy, and prosocial peer relations scales. More serious problems are assessed by additional indices, including the maladaptive index (e.g., Tourette’s syndrome, post-traumatic stress disorder) and the social readiness and atypical behavior scales (e.g., autism). [115]

An adapted version of the ITSEA was created in the original study design by selecting specific subscales to include within the study-specific questionnaire. The screener had six items from the ITSEA activity/impulsivity subscale comprising the externalizing domain, and four items from the ITSEA separation distress subscale plus one additional similar item in the internalizing domain. Several subscales of dysregulation domain were also included (e.g., eating, negative emotionality, sensory sensitivity, sleep) such that total length is 45 items.
The Brief Infant-Toddler Social and Emotional Assessment (BITSEA) is a shortened 42-item version of the original (ITSEA) screener, similar in length to our shortened adapted ITSEA. However, whereas our adapted ITSEA is composed of a selection of a few full subscales from the ITSEA, the BITSEA was designed to have a full distribution of subscales within each behavior domain similar to the of the ITSEA.[50] A study by Briggs-Gowan and Carter found the BITSEA to be capable of validly identifying infants at increased risk for later psychiatric disorders (e.g., generalized anxiety disorder, phobias, depression, attention-deficit/hyperactivity disorder).[52] suggesting our shortened adapted ITSEA may be capable of valid measurement as well.

Current analyses focus on items composing the internalizing and externalizing domains of our adapted ITSEA. “Total behavior problems” referred to the summed score of internalizing and externalizing behaviors. Due to the design of the original study, our analysis of internalizing behavior is limited to only the separation distress subscale, and externalizing behavior problem to the activity/impulsivity subscale. We would have liked to look at a wider range of internalizing and externalizing behavioral symptoms, however as this is a secondary data analysis we were limited.

**Infant Behavior Problems Threshold**

Within the literature, cut-points of the BITSEA tend to aim to identify about 25% of infants as possessing potential behavior problems.[52] The current study considered infants to have behavior problems if they scored within the top 30% of the sample distribution on the adapted version of the ITSEA screener. Distributions of infant total, internalizing, and externalizing scores were separately examined in order to choose cut-point scores for each that reflected as close to 30% of the population as possible. It has been stated within the literature that in order to
identify infants at the highest risk for behavior problems, cut-points need to be modified based on infant gender.[143] However, in the current analyses we observed group means for boys and girls to not different enough to warrant separate cut-points and thus utilized a single threshold value for all infants.

**Item-Level Threshold**

We performed an item-level analysis for each statement included on the adapted ITSEA. As each individual item of the adapted ITSEA is scored on a trichotomous Likert scale[93] (0=not true/rarely; 1=somewhat true/sometimes; 2=very true/often), we wished to collapse the item-level score into a dichotomous rating of each individual symptom (1=yes, 0=no).

Originally, we classified infants as having a particular behavior problem if their mothers reported that they display the behavior at all (1=somewhat true, very true; 0=not true). Resulting numbers and percentages of infants classified as problematic and non-problematic on each behavior symptom are displayed in Table A2.1. Using this classification scheme, many of the behaviors were found to be very common among infants at 12 months, yielding unreasonably high percentages of infants being classified as having problematic behavior. For example, on most items the majority of infants were classified as problematic (hangs onto mother, looks for mother when she leaves, gets wound up/silly when playing, constantly moving). Several items were parsed into nearly equal groups of infants classified as problematic versus non-problematic (cries when mother leaves, restless and can’t sit still, is very loud, screams, shouts a lot). This threshold only yielded two items that appeared to identify true outliers as problematic behavior (gets hurt often, goes from toy to toy quickly).

As we were aiming to identify only those infants who display a behavior more often than what is considered to be normal, utilizing any display of a behavior as the threshold appears to
be too lenient. Thus, we next examined a more stringent categorization scheme for identifying behavioral symptoms. For each behavior, we coded the child as having the problem only if the mother reported that the applicable statement was “very true” about their child (1=very true; 0=somewhat true, not true). Frequencies and percentages of infant classifications are displayed in Table A2.1. Utilizing this more stringent categorization yielded percentages that appear to more accurately reflect outlying behavior. Only one item still yielded a majority percentage as problematic (constantly moving) and one yielded equal sized problematic and non-problematic groups (looks for mother when she leaves), suggesting these behavior symptoms to be very prevalent within 12 month old infants. Frequencies varied widely across the range of behavior items. It is important to note that two items had very sparse frequencies using our more stringent classification criteria (gets upset with familiar person: n=6; gets hurt often: n=4). Overall, because the specific behavioral symptoms examined here tended to be highly prevalent among infants at 12 months, we felt that utilizing of a more stringent categorization of item-level infant problematic behavior yielded a more accurate indication of underlying behavior problems.
Table A2.1: Frequencies and percentages of infants categorized as problematic on each individual item-level behavioral symptom at two different threshold levels

