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Depression and anxiety in the postnatal period: An examination of infants' home language environment, vocalisations and expressive language abilities.

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This longitudinal study investigated the effects of maternal emotional health concerns, on infants' home language environment, vocalisation quantity, and expressive language skills. Mothers and their infants (at six and 12 months; 21 mothers with depression and or anxiety and 21 controls) provided day-long home-language recordings. Compared with controls, risk group recordings contained fewer mother-infant conversational turns and infant vocalisations, but daily number of adult word counts showed no group difference. Furthermore, conversational turns and infant vocalisations were stronger predictors of infants' 18-month vocabulary size than depression and anxiety measures. However, anxiety levels moderated the effect of conversational turns on vocabulary size. These results suggest that variability in mothers' emotional health influences infants' language environment and later language ability.

Infancy is the period during which environmental stimulation can substantially influence early language and cognitive development (Sohr-Preston & Scaramella, 2006). Unfortunately, this period is also associated with an increased risk of emotional health concerns for mothers (Matthey, Barnett, Howie & Kavanagh, 2003; Reck, Noe, Gerstenlauer & Stehle, 2012), in particular, risk for depression and anxiety. These are the two most common mental health conditions experienced in the postnatal period (Matthey et al., 2003; Reck et al., 2012), they are highly comorbid (Farr, Dietz, O'Hara, Burley & Ko, 2014), and both have been associated negatively with expressive language outcomes in infants (e.g., Kaplan et al., 2014; Reck et al., 2018). However, little is known about the impact of maternal emotional health concerns, both in cases in which mothers experience some sub-clinical symptoms related to these conditions and in cases in which clinically elevated symptoms are present, on infants' early language environment and their early language outcomes. For this purpose, we report a longitudinal study that is the first to assess the home language environment and language outcomes of infants born to mothers affected by emotional health concerns, and to evaluate the effects of depression and anxiety symptoms on mothers' daily interactions with infants in the first year of life and infants' language ability in the second year.

Maternal Emotional Health Concerns in the Postnatal Period

Mothers have an increased risk of developing depression in the period following the birth of their baby. Postnatal depression (PND) is not a diagnosis recognised by official classification systems such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-5: American Psychiatric Association [APA], 2013), which includes PND as a specifier for Major Depressive Disorder (MDD) and persistent depressive disorders. Health professionals frequently use the term PND, and have noted symptoms similar to those of MDD, including loss of appetite, sleep disturbance, weight changes, loss of interest in pleasurable activities, agitation, concentration difficulties, feelings of guilt and worthlessness, and suicidal thoughts (Clay & Seehusen, 2004). Empirical research based on clinical diagnosis of depression in the postnatal period often relies on a diagnosis of MDD as the criterion for inclusion into clinical versus non-clinical comparison groups. One-quarter to one-third of women in Western Societies experience one major depressive episode in their lifetime, with the majority likely to be diagnosed in their twenties, and at a time that commonly co-occurs within childbearing years (Sohr-Preston & Scaramella, 2006).

Maternal depression in the postnatal period has been associated with infants' social, emotional, cognitive, and language development, regardless of whether it has been detected through clinical diagnosis or via self-reported measures (Murray & Cooper, 1997). Infants of mothers with depression have been shown to have lower expressive language skills and to obtain lower scores on measures of cognitive-linguistic functioning compared to children of non-depressed mothers. The NICHD Early Child Care Research Network (1999) conducted a large scale longitudinal study that followed mother–infant dyads between 6 and 36 months. After controlling for demographic risk factors, the 36-month-old children of mothers with chronically or occasionally elevated depression scores were found to perform more poorly than controls on expressive language measures. Also, Kaplan et al. (2014) found a significant negative correlation between self-reported maternal depression scores and 12-month-old infants' percentile scores on the Bayley Expressive Communication subscale but not the general cognitive and receptive communication subscales of the Bayley-III (Bayley, 2006).

In addition to depression, postnatal anxiety is a common emotional health concern for new mothers. The DSM-5 denotes several different classifications of anxiety disorder, including specific phobias, panic disorder, and generalised anxiety disorders (APA, 2013). Prevalence rates of anxiety disorders are comparable to rates of depression in the postnatal period, with estimates ranging from 3% to 43% in Western Societies (Leach et al., 2017).

Nevertheless, research examining the relation between maternal anxiety and infant development is scarce (Leach et al., 2017). This is despite the high incidence of anxiety disorders among women of childbearing age (Nicol-Harper, Harvey & Stein, 2007), and the awareness that anxiety disorders can result in high levels of distress and impairment in mothers' daily functioning (Barlow, 2004). The scarcity of research in this field may be related to the difficulties associated with measuring anxiety (including the number of different anxiety classifications) (Leach et al., 2017), and the high levels of co-morbidity between postnatal anxiety and depression (Farr et al., 2014). There is strong evidence, however, that anxiety in the prenatal and postnatal periods leads to adverse child developmental outcomes (see Glasheen, Richardson, & Fabio, 2010 and Van den Bergh, Mulder, Mennes, & Glover, 2005 for reviews). For instance, Reck et al. (2018) found that mothers who met the criteria for an anxiety disorder in the postnatal period had infants who scored significantly lower than controls on a standardised measure of their emerging language abilities at 12 months.

While depression and anxiety have been assessed separately in the abovementioned studies, this is not always possible due to the high levels of comorbidity between the two conditions (Leach et al., 2017). In fact, it has been proposed that there are cases in which the effects of maternal mental health status on infants' cognitive development have been undetected due to the lack of homogeneity in maternal emotional health symptoms that would be considered to fall under the description for each disorder (e.g., Keim et al., 2011). For this reason, this study considers these two conditions in combination: we will use the term '*emotional health concerns*' to refer to the presence of maternal depression and or anxiety symptomatology in the first 18 months post-partum.

The Social Context of Language Acquisition

Social constructionist theories of language development highlight the importance of a child's social context as the most significant environmental factor influencing their language development. That is, children are predisposed to use language as a communication tool, and language learning is made possible by social interaction (Kuhl, 2007). Mothers can act as mediators of language learning given that the mother–infant interaction is typically the primary social context in which an infant acquires language. According to this view, the regular interactions that occur between the adult and the child form the foundation for language acquisition, which is established long before an infant says their first word (Golinkoff, Can, Soderstrom & Hirsh-Pasek, 2015).

Maternal emotional health concerns can have a negative impact on the quality and quantity of these early interactions between mothers and infants. The acoustic quality of Infant Directed Speech (IDS), the special speech register that caregivers use when speaking to infants, is important as it is posited to provide a rich environment for language learning for young infants (Golinkoff et al., 2015). The IDS of depressed mothers, however, is compromised by less-exaggerated pitch height and range (Porritt, Zinser, Bachorowski & Kaplan, 2014), and delayed response onset to infants' vocalisations (Bettes, 1988). Also, non-depressed mothers typically adjust their speech input to younger babies by shortening the mean length of their utterances, whereas mothers with depression do not make this adjustment (Reissland, Shepherd & Herrera, 2003). These effects on the acoustic quality and developmental appropriateness of maternal IDS could reduce infants' access to the language-promoting benefits of IDS in their home environment (Kaplan et al., 2014).

Carers also support communicative development through the *quantity* of their speech and day-to-day interactions with their infant, and it is another aspect of infants' early language environment that may be affected by maternal emotional health concerns and that may negatively influence infants' linguistic development. However, to the authors' knowledge, no studies to date have examined the home language environment of infants who have mothers with emotional health concerns, especially in their first years of life. This is despite empirical evidence that the quantity of speech available to children, impacts their cognitive and emotional development (Hart & Risley, 1995), which in turn predicts their later language skills (Zimmerman et al., 2009) including lexical processing and vocabulary size (Ramírez-Esparza, García-Sierra, & Kuhl, 2014; Weisleder & Fernald, 2013). In short, mothers who speak more to their infants tend to have children who also speak more and who later develop more advanced language abilities (e.g., Gilkerson et al., 2018; Romeo et al., 2018).

Individual differences in the quality and quantity of early mother-infant interactions have been related to the construct of *maternal responsiveness*. Highly responsive mothers are sensitive to their infants' cues and respond to them reasonably quickly, while establishing a clear contingency in ways that are well-matched to their infants' developmental level (Crockenberg & Leerkes, 2011). In turn, children of highly responsive mothers develop greater receptive and expressive language skills (Tamis-LeMonda, Damast, Baumwell, & Bornstein, 1996). However, maternal emotional health concerns can compromise responsiveness by impairing a mother's ability to both interpret her infant's communicative cues and to respond to them appropriately (Ainsworth, 1979).

