 ORIGINAL ARTICLES

The Combined Contributions of Newborn Stress and Parenting Stress on Toddler Language Development

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Objective To examine the longitudinal associations between newborn neurobehavioral stress signs, maternal parenting stress, and several indices of toddler language development.

Study design Participants include 202 mother-infant dyads (104 girls). We measured stress signs in neonates in the hospital at least 24 hours after birth using the Neonatal Intensive Care Unit Network Neurobehavioral Scale. At 7 months, parenting stress (competence, attachment, and role restriction) was assessed using the Parenting Stress Index. At 18 months, mothers completed the Communicative Development Inventories, which measured toddler gesturing, expressive vocabulary, and receptive vocabulary. Longitudinal path modeling was used to estimate associations between neonatal stress signs, parenting stress, and toddler language, and a model was generated for each language outcome. Child sex, birth weight, and family income were included as covariates.

Results Infants who exhibited greater neurobehavioral stress signs at birth produced significantly fewer social-communicative gestures at 18 months of age. Among infants whose mothers reported low (but not high) levels of parenting stress during the first postnatal year, newborn stress signs were negatively associated with 18-month-olds' receptive vocabulary size. Neither newborn stress signs nor parenting stress were significantly related to toddler expressive vocabulary size.

Conclusions Our findings uncover a negative association between newborn stress signs and toddler gesturing. Furthermore, our results suggest that caregiver stress and neonatal stress signs interact to predict toddler receptive vocabulary. Taken together, these results demonstrate that some neonates who exhibit increased neurobehavioral stress signs may be at heightened risk for experiencing language difficulties. These children may benefit from additional support in infancy. *(J Pediatr 2024;270:114006)*.

Measures of newborn neurobehavior provide an early window into infants' biobehavioral organization and functioning, which underlies early speech processing and in turn shapes the trajectory of child language development.[1-3] Behavioral signs of stress across several systems (eg, visual, gastrointestinal, autonomic) can be reliably measured in healthy term neonates using the Neonatal Intensive Care Unit Network Neurobehavioral Scales (NNNS).[1] Research reports a positive relation between newborn neurobehavioral dysregulation—which includes neonatal signs of stress—and behavioral problems later in childhood.[4] Because children's behavioral and linguistic functioning are closely related early in development,[5] greater stress signs at birth may also predict poor language outcomes. However, this association has yet to be systematically evaluated. Given that language lays the foundation for several core competencies in childhood (eg, self-regulation and academic success[6,7]), uncovering the earliest predictors of language development can assist in effectively and efficiently detecting infants at risk for communication difficulties, which can lead to targeted interventions during this period of heightened neural plasticity.[8]

By contrast, the relation between parenting stress and child language is well-established. Parenting stress can arise from many factors, including frustrating parent-child interactions, perceived role restrictions, and child-related financial concerns.[9] Mothers reporting higher levels of parenting stress tend to be less responsive during parent-child interactions,[9] produce fewer words when talking to their child,[10] and have children with smaller vocabularies.[11] Yet, no studies to date have explored the combined contributions of newborn stress signs and caregiver stress on later language development. This represents a major gap in the literature because infants who show signs of stress at birth may require additional support during their first postnatal year. Using a tool that is already used as standard of care in hospitals throughout the country (the NNNS), the current study

NNNS	Neonatal Intensive Care Unit Network Neurobehavioral Scale
CDI-WG	Communicative Development Inventory Words & Gestures
CDI-WS	Communicative Development Inventory Words & Sentences
RMSEA	Root mean square of approximation
SRMR	Standardized root mean squared residual
CFI	Confirmatory fit index
SD	Standard deviation
SE	Standard error

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sought to fill this knowledge gap by examining whether newborn stress signs are related to toddler language outcomes, and whether this association is moderated by maternal parenting stress at 7 months postpartum. We hypothesized that newborn stress signs would be negatively associated with several measures of language in toddlerhood, and that the magnitude of this relation would be greater among children of mothers experiencing higher levels of parenting stress.