<table>
<thead>
<tr>
<th></th>
<th>Displays Behavior At All</th>
<th>Displays Behavior Only Very Often</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problematic Behavioral N (%)</td>
<td>Non-Problematic Behavior N (%)</td>
</tr>
<tr>
<td><strong>Internalizing Behavior Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Items Relating to Separation Distress</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cries when mother leaves</td>
<td>130 (52.4)</td>
<td>118 (47.6)</td>
</tr>
<tr>
<td>Gets upset with new babysitter</td>
<td>64 (25.8)</td>
<td>184 (74.2)</td>
</tr>
<tr>
<td>Gets upset with familiar person</td>
<td>40 (16.1)</td>
<td>208 (83.9)</td>
</tr>
<tr>
<td>Hangs onto mother/wants to be in lap</td>
<td>150 (60.5)</td>
<td>98 (39.5)</td>
</tr>
<tr>
<td>Looks for mother when she leaves</td>
<td>205 (82.7)</td>
<td>43 (17.3)</td>
</tr>
<tr>
<td><strong>Externalizing Behavior Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Items Relating to Hyperactivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restless and can’t sit still</td>
<td>118 (47.6)</td>
<td>130 (52.4)</td>
</tr>
<tr>
<td>Constantly moving</td>
<td>222 (89.5)</td>
<td>26 (10.5)</td>
</tr>
<tr>
<td>Goes from toy to toy quickly</td>
<td>58 (23.4)</td>
<td>190 (76.6)</td>
</tr>
<tr>
<td><strong>Items Relating to Impulsivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets hurt often</td>
<td>23 (9.3)</td>
<td>225 (90.7)</td>
</tr>
<tr>
<td>Gets wound up/ silly when playing</td>
<td>184 (74.2)</td>
<td>64 (25.8)</td>
</tr>
<tr>
<td><strong>Items Relating to Anger</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very loud/ screams a lot</td>
<td>133 (53.6)</td>
<td>115 (46.4)</td>
</tr>
</tbody>
</table>
APPENDIX 3: SUPPLEMENTAL INFORMATIONS ON ADDITIONAL ANALYSES

Changes in the Selection of Infant Behavior Problems Threshold

We were concerned about whether altering the threshold used to designate the presence or absence of behavioral problems would influence our overall pattern of findings. We therefore reran our main analyses utilizing new cut-points to identify infants scoring within the top 20% of the sample. Frequencies and percentages of infants designated as having behavior problems using the 20% versus 30% threshold are displayed in Table A3.1. Due to small size of the overall analytic sample, examining infant behavior problem utilizing the more stringent 20% threshold yielded sparser data. The resulting overall odds ratios are displayed in Table A3.2 for the association between elevated maternal PPD symptomatology (EPDS scores ≥9) and infant behavior using the top 20% threshold. We observed that this change in the threshold used to identify infant behavior problems yielded results that were consistent with the original analyses, suggesting that results are robust to changes in how problem behaviors are determined. Due to the larger numbers of outcomes identified when using the top 30% threshold, we felt that this cut-point would provide us with greater statistical power for our main analyses.

Changes in the Cut-Offs Used to Determine Elevated Maternal PPD Symptomatology

Following our main analyses, in which EPDS scores of ≥9 were used to identify those women with elevated PPD symptomatology, we performed supplemental analyses to examine how changing group definitions may impact findings. We examined EPDS scores as a continuous variable, and with more stringent (score ≥13, clinical cut-off) and more liberal (score ≥5) cut-offs. Table A3.3 shows the numbers and frequencies of women classified as
having elevated versus non-elevated PPD symptomatology for each of the three threshold levels examined.

Maternal PPD Symptomatology as a Continuous Variable

We first examined the overall distribution of EPDS scores in the sample. As can be seen in Figure A3.1, scores were not normally distributed and data were sparse at the upper end of the distribution. There were no women with EPDS scores of 15, 17, 19, 21 or 22. This is largely why studies rarely use the EPDS as a continuous measure. Nevertheless, we included a continuous measure in these supplemental analyses because these analyses do have increased statistical power and allowed us to examine the robustness of findings.

Figure A3.2 displays the percentages of infants with total behavior problems according to maternal EPDS scores. We observed that for mothers scoring within low ranges of the EPDS (scores of 0-8), percentages of infants with total behavior problems fluctuated around about 20-40%. However, once reaching a score of 10 or higher, percentages were consistently above 50%. Similar patterns were observed for internalizing and externalizing behavior problems (not shown). These results suggest that the risk of infant behavior problems is heightened at a particular level of PPD symptomatology, rather than increasing incrementally over the range of scores. This served as a rationale for our main approach of using a threshold value to determine elevated PPD symptomatology, rather than using continuous PPD scores.