The association between maternal depression and adverse child developmental outcomes has been explained by the potentially negative impact of depression on a mother's ability to respond sensitively to her infant's needs or communication cues (Field, 1998). Mothers with depression have been observed to provide responses to their infants that are inconsistent, insensitive, intrusive, or rare (Malphurs, Raag, Field, Pickens & Pelaez-Nogueras, 1996). It is this potential disruption to the quality of the mother–infant interaction, rather than the depression or anxiety itself, that is used to explain adverse child developmental outcomes associated with emotional health concerns (Huang, Lewin, Mitchell & Zhang, 2012). Withdrawn and intrusive communication styles have also been associated with maternal anxiety (e.g., Murray, Cooper, Creswell, Schofield, & Sack, 2007). In fact there is evidence that maternal anxiety is a stronger predictor than maternal depression of maladaptive mother–infant interaction patterns (Crugnola et al., 2016), such as lower levels of maternal responsiveness and engagement (Murray et al., 2007; but see Reck, Tietz, Müller, Seibold & Tronick, 2018 for evidence that clinicaly anxious mothers interact with their infants similarly to non-anxious mothers). Nicole-Harper et al. (2007) found that mothers with high levels of anxiety engaged with their 10- to 14-month-old infants using less sensitive and emotional vocalisations. In another study, Field at al. (2005) assessed the anxiety and anger levels of mothers with depression. They found that mothers with higher scores on the State-Trait Anxiety Inventory (Spielberger, Gorsuch & Lushene, 1970) were more intrusive and interacted less sensitively with their 3-month-old infants compared to controls.

The effects of maternal mental health concerns on maternal responsiveness can also be manifested in infants' vocal behaviours in early mother-infant interactions. Mothers with high maternal responsiveness provide developmentally-appropriate and sensitively time-locked responses to their infant's vocalisations (Tamis-LeMonda, Kuchirko, & Song, 2014), which in turn leads to an increase in the number of their infants' vocalisations (Goldstein et al., 2003). The volume of infant vocalisations could be reduced for infants who have mothers with emotional health concerns, due to changes in the contingency of maternal responses. Bettes (1988) examined maternal speech directed to three- to-four-month-old infants, and found that mothers with higher levels of depression responded to their infants' vocalisations with fewer verbal responses with greater variability in response latency and pauses. These deficits could influence the vocalisation quantity of infants (Field, 2002). This hypothesis is supported by research demonstrating that preschool children (2.5–3.5 years) of depressed mothers speak less than children of non-depressed mothers (Breznitz & Sherman, 1987). This raises the question of whether infants who have mothers with emotional health concerns vocalise less in their day-to-day interactions, and if so, whether this predicts their later language abilities.

Home Language Environment

Technological advances enable researchers to time-efficiently record and examine the home language-learning environments of children. Recently, the Language Environment Analysis (LENA™) system (LENA Foundation, 2009) has been widely incorporated in this area of research, which is a small recording device equipped with software that generates automatic counts of the number of adult words (AWC), conversational turns (CTC), and child vocalisations (CVC). Using LENA, numerous studies have confirmed the fundamental role that the quantity (AWC) and quality (CTC) of early interactions play in infants' early and later language and general cognitive development (e.g., d'Apice et al., 2019; Gilkerson et al., 2018; Romeo et al., 2018; Weisleder & Fernald, 2013).

However, LENA has not been previously used to assess variations in children's language environments in relation to maternal emotional health concerns. It is known, however, from laboratory studies that mothers with emotional health concerns communicate less frequency with their infants, which suggests that the volume of speech to which infants are exposed at home could be reduced. For example, mothers with depression communicated with their infant less often (e.g., Reck et al., 2004), and they used a slower speech rate (Teasdale, Fogarty & Williams, 1980), a shorter mean length of utterance (Reck et al., 2004), and higher levels of negative affect and contact avoidance (Cohn, Matias, Tronick, Connell, & Lyons-Ruth, 1986). Mothers with anxiety have also been observed to interact less often with their infants compared to non-anxious mothers. For example, worry and rumination in mothers diagnosed with Generalised Anxiety Disorder was associated with lower responsiveness and vocal responses to vocalisations by their 10-month-old infants (Stein et al., 2012). The way these interactive behaviours impact the *home* language environment of infants remains unexplored. It is plausible, however, that a withdrawn interactive style together with a slower speech rate and contact avoidance, could reduce the overall speech quantity (AWC and CTC) of infants' home language environment. This raises the question of whether infants of mothers with emotional health concerns are exposed to fewer AWC and CTC in their day-to-day interactions, and if so, whether this predicts their later language abilities. Findings may guide interventions with mother–infant dyads in which infants are at risk of language delay due to their mothers' psychological symptoms.

The Present Study

Maternal mental health concerns have been demonstrated to have long-lasting effects on children's cognitive development. Their demonstrated effects on maternal responsiveness suggest that maternal mental health concerns may already impact infants' early language environment resulting in negative effects on their developing language abilities in the first years of life. To test this possibility, this longitudinal study was conducted. We assessed the home language environment of infants whose mothers have and have not experienced mental health concerns in the first 18 months post-partum. To assess the home language environment and quantity of infant vocalisations, home audio recordings were collected when the infants were six and 12 months. To assess early language ability, infants' expressive vocabulary size was measured at 18 month, which is the age that has been associated with a landscape change in infants' language use which is commonly referred to as the "vocabulary spurt" (e.g., Gilkerson et al., 2018). A parental-report was used for this purpose, which is a well-established method for obtaining valuable information about infants' early language development (Fenson, Marchman, Thal, Dale, & Reznick, 2007).

Mothers of all infants completed measures of depression and anxiety at each time point in this longitudinal study, which enabled us to employ two complementary analytical approaches. First, we employed a categorical approach with the aim to assess the differences in home language environment and language outcomes between infants whose mothers were and were not affected by emotional health concerns. In this case, mother-infant dyads were divided into a risk (n = 21) and control group (n = 21), whereby mothers in the risk group had a current diagnosis of depression and anxiety and/or elevated symptoms (reaching a clinical threshold) reported in the postnatal period. Second, we employed a continuous approach, which aimed to assess the relation between individual differences in the severity of maternal depression and anxiety symptoms and infants' language environment and language outcomes. In this case, data from the entire sample were collapsed placing mothers on a continuum of depression and anxiety measures and assessing the predictive validity of sub-clinical and clinical levels of emotional health concerns on infants' language development. The combination of these approaches is fundamental in representing the complex and dynamic nature of depression and anxiety symptoms in the postnatal period. While some mothers' symptoms may decrease to a sub-clinical range, categorisation based on previous clinical levels can detect the persistence of "depressed" mother–infant interaction styles that can continue to have adverse developmental outcomes beyond the remission of depression. Similarly, analyses at the sample level will capture other mothers who have not reached clinical levels, but have experienced some sub-clinical symptomatology may be experiencing considerable functional and social impairments, which may also impact the quality of the interactions with their infants (West & Newman, 2003).

Below the specific research questions and predictions are outlined for each of the analytical approaches included in this study:

Language environment in risk vs. control groups: It was predicted that infants in the risk group would be exposed to fewer adult words and conversational turns at six and 12 months of age compared to controls given that previous studies have reported a slower speech rate in mothers with depression (Teasdale et al., 1980) and withdrawn and intrusive interactive behaviours (Murray & Cooper, 1996). Similarly, infants in the risk group were predicted to vocalise less than controls at six and 12 months since infants with depressed mothers are less responsive (Field, 2002). Specifically, this difference was expected to be limited to conversational interactions and not situations in which infants vocalise alone given that infant vocalisations are influenced by the contingency of maternal responses (Goldstein et al., 2003), which can be impaired by maternal depression (Bettes, 1988).

Relations between individual depression and anxiety symptoms, infants' language environment and language outcomes. It was predicted that the number of adult words (e.g., Hart & Risley, 1995; Ramírez-Esparza et al., 2014), conversational turns (e.g., Romeo et al., 2018), and infant vocalisation (Field, 2002) in the first year of life would predict vocabulary size at 18 months. This was expected for the entire sample given the association between the severity of depression symptomatology (clinical and subclinical) and early language development (e.g., Kaplan et al., 2014).

Method

Participants

Forty-two mother–infant dyads participated in this study. Half of the dyads were allocated to the risk group (*n* = 21, 11 female infants) and half to the control group (*n* = 21, 12 female infants) based on the mothers' current diagnosis of depression and or anxiety or elevated symptoms (see depression and anxiety measures below). At the time of recruitment, mothers' age ranged from 25 to 41 years (*M* = 33, *SD* = 4.15). See Supplementary Materials, S1, for detailed demographic information of the mothers' sample.

Initial recruitment for this study was conducted by contacting a community sample of mothers who were previously enrolled in a large-scale longitudinal project examining the effects of prenatal anxiety on infants' development and cortisol levels at 12 weeks postpartum, and whose infants were within the correct age range for this study. This sample included mothers who did and did not have elevated depression and anxiety scores. Fourteen mother-infant dyads were recruited using this method. Additional 28 mother-infant dyads were recruited from an infant laboratory database and via the distribution of study flyers through community notice boards, libraries, playgroups, community agencies such and social media. Regardless of the recruitment method, all mothers completed the measures of depression and anxiety in order to be allocated to the risk or the control group. As a result, a total of 53 mother-infant dyads volunteered to participate, but 11 were not able to complete the home recordings at both six and 12 months (4 Risk and 7 Control), so they were excluded from the final analyses, resulting in the final sample of 42 mother-infant dyads.