Methods

Participants

Participants include 202 typically developing, monolingual English-learning children (104 females) and their mothers. Dyads came from a large-scale study examining mother-infant emotion dysregulation—oversampled relative to the general population—starting in the third trimester of pregnancy through 36-months postpartum. Pregnant birthing parents were recruited via flyers, brochures, media advertisements, or during prenatal care appointments at obstetrics/gynecology clinics. Participant demographics were collected during the third trimester of pregnancy and are representative of the geographic region from which the sample was recruited (**Table I**). Additional information regarding study recruitment, participant eligibility, and sample demographics for the larger longitudinal study can be found in[12] and.[13] Study procedures for the larger study were approved by the institutional review board at the University of Utah.

Infants enrolled in the larger study who were too young to participate in either the 7- or 18-month data collection waves at the time of data analysis were considered ineligible for the current study and were excluded from our analyses (n = 90). Of the 242 eligible infants, 33 infants were also excluded from our analyses because they: were not monolingual English learning (n = 16), were identified as having a hearing or vision impairment and/or were being monitored for a developmental delay (n = 13), or a combination of these reasons (n = 4). These exclusions were put in place because best practices typically involve measuring multilingual children's language performance in each language they are aquiring,[14] however, only the English version of the language questionnaire was administered in the current study. Further, children with audio/visual impairments as well as developmental delays often exhibit atypical language acquisition patterns for reasons other than those that were a focus of this study.[15-17] Thus, these children were excluded from our analyses because there was insufficient power to examine group-level differences as a function of audio/visual impairment, bilingual language, or developmental delay status. Among the remaining 209 mother-infant dyads, 192 infants participated in the newborn neurobehavior assessment. A total of 163 mothers completed the parenting stress questionnaire when their infant was 7 months, and 130 mothers completed the language questionnaire when their child was 18 months. The final sample size of 202 reflects the number of dyads who contributed usable data at 1 or more data collection waves. Power analyses using the G*Power program[18] indicated that our sample size was sufficient to detect a relatively small effect size of $f^2 \geq 0.07$ when $\alpha = .05$ and power = .80.[19] Dyads who did or did not participate across data collection waves did not differ in terms of child sex, family income, maternal age, maternal education attainment, newborn stress, or maternal parenting stress (all ps > .05). Little's Missing Completely at Random test[20] was not significant, $\chi^2(19) = 23.35$, $P = .22$.

Measures

Newborn Stress (Birth). The NNNS is a standardized, comprehensive evaluation of the neurobehavioral performance of newborns that includes neurological and behavioral measures and signs of stress.[1] The NNNS exam was conducted in the hospital no earlier than 24-hours after birth and no later than 2-months postdelivery, with age adjustment for preterm births ($M = 3.27$ days, range = 1 – 59 days). Each newborn exam was conducted by a certified examiner in approximately 20 minutes. Scoring was completed upon conclusion of the NNNS exams. The variable of interest was newborns' score on the Stress/Abstinence subscale of the NNNS, which demonstrated acceptable internal consistency ($\alpha = .70$). Although the NNNS was developed to look at newborns' overall neurodevelopment, previous studies have focused on specific NNNS subscales.[21,22] The Stress/Abstinence subscale was used to assess newborns' general signs of stress across seven domains: physiological, autonomic, central nervous system, skin, gastrointestinal, state, and visual (example items include infant back arching or gaze aversion). For this subscale, examiners recorded the observed presence or absence of 50 stress signs. The number of items marked as present across the 7 categories was summed and then divided by 50 to generate a summary score representing the amount of possible newborn stress that was observed.

Maternal Parenting Stress (7-Months). The Feelings About Parenting survey[23,24] was used to evaluate mothers' self-reported level of parenting stress midway through their infant's first postnatal year (Cronbach's $\alpha = .83$). Because many infants begin comprehending language and producing simple gestures between 6 and 9 months,[25,26] we measured parenting stress, which is related to maternal language input,[10] during this developmental window. This measure consists of the 25 items included in the Parent Domain on the Parenting Stress Index.[27] Mothers used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to indicate the extent to which they agreed or disagreed with statements about their parenting experience (eg, "I feel trapped by my responsibilities as a parent" or "I feel capable and on top of things when I am caring for my baby"). Mothers' responses to four out of the twenty-five items were reverse scored so that higher values reflect greater levels of perceived parenting

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Table I. Sample demographics