Table A3.4 presents the odds ratios resulting from regression analysis of infant behavior problems on maternal PPD symptomatology when treated as a continuous variable. ORs are expressed as a standard deviation increase in PPD symptomatology (SD=4). The fully adjusted model yielded results consistent with the main analyses.
Maternal PPD Symptomatology Threshold of ≥13

Having observed that maternal PPD symptomatology is more appropriately examined as a dichotomous rather than continuous variable, we next sought to examine the effects of manipulating our chosen threshold value of EPDS score of ≥9. Utilizing a clinical level cut-point of ≥13[114] yielded much larger odds ratios in the unadjusted models across all behavior categories, although this was accompanied by wider confidence intervals (Table A3.5). When adjusting for covariate factors, the overall associations resembled our main analyses, although externalizing behavior remained elevated. Yet it is important to note that the limited analytic sample (n=248) yielded too few women above this threshold value (n=14, Table A3.3) to reliably evaluate associations with this stringent criteria.

Maternal PPD Symptomatology Threshold of ≥5

Research has suggested that EPDS values less than 5 are indicative of non-depressed states, with ≥5 symptoms indicating elevated levels of PPD symptomatology.[138] We wanted to explore whether these subclinical levels of depression yielded associations with infant behavior problems, or whether higher levels of PPD symptomatology are required to reveal associations.

Resulting odds ratios from regression analysis are displayed in Table A3.6. We found that using a cut-point of 5 yielded overall smaller odds ratios across all categories of behavior. Given that the mean EPDS of this sample population was 4.5 (SD=4.4), utilizing a cut-point of 5 many include too many women in the normal range of PPD symptomatology. Additionally, an examination of the percentages infants exhibiting behavior problems according to number of EPDS symptoms (Figure A3.2) revealed that the impact of maternal PPD symptomatology on infant total behavior problems has a more meaningful impact at EPDS scores of 9 and above.
Thus, mixing in women with score of 5-8 into the category of elevated PPD symptomatology could reduce observed associations.

Table A3.1: Frequencies and percentages of infants classified as having behavior problems\(^1\) at different thresholds

<table>
<thead>
<tr>
<th></th>
<th>Threshold of Top 30% N (%)</th>
<th>Threshold of Top 20% N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total behavior problems</td>
<td>71 (29.0)</td>
<td>51 (20.6)</td>
</tr>
<tr>
<td>Internalizing behavior problems</td>
<td>63 (25.4)</td>
<td>42 (16.9)</td>
</tr>
<tr>
<td>Externalizing behavior problems</td>
<td>71 (28.6)</td>
<td>42 (16.9)</td>
</tr>
</tbody>
</table>

\(^1\) As assessed by adapted version of Infant-Toddler Social and Emotional Assessment.

Table A3.2: Associations between elevated maternal PPD symptomatology (EPDS score of \(>9\)) and infant behavioral problems (top 20%), unadjusted and adjusted models

<table>
<thead>
<tr>
<th></th>
<th>Model 1(^1) Odds Ratio (95% Confidence Interval)</th>
<th>Model 2(^2) Odds Ratio (95% Confidence Interval)</th>
<th>Model 3(^3) Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total behavior problems</td>
<td>2.59 (1.20-5.56)*</td>
<td>1.78 (0.77-4.12)</td>
<td>1.58 (0.67-3.73)</td>
</tr>
<tr>
<td>Internalizing behavior problems</td>
<td>2.16 (0.95-4.92)</td>
<td>2.05 (0.87-4.85)</td>
<td>2.02 (0.85-4.79)</td>
</tr>
<tr>
<td>Externalizing behavior problems</td>
<td>2.57 (1.45-5.75)*</td>
<td>1.79 (0.75-4.28)</td>
<td>1.56 (0.63-3.85)</td>
</tr>
</tbody>
</table>

\(^1\) Model 1: unadjusted association between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age.
\(^2\) Model 2: association between elevated PPD symptomatology and infant behavioral outcomes adjusted for infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy.
\(^3\) Model 3: Model 2 plus additional adjustment for elevated maternal parenting stress at the 12 month assessment.