All infants were born into two-heterosexual parent households, full-term (37-42 weeks), with normal birth weight, and no history of birth or postnatal complications. Infants were acquiring English in a monolingual context and were not exposed to a second language, and they had no reported hearing difficulties, neurological conditions, or health problems. See Supplementary Materials, S2, for detailed demographic information of the infant sample.

Infants commenced the study at six months of age. Given that maternal depression has been linked to deficits in general cognitive development, the Cognitive Subscale of the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III) (Bayley, 2006) was administered as a measure of infants' IQ when they were 18 months of age. These data were available for 36 infants (18 Control, 18 Risk) of the sample (IQ data for six babies were missing due to fussiness [1] and inability to come to the lab [5]). All infants' scores were within the normal range, and there were no differences in IQ scores between the control (M = 107, SD = 10) and risk groups (M = 106, SD = 13), $t(34) = .30$, $p = .770$, $d = .09$.

Maternal education and average household income were used as indices of participants' SES. Education levels for all mothers ranged from high school to postgraduate degree. The median education level for mothers was an undergraduate university degree, and this did not differ between the risk and control groups, Mann-Whitney $U = 165$, $p = .264$. As SES is multifaceted, household income was included as an additional measure of SES. The estimated average household weekly income levels were calculated based on the postcodes of participants' place of residence (Australian Bureau of Statistics). There was no significant difference in estimated household income level between the risk and control groups, Mann-Whitney $U = 151$, $p = .081$.

Maternal Measures

Given the high comorbidity of depression and anxiety, all mothers were administered measures of both conditions. The Centre for Epidemiologic Studies Depression Scale-Revised (CESD-R: Eaton, Smith, Ybarra, Muntaner, & Tien, 2004) was used to measure depression symptoms. The CESD-R is a 20-item self-reported scale of depressive symptoms and has been used widely with maternal populations in the perinatal period (Engle, 2009). It has demonstrated excellent psychometric properties including strong factor loadings, high internal consistency, and theoretically consistent convergent and divergent validity (Van Dam & Earleywine, 2011). The State Scale of the State-Trait Anxiety Inventory (STAI: Spielberger, Gorsuch, & Lushene, 1970) is a reliable and valid measure of current self-reported anxiety that is one of the most commonly used measures to capture clinical and subclinical anxiety levels. The STAI has demonstrated good internal consistency in prior Australian studies with childbearing women (e.g., Grant, McMahon, & Austin, 2008).

Due to variability in the onset time of emotional health concerns following the birth of a baby, questionnaires were completed at several time points during the postnatal period (six, nine, 12, and 18 months). Mothers were allocated to the risk group if they: (i) had a current diagnosis of depression or anxiety or (ii) reported depression and or anxiety scores that exceeded the clinical threshold (i.e. CESD-R $\geq$ 16; STAI $\geq$ 40) at any of the four testing time points. The remaining mothers were allocated to the control group. Mother–infant dyads remained in the risk group for the duration of the study despite potential changes to their emotional health scores, due to evidence that impaired mother–infant interactions styles can persist beyond the remission of depression with ongoing risks to infant developmental outcomes.

The risk group consisted of five mothers who had received a diagnosis and were being treated for depression in the postnatal period, and one mother with both postnatal depression and anxiety diagnoses. All six mothers remained on medication for the duration of the study, with a gradual reduction in medication for two mothers. Four of these mothers did not have elevated scores on emotional health variables due to treatment effects. The remaining 17 mothers in the risk group obtained elevated scores on at least one-time point, e.g., for depression only (n = 3), anxiety only (n = 8) and both depression and anxiety measures (n = 6). To account for the potential variation in the *severity* and *persistence* of symptoms of maternal emotional health concerns during the postnatal period, which is known to influence child development outcomes, mean postnatal depression score and mean postnatal anxiety score was calculated for each participant by averaging scores obtained at each data collection point (see Supplementary Materials, S3, for detailed demographic information of the mothers' sample). The mean depression and anxiety scores differ from the cut off scores described in the group allocation criteria as they reflect the average score obtained across the four assessment time points.

Home Language Recordings

Daylong home recordings were obtained and analysed using the LENA system (LENA™ Foundation, 2009), which is an automatic speech monitoring and language environment analysis tool used for infants and toddlers. The LENA Digital Language Processor (DLP) is a small device (approximately 1×5×8 cm, 85 grams) that records all sounds in an infant's environment. The DLP stores up to 16 hours of digitally recorded sound. Infants wear it in a snap locked pocket on the front of a custom-made vest. The LENA System segments the audio recordings into 12 categories including speakers, environmental sounds, and silence (see Ford, Baer, Xu, Yapanel, & Gray, 2008).

The LENA software was used to obtain automatically produced 12-hour projections of three home language measures: adult word count, child vocalization count, and conversational turn count. Each measure was used as a dependent variable in our analyses, and it is explained in detail below.

Adult word count. This estimates the number of adult words spoken "near and clear" to the infant, or loudly enough to register clearly in the DLP. In practice, words typically occur within a 10-ft radius of the DLP. As the adult word count excludes adult words that overlap with other voices, it may slightly underestimate the actual adult words spoken (Xu et al., 2009).

Conversational turn count. A conversational turn count is registered by the LENA software when an adult (male and female) vocalisations occurs within five seconds of a child vocalisation and vice versa.

Child vocalisation count. This estimates the number of speech-related vocalisations (e.g., words, babbling, and pre-speech sounds) produced by the infant that are bound by at least 300 milliseconds of non-speech sounds or silence. This count excludes all non-speech sounds such as crying, burping, coughing, and sneezing.

In addition to the total CVC estimate registered by the LENA software, the Advanced Data Extractor ADEX software (Ford et al., 2008) was used to extract Vocalization Activity Blocks (VABs) enabling estimations of child vocalization counts (i) during mother–infant conversations, and, (ii) during infant monologues. A VAB begins with any human vocalisation (child or adult initiated) and concludes with at least five seconds of silence. The VABs containing reciprocated interactions are considered conversations and are labelled according to who initiated (e.g., female adult, male adult, or child) and who responded (e.g., adult or child). Preliminary analysis of VABs yielded no significant group difference (risk vs. control) in male and female adult word counts (see Supplementary Materials, S4, for details). The block types used in the present study were CVCs in conversations (female adult initiated with infant response [AICF] and infant initiated with adult response [CIC]). Infant vocalisation counts within these blocks were summed to obtain CVC in conversation (CVC-C). VABs that consisted of a single voice labelled as "Child" were used to obtain CVC in monologues (CVC-M).

Procedure

LENA recordings were collected when infants were six and 12 months of age. Mothers were issued with a recording kit during a home visit by the experimenter and were instructed on its use. The recording kit consisted of a DLP, a custom-made infant vest, and laminated instructions. To ensure that sufficient recording time was obtained (≥ 10 hours) to generate the 12-hour projections, mothers were instructed to begin recording when their infant woke in the morning and to stop recording when their infant went to bed at night. Mothers were instructed to remove the vest during baths and naps, but to leave it close to continue recording.

As the present study investigated the influence of maternal emotional health concerns on home language measures and infant vocabulary, mothers were asked to choose a recording day when the infant spent most of the day with the mother. This instruction was given to ensure that mothers were the primary caregiver on recording days. As such, a decision was made to refer to Adult Word Counts, Conversational Turn counts and Female Speech as if the adult speaker was the mother. We acknowledge however, this may not have always been the case. Mothers were also advised to avoid activities that involved considerable background noise (e.g., sporting events) as the accuracy of LENA counts reduces in these contexts (Xu et al., 2009). Upon completion, mothers notified the researcher who picked up the recording kit from the participant's home, eliminating the need for participant travel.

A total of 84 (42 x 2) daylong recordings were obtained. Recordings for one participant (risk group) were excluded because the mother failed to follow the recording instructions accurately. The recording duration of the remaining (n = 41) six-month recordings ranged from 11 hours 23 minutes to 16 hours (M = 14 h 24 min), and 12-month (n = 41) recordings ranged from 10 hours 29 minutes to 16 hours (M = 14 h 41 min).

Expressive Vocabulary Size

When the infants were 18 months of age, mothers completed the Australian English (OZI: Kalashnikova, Schwarz, & Burnham, 2016) adaptation of the MacArthur-Bates Communicative Inventory (Fenson et al., 1994). It is a vocabulary checklist consisting of 558 words that are likely to be familiar to infants from 12 to 30 months. Mothers were asked to identify words on the checklist that their child can say. Data for one infant (control group) were missing due to failure to complete the OZI.

Results

Maternal Mental Health Concerns

Independent samples t-tests confirmed that there was a significant difference in mean depression scores (CESD-R) for mothers in the risk group (M = 8.54, SD = 6.50) compared to mothers in the control group (M = 4.77, SD = 3.42), $t(40) = -2.36$, $p = .024$, $d = .73$, and in the mean anxiety scores (STAI) for mothers in the risk group (*M* = 35.10, *SD* = 7.38) compared to controls (*M* = 28.32, *SD* = 4.94), *t*(40) = -3.50, *p* = .001, *d* = 1.08.