Demographic variable	N	Percent	Mean (SD)	Min–Max
Maternal Race and Ethnicity	202	100%		
American Indian/Alaskan Native (Hispanic)	1	0.5%		
American Indian/Alaskan Native (Not Hispanic)	5	2.5%		
Asian (Not Hispanic)	13	6.4%		
Native Hawaiian/Pacific Islander (Not Hispanic)	2	1.0%		
Black/African American (Not Hispanic)	4	2.0%		
White (Hispanic)	29	14.4%		
White (Not Hispanic)	131	64.9%		
Multiracial (Hispanic)	2	1.0%		
Multiracial (Not Hispanic)	13	6.4%		
Race not reported (Hispanic)	2	1.0%		
Maternal education	201	99.5%		
Less than 12th grade	8	3.5%		
High school graduate or equivalent	19	9.5%		
Some college or technical school	56	27.9%		
College graduate	71	35.3%		
Any post-graduate school	47	23.3%		
Maternal age in years (at 7-month visit)	167	82.7%	29.8 (4.4)	19–41
Household income	179	95.4%		
Under $9000	9	5%		
$9000-$14,000	9	5%		
$15,000-$19,999	5	2.8%		
$20,000-$24,999	4	2.2%		
$25,000-$29,999	11	6.2%		
$30,000-$39,999	15	8.4%		
$40,000-$49,999	12	6.7%		
$50,000-$79,999	55	30.7%		
$80,000-$99,999	18	10.1%		
$100,000 or more	33	18.4%		
Infant sex	202	100%		
Female	104	51.4%		
Male	98	48.5%		
Infant gestational age in weeks (at delivery)	202	100%	39.3 (1.1)	34.1*–41.4
Infant birth weight in grams	198	98%	3372.4 (459.4)	1770–4560
Infant Race and Ethnicity	201	99.5%		
American Indian/Alaskan Native (not Hispanic)	1	0.5%		
Asian (not Hispanic)	4	2.0%		
Native Hawaiian/Pacific Islander (not Hispanic)	2	1.0%		
Black/African American (not Hispanic)	4	2.0%		
White (Hispanic)	36	17.9%		
White (not Hispanic)	116	57.7%		
Multiracial (Hispanic)	7	3.5%		
Multiracial (not Hispanic)	29	14.4%		
Race not reported (not Hispanic)	2	1.0%		

SD, standard deviation.
*Six infants were late preterm within our sample of 202 infants (less than 3% of the sample). Among these six infants, two were delivered at 36w6d gestation. We conducted our analyses with the six late preterm infants removed from the sample and decisions about the statistical significance of the primary results remained unchanged. For this reason, we present our descriptive statistics and path model findings with the six late preterm infants included in the sample.

stress across all items. Mothers' scores across the 25 items were then summed to create a total parenting stress value.

Toddler Language (18 Months). The MacArthur-Bates Communicative Development Inventory: Words & Gestures (CDI-WG) and Words & Sentences (CDI-WS) short forms are parent-report measures of child gesturing (CDI-WG) and vocabulary (CDI-WS).[28] The CDI-WG is normed for 8- to 18-month-olds and the CDI-WS is normed for 16- to 30-month-olds. Both forms demonstrate high reliability, internal consistency, and validity.[29] For the CDI-WS, parents completed an 89-item checklist indicating the number of words their child understands (receptive vocabulary) and produces (expressive vocabulary). For the CDI-WG, parents completed a 63-item checklist measuring toddlers' nonverbal, intentional actions/gestures, which includes: first communicative gestures, games and routines, actions with objects, pretending to be a parent, and imitating other adult actions. The variables of interest were toddlers' raw receptive vocabulary (range: 0–89), expressive vocabulary (range: 0–89), and gesture scores (range: 0–63), and higher values represent more advanced linguistic and/or social communication skills.