*\(p<0.05\)

Table A3.3: Frequencies and percentages of maternal PPD symptomatology\(^1\) at various threshold levels

<table>
<thead>
<tr>
<th></th>
<th>Elevated PPD Symptomatology N (%)(^2)</th>
<th>Non-Elevated PPD Symptomatology N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score of (\geq 9)</td>
<td>36 (14.5)</td>
<td>212 (85.5)</td>
</tr>
<tr>
<td>Score of (\geq 13)</td>
<td>14 (5.7)</td>
<td>234 (94.4)</td>
</tr>
<tr>
<td>Score of (\geq 5)</td>
<td>104 (41.9)</td>
<td>144 (58.1)</td>
</tr>
</tbody>
</table>

\(^1\) As measured by the Edinburgh Postnatal Depression Scale at eight weeks postpartum.
### Table A3.4: Associations between elevated PPD symptomatology (as a continuous variable) and infant behavior problems, unadjusted and adjusted models

<table>
<thead>
<tr>
<th></th>
<th>Model 1&lt;sup&gt;1&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 2&lt;sup&gt;2&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 3&lt;sup&gt;3&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total behavior problems</td>
<td>1.52 (1.18-1.95)&lt;sup&gt;*&lt;/sup&gt;</td>
<td>1.37 (0.98-1.91)</td>
<td>1.31 (1.00-1.73)&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td>Internalizing behavior problems</td>
<td>1.23 (0.96-1.58)</td>
<td>1.17 (0.89-1.53)</td>
<td>1.12 (0.85-1.48)</td>
</tr>
<tr>
<td>Externalizing behavior problems</td>
<td>1.32 (1.03-1.68)&lt;sup&gt;*&lt;/sup&gt;</td>
<td>1.22 (0.94-1.58)</td>
<td>1.17 (0.89-1.52)</td>
</tr>
</tbody>
</table>

Note: Odds ratios represent a standard deviation increase in PPD scores (SD=4).

1 Model 1: unadjusted association between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age.

2 Model 2: association between elevated PPD symptomatology and infant behavioral outcomes adjusted for infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy.

3 Model 3: Model 2 plus additional adjustment for elevated maternal parenting stress at the 12 month assessment.

*p<0.05

### Table A3.5: Associations between elevated PPD symptomatology (EPDS score of ≥13) and infant behavior problems, unadjusted and adjusted models

<table>
<thead>
<tr>
<th></th>
<th>Model 1&lt;sup&gt;1&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 2&lt;sup&gt;2&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
<th>Model 3&lt;sup&gt;3&lt;/sup&gt; Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total behavior problems</td>
<td>3.54 (1.18-10.60)</td>
<td>2.12 (0.66-6.80)</td>
<td>1.79 (0.54-5.89)</td>
</tr>
<tr>
<td>Internalizing behavior problems</td>
<td>2.33 (0.78-7.00)</td>
<td>1.79 (0.58-5.72)</td>
<td>1.55 (0.48-5.03)</td>
</tr>
<tr>
<td>Externalizing behavior problems</td>
<td>3.62 (1.21-10.84)</td>
<td>2.58 (0.82-8.13)</td>
<td>2.24 (0.70-7.19)</td>
</tr>
</tbody>
</table>

1 Model 1: unadjusted association between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age.

2 Model 2: association between elevated PPD symptomatology and infant behavioral outcomes adjusted for infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy.

3 Model 3: Model 2 plus additional adjustment for elevated maternal parenting stress at the 12 month assessment.

*p<0.05
Table A3.6: Associations between elevated PPD symptomatology (EPDS score of \( \geq \)5) and infant behavior problems

<table>
<thead>
<tr>
<th>Model 1(^1) Odds Ratio (95% Confidence Interval)</th>
<th>Model 2(^2) Odds Ratio (95% Confidence Interval)</th>
<th>Model 3(^3) Odds Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Behavioral Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.19 (1.25-3.82)*</td>
<td>1.97 (1.08-3.62)*</td>
<td>1.82 (0.98-3.37)</td>
</tr>
<tr>
<td><strong>Internalizing Behavior Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.49 (0.84-2.64)</td>
<td>1.40 (0.76-2.58)</td>
<td>1.28 (0.69-2.40)</td>
</tr>
<tr>
<td><strong>Externalizing Behavior Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.41 (0.81-2.45)</td>
<td>1.25 (0.70-2.26)</td>
<td>1.14 (0.63-2.08)</td>
</tr>
</tbody>
</table>

1 Model 1: unadjusted association between elevated PPD symptomatology and infant behavioral outcomes at 12 months of age.
2 Model 2: association between elevated PPD symptomatology and infant behavioral outcomes adjusted for infant gender, maternal race/ethnicity, maternal marital/relationship status, and maternal smoking during pregnancy.
3 Model 3: Model 2 plus additional adjustment for elevated maternal parenting stress at the 12 month assessment.
*p<0.05

Figure A3.1: Distribution of PPD symptomatology scores

![Distribution of PPD Symptomatology Scores](image)
Figure A3.2: Percentages of infants with total behavioral problems according to number of maternal depressive symptoms