Language Environment in Risk vs. Control Groups

First, to test the prediction that infants in the risk group would be exposed to fewer adult words and conversational turn counts, and would produce fewer vocalisations, Analyses of Variance (ANOVA) were used to compare the home language environment measures between the risk and control groups. Each model included AWC, CTC and CVC as the dependent variables respectively, and group (control and risk) and infants' age (six and 12 months) as the independent variables. These measures are depicted in Figure 1, and the full descriptive statistics for each measure can be found in the Supplementary Materials, S5.

Preliminary *t*-tests and correlational analyses assessed the effects of infants' sex on home language and vocabulary measures, and the relations of these measures to maternal education (as an index of families' SES). All these results were not statistically significant, so these factors were not included in any subsequent analyses. All data included in the ANOVAs reported below were screened for outliers, and statistical assumptions were deemed satisfactory.

Adult word count. There was no main effect of group, $F(1, 39) = 1.145$, $p = .291$, $\eta^2 = .029$, age, $F(1, 39) = .073$, $p = .788$, $\eta^2 = .002$, and no group by age interaction ($F(1, 39) = 1.96$, $p = .302$, $\eta^2 = .027$). This indicates that infants in the risk (versus control) group did not significantly differ in the number of adult words they were exposed to in their environment as six and 12 months of age.

Conversational turn count. The ANOVA yielded a main effect of group, whereby mother–infant dyads in the risk group yielded fewer conversational turn counts compared with controls, $F(1, 39) = 5.848$, $p = .02$, $\eta^2 = .130$. There was also a main effect of age, $F(1, 39) = 4.834$, $p = .034$, $\eta^2 = .110$, but no significant group by age interaction, $F(1, 39) = .084$,

p = .773, η^2 = .002. Regardless of group, the number of conversational turn counts increased with infant age.

Child vocalisation count. First, the total CVC was entered as a dependent variable in the ANOVA. The analysis yielded a main effect of group, $F(1, 39)$ = 8.691, p = .005, η^2 = .944, but there was no main effect of age, $F(1, 39)$ = 1.224, p = .275, η^2 = .030, and no significant group by age interaction, $F(1, 39)$ = 1.080, p = .305, η^2 = .027. Consistent with our predictions, infants in the risk group produced fewer vocalisations compared to the control infants.

The total CVC includes all instances of infants' vocalisations, so it is possible that it could reflect that infants in the risk group tended to vocalise less overall or that they had fewer opportunities to engage in conversational interactions (as evidenced by lower CTC counts in this group). For this purpose, two additional ANOVAs were constructed using CVCs in conversation and monologues as the dependent variables respectively (Figure 1). These measures were entered into a mixed repeated-measures ANOVA with context (conversation, monologue) and age (six and 12 months) as the within-subject factors and group (control and risk) as the between-subject factors. This analysis showed a main effect of context, $F(1, 38)$ = 125.295, p = .000, η^2 = .767, no main effect of age, $F(1, 38)$ = .075, p = .786, η^2 = .002, and a main effect of group, $F(1, 38)$ = 5.744, p = .022, η^2 = .131. Importantly, there was a significant context by risk group interaction, $F(1, 38)$ = 10.296, p = .003, η^2 = .213. The interaction of context by age was also significant, $F(1, 38)$ = 8.617, p = .006, η^2 = .185, but this was not the case for the age by risk group and context by age by risk group interactions, Fs < 1. In order to understand the source of the context by risk group interaction, independent-samples t-tests were conducted collapsing the 6- and 12-month data within each group (p-values adjusted to .025 via the Bonferroni correction to account for multiple comparisons), which demonstrated that infants in the risk group (M = 510.61, SD =

251.44) vocalised significantly less than controls (*M* = 763.86, *SD* = 267.19) in the context of conversations, $t(38) = 3.078$, $p = .004$, $d = .998$. On the contrary, there was no significant difference in the number of vocalisations by risk (*M* = 190.03, *SD* = 170.71) and control infants (*M* = 185.62, *SD* = 93.53) when they were vocalising alone, $t(38) = .103$, $p = .919$, $d = .033$.

In summary, there was no significant group difference (risk versus control) in the number of adult words to which infants were exposed to in their environment. However, infants in the risk group had a lower conversational turn count and vocalised less in the context of conversations despite having access to a similar number of adult words in their environment compared to controls.

Finally, infants' vocabulary size at 18 months was compared between the control and risk groups as indexed by the scores obtained in the OZI. One participant's OZI score was classified as an outlier because it was above three standard deviations from the mean and excluded from further analysis (Field, 2009). While infants in the risk group had numerically lower scores (*M* = 60.74, *SD* = 68.75) than controls (*M* = 78.25, *SD* = 49.88), independent *t*-tests revealed that this group difference was not statistically significant, $t(37) = .91$, $p = .367$, $d = .292$. In sum, there was no significant group difference (risk vs. control) in expressive vocabulary size at 18 months.

Relations between Individual Depression and Anxiety Symptoms, Infants' Language Environment, and Language Outcomes

In order to test the hypothesis that the number of adult words, conversational turns, and infant vocalisations would significantly relate to infant vocabulary size at 18-months, correlational analyses and a series of regression models were conducted. First, we conducted correlational analyses to assess the relation between maternal emotional health, home language environment measures, and infants' vocabulary scores within the entire sample, collapsing the Risk and Control groups. An inspection of the data revealed that maternal depression and anxiety scores and infants' vocabulary size were not normally distributed, so Spearman correlations were conducted. As can be seen in the results reported in Table 1, vocabulary scores were negatively correlated with the mean anxiety measure. Thus, even though there were no significant group differences in infants' vocabulary size, these correlational analyses suggest that individual differences in mothers' anxiety levels do relate to their infants' vocabulary at 18 months. Also, vocabulary scores were positively correlated with conversational turns and infant vocalisations at 12 months but not at six months of age. Vocabulary scores were not significantly correlated with adult word counts at either age.

Next, three stepwise hierarchical regression models were constructed. All three models included vocabulary size at 18 months as the dependent variable, and as predictor variables, maternal emotional health measures were entered at Step 1. At Step 2, Model 1 included CTC scores, Model 2 included CVC scores, and Model 3 included AWC scores, at six and 12 months. This order was determined by the prediction that after controlling for maternal depression and anxiety, the number of conversational turn counts (Model 1), child vocalisation counts (Model 2) and adult word counts (Model 3) at each age, would explain a significant amount of variance in infants' vocabulary scores at 18 months of age. CTC, CVC and AWC were entered as predictors into separate models given that CTC was significantly correlated with CVC and AWC at both six and 12 months. Maternal depression and anxiety as continuous measures and not as categorical measures in line with the continuous analytical approach proposed to address our prediction regarding the relation of these measures to infants' language outcomes. Results of the models are summarised in Table 2. Initially, we also conducted regression models including an additional first step that accounted for infant sex and family SES (indexed by maternal education) as covariates. These variables did not explain a significant amount of variance in infants' vocabulary scores, so they were excluded from the models reported here. The output of these additional models can be found in Supplementary Materials, S6.

Model 1 (CTC) accounted for 38% of the variance in expressive vocabulary scores ($F(1, 34) = 9.57$, $p < .01$; $R^2 = .38$), Model 2 (CVC) accounted for 31% of variance ($F(1, 34) = 5.64$, $p < .05$; $R^2 = .31$), and Model 3 (AWC) ($F(1, 34) = 2.34$, $p = .14$; $R^2 = .25$) was not significant. Maternal emotional health variables accounted for a significant 19% of variance in expressive vocabulary. In the second step of all three models, the addition of six-month CTC (Model 1), CVC (Model 2) and AWC (Model 3), did not explain a significant amount of variance in expressive vocabulary. In the third step of Models 1 and 2, the addition of 12-month CTC (Model 1) and 12-month CVC (Model 2) did explain a significant amount of variance in expressive vocabulary at 18 months. In the third step of Model 3, the addition of 12-month AWC did *not* explain a significant amount of variance in expressive vocabulary at 18 months.

As can be seen, both Models 1 and 2 yielded identical patterns whereby only maternal anxiety, and not depression, was a significant predictor of infants' vocabulary size. However, this was no longer the case in Step 3 in which only CTC and CVC measures at 12 months remained as significant predictors. These patterns indicate that maternal anxiety may be acting as a moderator of the relation between the 12-month language environment measures and infants' vocabulary size (Hayes, 2018).

Moderation Effect of Anxiety

To test the possibility that anxiety may moderate the effects of CVC and CTC at 12 months on infant vocabulary, two moderation analyses were conducted. Moderation implies an interaction effect, whereby the introduction of a moderating variable (M) changes the magnitude of the relation between the predictor variable (X) and outcome variable (Y) (Hayes, 2018). The moderation analyses were conducted following the regression-based

Conditional Process Analysis approach using custom dialogue “PROCESS” (Version 3.3; Hayes, 2018) in SPSS. This approach adds a second step to the hierarchical regression models (Models 1 and 2) described above and includes an additional test of the interaction between M and X as a potential predictor of variance in Y. In this second step the standard errors and 95% confidence interval (CI) of the moderation effect are bootstrapped and bias-corrected (based on 5000 samples). To assist with its interpretation and to avoid multicollinearity, the analysis package automatically standardises all variables by centring them around the mean.