Statistical Analyses

Descriptive statistics and correlations were carried out using SPSS (Version 26), and the data were inspected for outliers (values ± 3 standard deviations (SD) of the mean; n = 4). We conducted our analyses with the outliers retained as well as with the outliers handled via Winsorization.[30] As no differences emerged as a function of outlier treatment, we

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Table II. Descriptive statistics and correlation matrix

Variable	1	2	3	4	5	N	Mean (SD)	Min–Max
Birth								
1. Newborn signs of stress	–					192	0.10 (.07)	0.00–0.31
7-months								
2. Maternal parenting stress	−.12	–				163	50.89 (14.05)	25.00–96.88
18-months								
3. Toddler gesturing	−.16*	−.05	–			129	44.57 (9.38)	22.00–62.00
4. Toddler receptive vocabulary	−.07	−.02	.72†	–		130	62.83 (19.27)	6.00–89.00
5. Toddler expressive vocabulary	−.15*	−.03	.45†	.51†	–	130	22.69 (19.63)	0.00–89.00

SD, standard deviation.
*$P < .01$.
†$P < .10$.

present our results below with the outlier values retained in the dataset. The relations between newborn stress, maternal parenting stress, and toddler language were tested using path modeling in Mplus (Version 8).[31] Full information maximum likelihood was used to account for missing data. For each outcome variable (ie, toddler gesture, receptive vocabulary, and expressive vocabulary), a separate path model was generated. We controlled for demographic variables that are known to be related to language development, including child sex, birth weight, and household annual income.[32-34] Model fit was evaluated using the chi square (χ^2) goodness of fit test, the root mean square of approximation (RMSEA), standardized root mean squared residual (SRMR), and confirmatory fit index (CFI). Acceptable model fit is indicated by RMSEA ≤ .08, SRMR ≤ .08, CFI ≥ .90.[35,36] Prior to creating the interaction term, the newborn stress and parenting stress variables were mean centered, which can reduce the risk of nonessential multicollinearity. Moderation was probed by estimating the simple slopes of newborn stress at values of maternal parenting stress that correspond to high (mean + 1 *SD*) and low (mean – 1 *SD*) stress levels.

Results

Descriptive statistics and correlations between the primary study variables were inspected (**Table II**). No evidence of nonnormality was detected in the dataset (ie, skew < ±3 and kurtosis < ±10),[37] and ordinary least squares assumptions were met prior to data analysis.

Newborn Stress, Parenting Stress, and Toddler Gesturing

Acceptable model fit was achieved, $\chi^2(5) = 4.25$, $P = .37$; RMSEA = .02; SRMR = .05; CFI = .95, and the path model accounted for 9.7% of the total variance in toddler gesturing (**Figure 1**). A significant direct effect between newborn stress and toddler gesturing was detected ($\beta = -0.19$, standard error *[SE]* = .09, $P = .03$), which indicates that newborns who exhibited greater signs of stress at birth produced fewer gestures 18 months later. The direct effect of maternal parenting stress on toddler gesturing was not significant, and no evidence of moderation was detected.

Newborn Stress, Parenting Stress, and Toddler Receptive Vocabulary

Acceptable model fit was once again achieved, $\chi^2(5) = 5.15$, $P = .40$; RMSEA = .01; SRMR = .05; CFI = .98 (**Figure 1**). The model accounted for 11.9% of the variance in toddler receptive language. Neither newborn stress nor maternal parenting stress directly predicted toddlers' receptive vocabulary size. However, the interaction term was significant and indicates that newborns' stress level interacted with mothers' parenting stress level when predicting toddlers' receptive vocabulary size ($\beta = .20$, $SE = .09$, $P = .03$). Among children whose mothers reported low levels of parenting stress, signs of stress at birth were negatively associated with receptive vocabulary size at 18 months ($B = -4.51$, $SE = 2.33$, $P = .05$; **Figure 2**). By contrast, the relation between newborn stress and toddler receptive vocabulary was not significant among mothers with relatively high levels of reported parenting stress ($B = 2.74$, $SE = 2.37$, $P = .25$).

Newborn Stress, Parenting Stress, and Toddler Expressive Vocabulary

Mediocre model fit was achieved as the CFI value did not meet the minimum acceptable criteria, $\chi^2(5) = 5.18$, $P = .39$; RMSEA = .02; SRMR = .05; CFI = .88 (**Figure 1**), which can be indicative of weak intercorrelations between variables. Neither newborn stress nor maternal parenting stress directly predicted toddler expressive vocabulary size, and no evidence of moderation was detected in the model. Only 6.2% of the total variance in toddler expressive vocabulary was captured by this model, which suggests that the variables in the model had limited predictive validity in terms of expressive vocabulary development.