The first regression model was conducted to test the hypothesis that mothers’ anxiety levels moderate the relation between CVC at 12 months and infant vocabulary scores. In the first step, two variables were included: CVC and mothers’ anxiety. These two variables accounted for a significant amount of variance in infant vocabulary, $Adj\ R^2 = .246$, $F(2, 36) = 711.2$, $p = .002$, reflecting the regression results reported above. The CVC and anxiety variables were used to create the CVC × anxiety interaction term. In Step 2, the interaction term was added to the regression model, which was not statistically significant, $\Delta R^2 = .032$, F change $(1, 35) = 1.630$, $p = .210$. Maternal anxiety does not, therefore, have a significant moderating effect on the relation between child vocalisation counts and vocabulary.

A second regression model was conducted to test the hypothesis that mothers’ anxiety levels moderate the relation between CTC at 12 months and infant vocabulary. In the first step, two variables were included: CTC and mothers’ anxiety. These two variables accounted for 33% of variance in infant vocabulary, $Adj\ R^2 = .332$, $F(2, 36) = 10.451$, $p < .001$. In Step 2, the interaction term of CTC × anxiety was created and added to the regression model. This accounted for 8% of variance in infants’ vocabulary scores, $\Delta R^2 = .082$, $F\ (1, 35) = 5.227$, $p = .028$. Maternal anxiety, therefore, has a moderating effect on the relation between conversational turn counts and vocabulary.

To understand the source of this significant moderation effect, an interaction plot was constructed (Figure 2), which illustrates that maternal anxiety levels have a *decreasing* influence on the effects of CTC on vocabulary scores, but this influence is conditional. When mothers' anxiety scores fall in the low- or mid-range, low CTCs are associated with low infant vocabulary scores, and high CTCs are associated with high vocabulary scores. On the other hand, infants of mothers with anxiety levels in the high range have low vocabulary scores regardless of CTCs.

Discussion

This is the first longitudinal investigation of the home language environment experienced by infants of mothers with emotional health concerns, with a specific focus on conversational interactions during the first year of life and relation to infants' developing vocabulary size. Our findings showed that infants in the risk and control groups did not significantly differ in the number of adult words to which they have access in their environment. However, infants in the risk group had access to fewer conversational turn counts. They also had lower vocalisation counts in the context of conversations but not when vocalising alone. Mothers who reported elevated anxiety symptoms also had infants with lower vocabulary scores at 18 months of age. The quantity of conversational turns and infant vocalisations were stronger predictors of infant vocabulary than depression and anxiety measures. Finally, the severity of mothers' anxiety symptoms moderated the effects of conversational turn counts on infant vocabulary size.

Maternal Emotional Health Concerns and Infants' Home Language Environment

Contrary to our prediction, the amount of adult words heard by infants did not significantly differ between risk and control groups. However, and consistent with our prediction, the number of conversational turn counts was significantly smaller in the risk versus the control group. Conversational turns may be especially valuable in supporting language development as they provide increased opportunities for infants to both experiment with their language (by vocalizing) and receive immediate feedback from adults (Romeo et al., 2018). The importance of the quantity of conversational turns (as opposed to overheard speech) is that it creates a social feedback loop in which mothers modify their responses and quality of infant-directed speech according to their infants' age and developmental needs (Kitamura & Burnham, 2003).

There are several potential explanations for the group difference in the quantity of conversational turn counts observed here. The first relates to potential deficits in maternal responsiveness that may be associated with emotional health concerns. Maternal responsiveness is proposed to facilitate infant language learning (Tamis-LeMonda et al., 2014), and it refers to maternal behaviours in response to a child's exploratory and communicative overtures that are contingent, prompt, and developmentally-appropriate (Bornstein, 1989). The majority of research examining maternal responsiveness either implicitly or explicitly highlights the importance of a mother's response being contingent or linked conceptually and temporally to changes in her infant's behaviour (Tamis-LeMonda & Baumwell, 2010). Maternal depression is the most commonly cited factor that adversely impacts maternal responsiveness (Lovejoy, Graczyk, O'Hare, & Neuman, 2000). Mothers with elevated depression are more likely to provide responses to their infant that are inconsistent, insensitive, intrusive, or rare (Ainsworth, 1979). In addition to intrusive behaviours, there is evidence that mothers with high anxiety are less responsive and engaged with their infants (Murray et al., 2007). It is this potential disruption in social engagement, rather than the emotional health diagnosis itself, that has been used to explain adverse developmental outcomes for children (Huang et al., 2012).

On a related note, the fewer conversational turn counts recorded in the risk group may reflect disruptions to the temporal contingency of maternal responses. Mothers with depression commonly demonstrate disruptions to temporal contingency in the form of rare or delayed responses to their infant (Ainsworth, 1979). This particularly can impact the use of automatic measures since conversational turn count (versus AWC) may encompass dyadic and social aspects of communication such as contingency (Romeo et al., 2018). For example, LENA defines a conversational turn count as an adult vocalisation produced within five-seconds of an infant's vocalisation and vice versa, so if the responses produced by mothers in the risk group were delayed, they would have been excluded from the final counts. CTC may, therefore, be more sensitive to interaction deficits associated with maternal emotional health concerns.

In the present study, it is unclear whether the reduced quantity of conversational turn counts in the risk group was driven by adults or infants. As the adult–infant interactive feedback loop is dynamic and continually-evolving, it is likely that both mothers and infants influenced the lower number of conversational turns in the risk group (Kuhl, 2007). Field and colleagues (1988), for example, found that young (three- to six-month-old) infants of postnatally depressed mothers generalised their "depressed" interaction pattern to interactions with adults who were not depressed. In turn, these non-depressed mothers began to demonstrate interactional behaviours similar to the depressed mothers (e.g., decreased contingent responsivity, vocalisations, and game playing).

Congruent with our prediction, the infants' vocalisation count was significantly lower in the risk group compared with the control group, a finding that has not been reported in previous research. Another unique finding consistent with our prediction, is that the difference in the volume of vocalisation counts was only evident in the context of LENA conversational blocks and not infant monologue blocks. These results patterns are intriguing since they do not reflect the effects that other risk factors have on infant vocalisations such as low family SES (Dwyer et al., 2019), hearing loss (Iyer & Oller, 2008), and premature birth

(Casky, Stephens, Tucker, & Vohr, 2011), which have been shown to reduce infant vocalisation counts when vocalising alone. Together these findings suggest that the vocalisation pattern demonstrated by infants in the risk group may be specific to infants who have mothers with emotional health concerns.

Infant vocalisations contribute to the mother–infant conversational exchange and the framework within which their relationship develops (Franklin et al., 2013). That is, infants are not merely passive "listeners" of IDS but can act as agents in their interactions and language learning. For example, infant vocalisations, even when pre-linguistic, elicit immediate adult responses (e.g., Goldstein et al., 2003). Further evidence of infants' agency in conversational exchanges, is provided by Ko and colleagues (2016), who found infants' (12-30 months) vocalisations were more mature (e.g., longer in duration) when they were initiators rather than responders in the context of mother–infant interactions.

Mothers also play an important role in the interaction with their infants, in both maintaining and repairing the flow of conversational exchanges (Golinkoff, 1986). When mothers' vocal responses are sensitively time-locked (contingent) to their infants' vocalisations, both the *quality* and *quantity* of infants' vocalisations increases; for example, Goldstein and Schwade (2008) found that nine-month-old infants produced vocalisations that are more mature and complex when their mothers responded contingently to their babbling compared to when they responded following a delay (see Goldstein et al., 2003 for similar findings). Given that depressed mothers' responses tend to be less contingent (Biringen et al., 2000), it is plausible that mothers in the risk group responded less contingently to their infants' vocalisations, leading to an overall reduction in their vocalisation counts. As babbling (when examined in a social context) constitutes an important phase in language development (Goldstein & Schwade, 2008), it is not surprising that the quantity of infant vocalisations is also a predictor of vocabulary size in the present study.

Fewer infant vocalisations in the risk group may also have resulted from infants imitating their mothers' interactive style (Field, 1988; Reck et al., 2012). Research has shown that infants of depressed mothers can demonstrate a general "depressive" or withdrawn/avoidant interaction pattern. This includes increased avoidance of eye contact and lower levels of positive affect (Cohn, Matias, Tronick, Connell, & Lyons-Ruth, 1986). This unique interactive style may serve a self-regulatory function for infants (Tronick & Gianino, 1986), whereby frequent head-turning and eye-contact avoidance, serves a self-protective function, i.e. to avoid the interaction stress associated with a non-responsive mother (Reck et al., 2008). Field and colleagues (1998), in their study of three- to six-month-old infants, revealed clear signs of infant stress (elevated pulse, cortisol levels and decreased vagal tone) when infants were interacting with postnatally depressed mothers. The reduced vocalisation count in the risk group may reflect a similar withdrawn interactive pattern by infants to avoid stress. This would also explain why infants in the risk group, had a reduced number of vocalisations in a social context (conversations) as opposed to when vocalising alone (monologues).

Maternal Emotional Health, Home Language Environment and Vocabulary

To complement our categorical approach using group comparisons, we also took a 'whole-sample' approach to see how sub-clinical symptoms could impact language environment and language development. Conversational turn counts were a significant predictor of infants' later vocabulary size above maternal emotional health measures. These findings highlight the importance of the social context and qualitative aspects of infants' language experience (e.g., turn-taking and maternal responsiveness) as opposed to the sheer volume of exposure to adult speech. In fact, the vocabulary scores between the two groups were not statistically different suggesting that maternal emotional health concerns on their own, do not explain individual differences in language development.

The finding that conversational turn count is the strongest predictor of vocabulary size also supports language development theories that emphasise social interaction. Kuhl (2007) coined the term "social gating" to describe the importance of the social context of IDS in promoting infant's acquisition of knowledge specific to their native language, as IDS does not occur in isolation but within a social context (Golinkoff et al., 2015). This context can be affected by maternal factors such as emotional health concerns. The present finding of the social aspect of language exposure (i.e. conversational turns and not adult words) as more important in supporting language development dovetails with similar findings with older children (Gilkerson et al., 2018; Romeo et al., 2018) by highlighting the importance of this social exchange in the first year of life.

Infants' degree of exposure to the acoustic qualities of IDS that support language development can also partially account for the link between conversational interactions and infants' developing vocabulary size observed here. The LENA AWC measure does not distinguish between speech directed specifically to the infant, and adult-to-adult speech overheard by the infant. The CTC measure also does not reflect the number of words spoken directly to the infant as it could include incidental occasions in which an infant and adult vocalised within a five-second time period of each other. However, CTC is more likely to include incidences of IDS in the infants' environment, which is the speech register that promotes language learning and contributes to their later vocabulary size (Kalashnikova & Burnham, 2018). Thus, fewer conversational turn counts would imply less exposure to the language-promoting benefits of IDS, resulting in smaller vocabulary sizes.

Anxiety Moderates the Effect of Conversation Turn Counts on Vocabulary Size

Our analyses further demonstrated that infant vocabulary size was negatively correlated with anxiety measures, which is consistent with recent research findings (Reck et al., 2018). It is also true for the entire sample, containing mothers with normal, elevated subclinical, and elevated clinical scores, higher anxiety scores were associated with lower infant vocabulary scores. Disruptions to temporal contingency may explain the negative correlations between anxiety symptoms and expressive vocabulary scores. The timing of a mother's response to her infant predicts and may promote language acquisition (Bornstein,Tamis-LeMonda, Hahn & Haynes, 2008). Infants strongly depend on time windows to associate words with objects (Plunkett, 1997) as their linguistic knowledge and associative networks are in a formative stage.

Previous empirical evidence has established a link between maternal emotional health concerns and disruptions to the mother-infant interaction (Murray et al., 2007), which is in line with the social constructivist view that supports a relation between the quantity of conversations and language acquisition (Golinkoff et al., 2015; Kuhl, 2007) . Here, we demonstrate for the first time that this is as a *moderation* relation. That is, anxiety reduces the positive influence that conversational turn counts have on infants' vocabulary. Crucially, this relation is conditional i.e. when mothers' anxiety scores fall in the low- or mid-range, low CTCs are associated with low infant vocabulary scores, and high CTCs are associated with high vocabulary scores. In contrast, infants of mothers with anxiety levels in the high range have low vocabulary scores regardless of the range of CTCs.

These results have several clinical implications for interventions to assist mother–infant dyads, where infants may be at risk for language delay. While medication and psychological treatments can assist in the reduction of maternal emotional health symptoms (Austin & Priest, 2005), they do not necessarily improve the quality of the mother–infant interaction and mitigate the risks to child development (Field, 1998; Murray & Cooper, 2003). Both screening and intervention strategies may need to take into account infants' home language measures, in addition to maternal anxiety scores, in order to address all levels of inferred risk. As can be seen from the interaction plot, an infant exposed to fewer CTCs in the home environment has a low vocabulary size regardless of their mothers' level of anxiety (low, average, or high). Focusing treatment on the maternal anxiety in isolation from the home language environment (specifically CTC) is unlikely to mitigate the risks to infant language development.

In this study, maternal depression and anxiety were collapsed into the single category of maternal mental health concerns given that subclinical symptomatology has also been associated with functional and social impairments (West & Newman, 2003). However, our correlational and moderation analyses identified that anxiety and not depression had a significant impact on infants' developing vocabulary size. This may be related to recent findings that maternal anxiety is a stronger predictor than maternal depression of maladaptive mother–infant interaction patterns (Crugnola et al., 2016). However, the scarcity of research examining maternal anxiety and infant language development highlights the need for further research. In our study, we assessed depression and anxiety together to represent the high degree of comorbidity between these conditions, but in light of our findings, future research should consider direct comparisons between groups of mothers who have depression with those who have anxiety, and mothers who have symptoms of both, as comorbidity can be a marker of severity (Masi et al., 2004). Furthermore, while our sample size was sufficient to reveal significant effects and were suitable for the statistical analyses reported here, a larger sample size may have allowed us to conduct such sub-group comparisons and to gain further insights into the relations between maternal anxiety and depression, infants' language environment, and developing vocabulary skills.

There are several methodological aspects that could have influenced the findings reported in this study. The adoption of a categorical approach enabled the inclusion of mothers into the risk group who may be in remission at some point during the postnatal period, to account for evidence that impaired mother–infant interactions styles can persist beyond the remission of depression. This may have contributed, however, to the absence of group differences (risk vs. control) in infants' vocabulary size. The advantage of longitudinal studies (vs. a single cross-sectional assessment) and our continuous approach to examining the effects of maternal health concerns is that they enable a profile of longer-term exposure to maternal health symptomatology. Chronic anxiety is more likely to have a negative impact on mother-infant bonding than occasional elevations to maternal anxiety symptoms (Dawson, Ashman, & Carver, 2000), and expressive language scores are likely to be lower for children of chronically depressed mothers when compared to children of less depressed mothers (NICHD Early Child Care Research Network, 1999). Future research could seek to further control for length and chronicity of symptom exposure.

It is also noteworthy that we employed a parental report of vocabulary size instead of an objective measure in this study. While parental-reports can be vulnerable to under- or over-estimating their child's abilities (Feldman et al., 2000), their validity has been demonstrated (Fenson et al., 1994, and Kalashnikova et al., 2016 for the specific adaptation of the CDI used here). Another important consideration is that we employed automated measures of language environment. The limitations associated with automated measures could be mitigated in future studies through the transcription of excerpts from the LENA recordings to calculate the language measures manually. For example, the adult word count does not capture variations in the lexical diversity of input such as diversity in vocabulary, phrases, and clauses that the mothers used in speech to their infant. Also, and of particular relevance for this research, adult-word counts possibly included other speakers and not only the mother. We took special care to ensure that recordings were collected when mothers were the primary caregiver interacting with their infants, and this was possible given the caregiving arrangements of the participating families, but it remains possible that the recordings captured vocalisations from other adults. Transcription of excerpts could allow for more targeted assessments of each speaker's interactions with the infants and the linguistic properties of each interaction. However, it is noteworthy that these limitations of the LENA system applied similarly to the dyads in the risk and the control groups in this study, so it is unlikely that they could account for the significant group differences reported here.

Conclusion

Empirical evidence repeatedly affirms the relation between frequent and high-quality language input and greater language abilities such as expressive language skills. Our study provides direct evidence that this link can be compromised by maternal emotional health concerns. We did not find significant differences in vocabulary size between the risk and control groups, which raises the question about additional factors that could be influencing vocabulary growth in this risk population. However, we showed that mean anxiety scores were significant predictors of infants' vocabulary scores, so it appears that the *severity of symptoms* explains variance in expressive vocabulary size. In addition, we found that maternal anxiety moderates the relation between conversational turns and infant vocabulary size. This finding could support the benefit of seeking treatment for maternal emotional health symptoms during the postnatal period.

The present study provides evidence for the importance of early and frequent conversational interactions with young infants to support their vocabulary development. This seems especially critical in mother–infant dyads where the mother has emotional health concerns, as this is associated with a reduction in the number of conversational turn and infant vocalisation counts, that in turn predict later vocabulary size. The relation between these measures at 12 months of age and infants' later vocabulary size, and the moderating effect of maternal anxiety highlight the need for attention to early communicative interactions between parents and their infants as well as for screening for emotional health symptoms soon after or even before birth.