Discussion

Among children ages three and under, the prevalence of language delay is high, ranging from 13.5% to 17.5% among 18- to 36-month-olds.[38] Untreated speech and language problems persist in approximately 20%-30% of these children, which places them at an increased risk for social, emotional, behavioral, and educational problems later in

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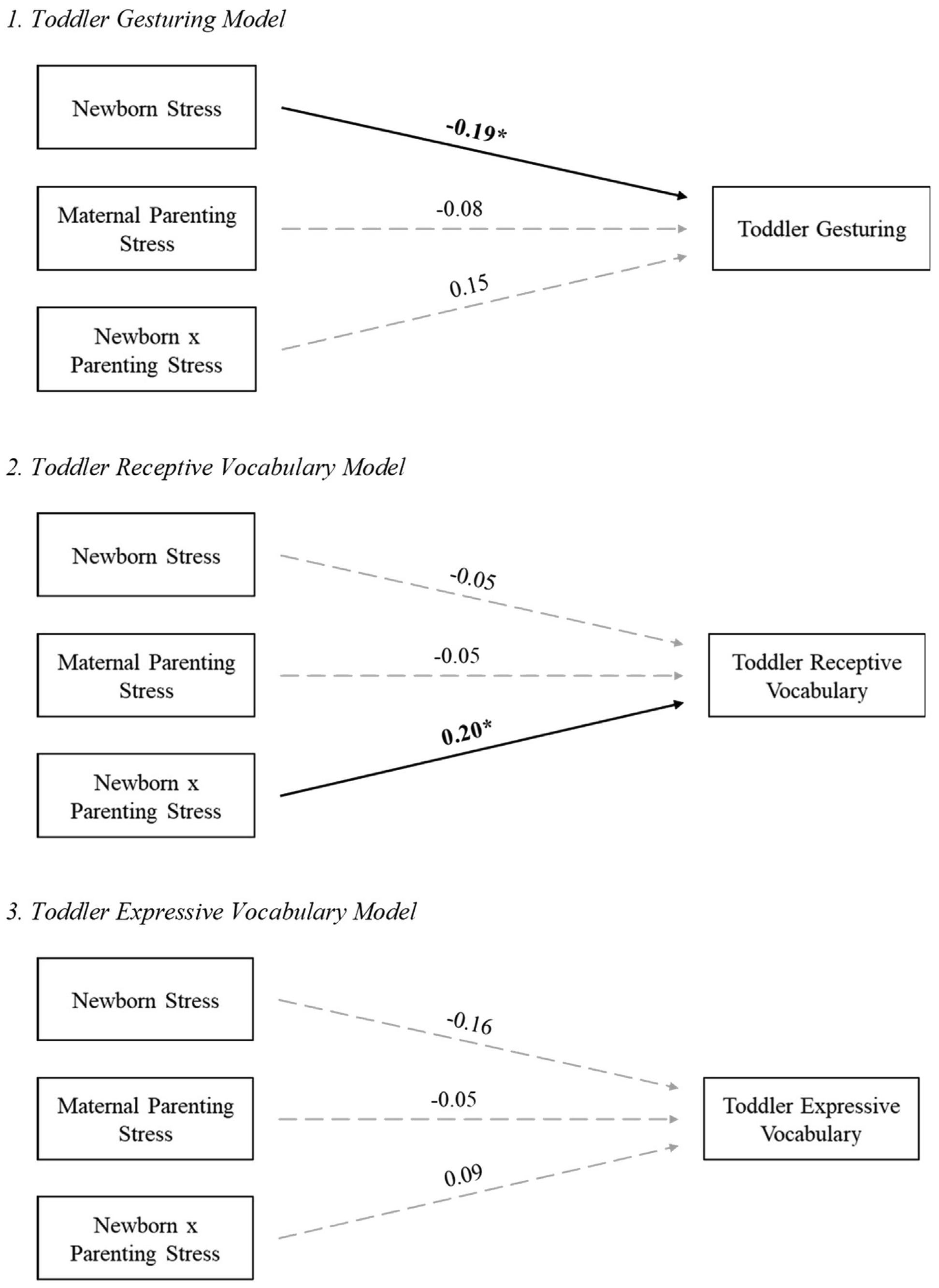

Figure 1. Path model diagrams child sex, birth weight, and family income were included in the path models as covariates. $^{*}P < .05$.

development.[39-41] A proactive approach to detection and intervention requires in-depth knowledge of the earliest risk factors to language development. Decades of research have identified intrinsic and extrinsic factors that contribute to variability in child language development.[3,10,42,43] Yet, we are not aware of any studies that have investigated the interplay between neonatal and early caregiving stress as they relate to language development. This study sought to address this gap in the literature by examining whether signs of infant stress, present 24 hours after birth, and maternal parenting stress at 7 months postpartum interact to predict several language outcomes during toddlerhood.