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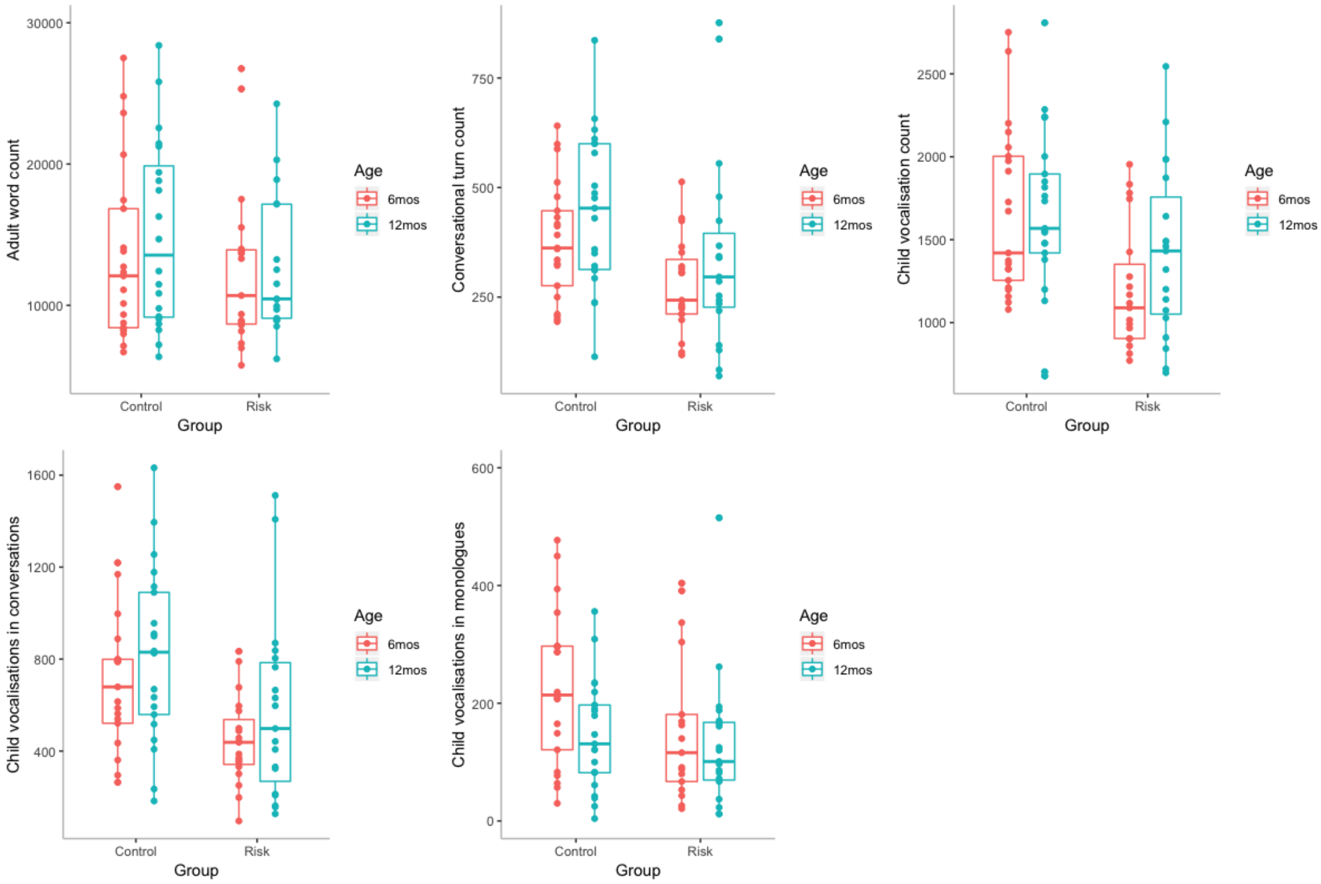

Figure 1. Language environment measures at six and 12 months in the risk and control groups (the internal line of the boxplots represents the median, and the hinges extend to the first and third quartiles). The top panel displays (from left to right) adult word count, conversational turn count, and infant vocalisations; the bottom panel displays (from left to right) infant vocalisations in conversations and infant vocalisations in monologues.

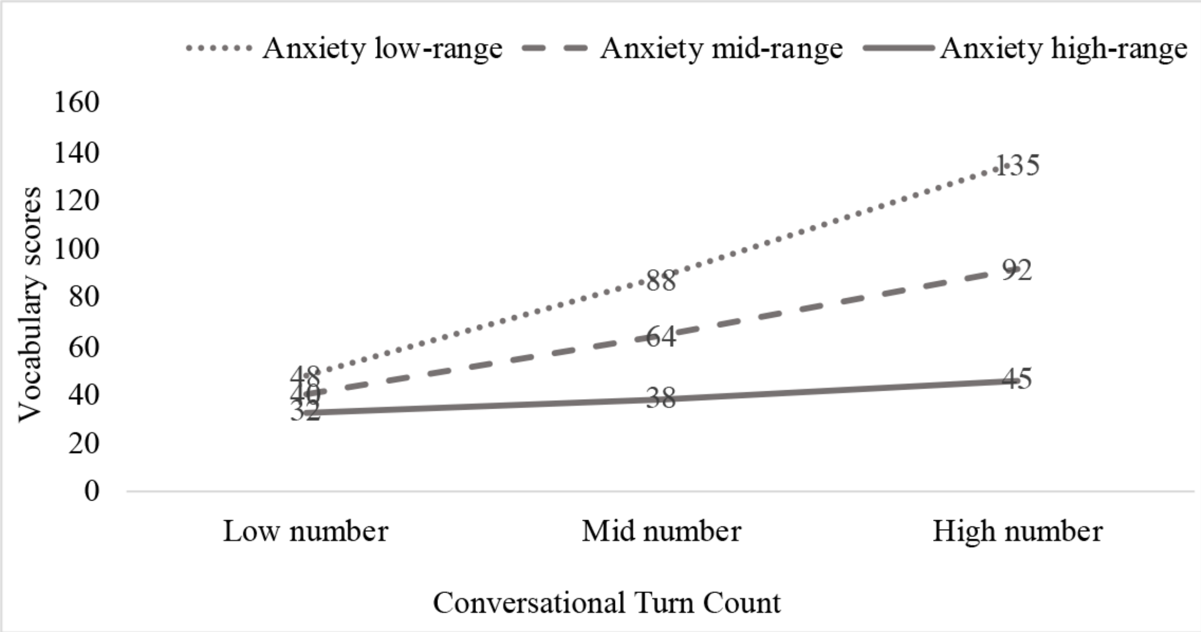

Figure 2. An interaction plot illustrating the moderation effect of maternal anxiety on the relation between conversational turns and infant vocabulary scores.

Table 1.

Results of correlational analyses (Spearman ρ) including infant expressive vocabulary scores, automated LENA language measures and mean maternal depression and anxiety measures.

	1. OZI	2. AWC		3. CTC		4. CVC		5. Mean Depression
		a	b	a	b	a	b	
1.OZI								
2. AWC								
a. 6 months	.09							
b. 12 months	.30							
3. CTC								
a. 6 months	.20	.55***	.52**					
b. 12 months	.50**	.14	.66***					
4. CVC								
a. 6 months	.09	-.18	.08	.51**	.34*			
b. 12 months	.43**	-.13	.17	.20	.72***			
5. Mean Depression	-.23	.00	-.04	-.12	-.13	-.05	.13	
6. Mean Anxiety	-.39*	-.10	-.04	-.07	-.18	-.06	-.22	.65***

Note. * $p <. 05$; ** $p < .01$; *** $p < .001$; OZI = Australian English Communicative Development Inventory; AWC = Adult Word Count; CTC = Conversational Turn Count; CVC = Child Vocalisation Count; Mean depression = average CESD-R scores; Mean anxiety = average STAI scores.

Table 2.

Multiple regression models with maternal emotional health and conversational turn count (Model 1), child vocalisation count (Model 2), and adult word count (Model 3) at six and 12 months predicting expressive vocabulary.

Model 1: Conversational turn count					
	Step 1: R^2= .194, ΔR^2 =.194, $F(2, 36)$ = 4.328, p = .021				
Predictors	**B**	***SEM***	***β***	***T***	***P***
Mean postnatal depression	-.331	2.195	-.030	-.151	.881
Mean postnatal anxiety	-3.572	1.699	-.420	-2.103	.043
	Step 2: R^2= .202, ΔR^2 = .008 F change (1, 35) = .340, p = .564				
Mean postnatal depression	-.102	2.249	-.009	-.046	.964
Mean postnatal anxiety	-3.647	1.719	-.428	-2.121	.041
6 months, conversational turn count	.040	.069	.090	.583	.564
	Step 3: R^2= .377, ΔR^2 =.175, F change (1, 34) = 9.567, p = .004				
Mean postnatal depression	-.035	2.016	-.003	-.017	.986
Mean postnatal anxiety	-3.073	1.552	-.361	-1.980	.056
6 months, conversational turn count	-.049	.068	-.109	-.717	.478
12 months, conversational turn count	.138	.045	.471	3.093	.004
Model 2: Child vocalisation count					
	Step 1: R^2= .194, ΔR^2 =.194, $F(2, 36)$ = 4.328, p = .021				
Predictors	**B**	***SEB***	***β***	***T***	***P***
Mean postnatal depression	-.331	2.195	-.030	-.151	.881
Mean postnatal anxiety	-3.572	1.699	-.420	-2.103	.043
	Step 2: R^2= .194, ΔR^2 =.000, F change (1, 35) = .010, p = .932				
Mean postnatal depression	-.349	2.233	-.032	-.156	.877
Mean postnatal anxiety	-3.576	1.723	-.420	-2.076	.045
6 months, child vocalisation count	-.002	.018	-.015	-.098	.923
	Step 3: R^2= .309, ΔR^2 =.115, F change (1, 34) = 5.643, p = .023				
Mean postnatal depression	-.673	2.102	-.061	-.320	.751
Mean postnatal anxiety	-2.923	1.642	-.343	-1.780	.084
6 months, child vocalisation count	-.019	.019	-.162	-1.035	.308
12 months, child vocalisation count	.043	.018	.376	2.375	.023
Model 3: Adult word count					
	Step 1: R^2= .194, ΔR^2 =.194, $F(2, 36)$ = 4.328, p = .021				
Predictors	**B**	***SEB***	***β***	***T***	***P***
Mean postnatal depression	-.331	2.195	-.030	-.151	.881
Mean postnatal anxiety	-3.572	1.699	-.420	-2.103	.043
	Step 2: R^2= .195, ΔR^2 =.001, F change (1, 35) = 062, p = .804				
Mean postnatal depression	-.341	2.234	-.031	-.152	.880
Mean postnatal anxiety	-3.562	1.738	-.418	-2.049	.048
6 months, adult word count	6.549	.001	.007	.046	.963
	Step 3: R^2= .247, ΔR^2 =.052, F change (1, 34) = 2.343, p = .135				
Mean postnatal depression	.097	2.223	.009	.044	.965
Mean postnatal anxiety	-3.552	1.713	-.417	-2.074	.046
6 months, adult word count	-.001	.002	-.085	-.519	.607
12 months, adult word count	.002	.001	.237	1.431	.161

Supplementary Materials

S1.

Maternal characteristics in the mother–infant control and risk groups.

	Group				
Maternal Characteristics	Control (*n* = 21)	Risk (*n* = 21)	*t*	*df*	*p*
Age (years) Range	26-40	25-40			
Mean (SD)	33.57 (3.67)	32.62 (4.62)	.74	40	.952
			U	*Z*	*Sig.*
Education level: *n* (%)					
High School	2 (10)	0 (0)			
Diploma or trade	3 (14)	1 (5)			
Undergraduate degree	12 (57)	15 (71)			
Postgraduate degree	4 (19)	5 (24)			
Mean rank	18.75	22.25	165	-1.118	.264
Household income level					
Mean rank	18.03	23.83	150.50	-1.744	.081
Paid employment 6 months: *n* (%)					
Nil paid work	9 (43)	4 (19)			
Part-time paid work	9 (43)	14 (67)			
Full-time paid work	3 (14)	3 (14)			
Mean rank	22.39	29.15	171.50	-1.122	.252
Paid employment 12 months: *n* (%)					
Nil paid work	6 (29)	3 (14)			
Part-time paid work	11 (52)	15 (72)			
Full-time paid work	4 (19)	3 (14)			
Mean rank	20.15	21.81	193	-.528	.597
Paid employment 18 months: *n* (%)					
Nil paid work	5 (24)	2 (9)			
Part-time paid work	13 (62)	13 (62)			
Full-time paid work	3 (14)	6 (29)			
Mean rank	18.93	22.98	168.50	-1.265	.206

Note. Coding for education: Primary school =1, High School = 2, Diploma or trade = 3, Undergraduate degree = 4, Postgraduate = 5; Coding for employment, Nil Paid work = 1, Part time work = 2, Full-time work = 3.

S2.

Infant characteristics in the mother–infant control and risk groups.

Infant Characteristic	Total sample (*N* = 42)	Control group (*n* = 21)	Risk group (*n* = 21)	*t*	*df*	*p*
Gender: *n* (%)						
Male	19 (45)	9 (43)	10 (48)			
Female	23 (55)	12 (57)	11 (52)	.303	40	.764
Birth weight (kg)						
Range	2.38-4.89	2.38-4.74	2.70-4.89			
Mean (SD)	3.57 (.53)	3.57 (.55)	3.57 (.53)	.049	39	.961
Birth order: *n* (%)						
First-born	30 (71)	14 (67)	16 (76)	-.623	40	.537
Age: 6 months						
Range	5.85-7.86	6.05-7.86	5.85-7.73			
Mean (SD)	6.84 (.60)	6.92 (.60)	6.72 (.59)	.971	39	.338
Age: 12 months						
Range	11.90-14.86	11.90-14.86	12.00-13.07			
Mean (SD)	12.97 (.61)	13.04 (.70)	12.89 (.52)	.810	40	.423
Age:18 months						
Range	18.01-19.33	18.31-19.33	18.01-19.16			
Mean (SD)	18.66 (.27)	18.67 (.24)	18.65 (.30)			
				U	Z	Sig.
Childcare: hrs/wk						
6 months: *n* (%)						
Less than 10	37 (88)	20 (95)	17 (80)			
10 – 20	2 (5)	0 (0)	2 (10)			
20 – 30	2 (5)	1 (5)	1 (5)			
30 – 40	1 (2)	0 (0)	1 (5)			
More than 40	0 (0)	0 (0)	0 (0)			
Mean rank		19.55	22.38	181	-1.331	.183
12 months: *n* (%)						
Less than 10	20 (48)	10 (47)	10 (47)			
10 – 20	11 (26)	4 (19)	7 (32)			
20 – 30	5 (12)	4 (19)	1 (5)			
30 – 40	3 (7)	1 (5)	2 (10)			
More than 40	3 (7)	2 (10)	1 (5)			
Mean rank		21.95	20.10	191	-.529	.597
18 months: *n* (%)						
Less than 10	13 (31)	8 (38)	5 (24)			
10 – 20	15 (35)	7 (33)	8 (38)			
20 – 30	7 (17)	4 (19)	3 (14)			
30 – 40	4 (10)	1 (5)	3 (14)			
More than 40	3 (7)	1 (5)	2 (10)			
Mean rank		19.30	22.62	176	-.924	.355

Note. Coding for Child Care, < 10 hours = 1, 10-20 hours = 2, 20-30 hours = 3, 30-40 hours = 4, > 40 hours = 5

S3.

Maternal depression and anxiety scores in the control and risk groups.

Descriptive statistics		Group: Control	Group: Risk	*t*	*df*	*p*
6-month assessment		*n* = 21	*n* = 19			
Depression	Range	0 - 11	0 - 28			
	Mean (SD)	4.71(3.58)	9.32 (7.61)	-2.406	25.03	.024
	%	0	16			
Anxiety	Range	21 - 39	22 - 52			
	Mean (SD)	29.00 (5.80)	34.47 (9.23)	-2.220	29.74	.034
	%	0	26			
9-month assessment		*n* = 20	*n* = 20			
Depression	Range	0 - 13	1 - 23			
	Mean (SD)	4.75 (4.25)	9.45 (8.07)	-2.067	28.38	.048
	%	0	30			
Anxiety	Range	20 - 46	21 - 55			
	Mean (SD)	29.21 (6.52)	36.45 (8.96)	-2.583	38	.014
	%	0	40			
12-month assessment		*n* = 19	*n* = 20			
Depression	Range	0 - 10	0 - 27			
	Mean (SD)	4.78 (3.94)	9.17 (7.77)	-2.298	27.04	.030
	%	0	20			
Anxiety	Range	21 - 39	20 - 51			
	Mean (SD)	28.30 (4.99)	35.87 (8.69)	-3.557	28.36	.001
	%	0	40			
18-month assessment		*n* = 18	*n* = 21			
Depression	Range	0 - 20	0 - 26			
	Mean (SD)	5.04 (4.51)	8.96 (7.98)	-1.597	34.91	.130
	%	0	19			
Anxiety	Range	20 - 42	20 - 62			
	Mean (SD)	28.29 (6.52)	34.83 (10.90)	-2.126	38	.040
	%	0	30			
Mean postnatal score		*n* = 21	*n* = 21			
Depression	Range	0 - 13	0 - 22.5			
	Mean (SD)	4.72 (3.54)	9.05 (6.79)	-2.355	30.27	.025
Anxiety	Range	20.75 - 39.67	21 - 45			
	Mean (SD)	28.29 (4.75)	35.28 (7.26)	-3.498	40	.001

Note. Depression = CESD-R scores; Anxiety = STAI scores; % = the percentage of mothers with scores at or above the clinical threshold.

S4.

Adult female versus adult male word count.

Preliminary analysis of home recordings was conducted to examine the quantity of male vs. female adult word counts in the risk and the control groups, by using ADEX software to extract the female and male word counts separately. This was to ensure that any differences between the home environments of the two groups of infants were not due to significant differences in adult vs. female adult word counts. Independent *t*-tests revealed that there was no significant difference in male adult word count between the control (M = 796, SD = 541) and risk groups (M = 973, SD = 802) at six months, $t(39) = -.765$, $p = .131$, d = .238, and 12 months (Control M = 4141, SD = 3823; Risk M = 3678, SD = 2795), $t(40)$ = .572, $p = .275$, $d = .177$. There was also no difference in female adult word count between the control (M = 2569, SD = 1177) and risk groups (M = 2619, SD = 1143) at six months, $t(39)$ = -.047, $p = .566$, $d = .015$, and 12 months (Control M = 11793, SD = 5423; Risk M = 9584, SD = 1084), $t(40) = 1.401$, $p = .193$, $d = .432$.