In this multimethod study of 202 mother-infant dyads, we found that signs of stress at birth were negatively related to children's receptive vocabulary size at 18 months; however, this association was only significant among children of mothers who reported low levels of parenting stress. Although a significant interaction was detected, it was not in the anticipated direction. Caregivers who report low stress tend to produce child-directed speech at a higher quantity

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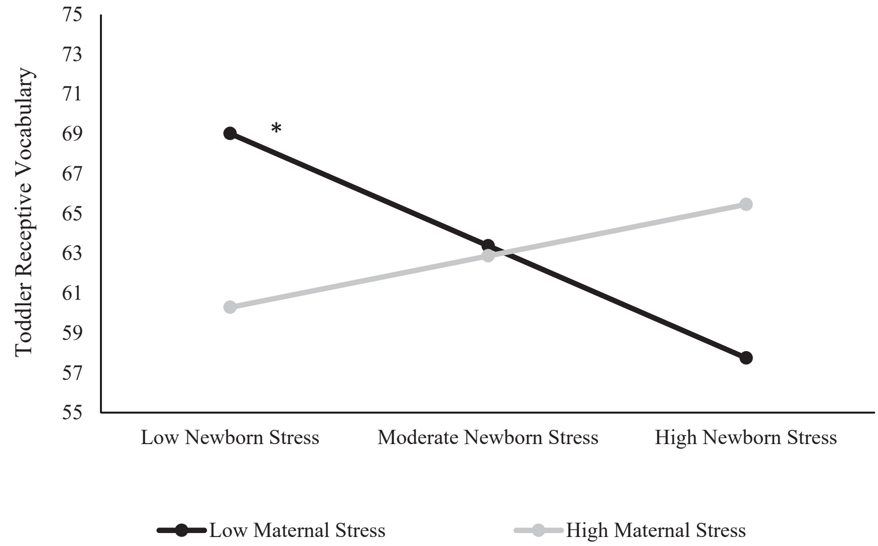

Figure 2. Interaction of newborn stress and maternal parenting stress predicting toddler receptive vocabulary. *$P < .05$.

and quality,[10,42] which is associated with accelerated language growth.[44] Thus, we expected that low parenting stress levels would serve as a protective factor against poor language outcomes among neonates showing signs of stress, but this hypothesis was not supported. In contrast, no receptive vocabulary differences were detected as a function of newborn stress signs among children of mothers reporting higher stress levels. Importantly, our results suggest that low levels of both newborn and parenting stress may be necessary for optimal receptive vocabulary development.

In support of this finding, developmental research has shown that word learning relies on several domain-general cognitive processes in infancy (eg, recall and recognition memory).[45] That is, infant attention, memory, and processing speed are related to language acquisition, and acute stress has been shown to negatively influence these processes.[45-49] Even if caregivers are exposing their children to rich language input, distressed infants require resources to manage their physiological and emotional arousal, which may leave these infants with fewer resources for language-relevant activities (eg, detecting the novel words their mother produces and mapping them to referent objects).[50] Thus, when mothers' stress levels are low, newborn stress signs appear to be an important predictor of toddler receptive vocabulary. However, when mothers are highly stressed (and presumably engaging in less child-directed speech and/or less responsive caregiving as a result[9,10]), the relation between newborn stress signs and toddler receptive vocabulary is no longer significant. Our findings suggest that efforts to reduce maternal parenting stress in isolation may be insufficient to foster receptive language development for some children. Rather, preventative efforts to target both newborn signs of stress and parenting stress may be necessary to promote optimal language comprehension in toddlerhood.

Additionally, our findings show that newborn stress signs negatively predicted the number of gestures toddlers produced at 18 months, regardless of caregivers' reported stress level. In contrast to early word learning, which requires exposure to language by an experienced speaker,[45,51] toddlers may use gestures to communicate a request, initiate an interaction, or direct their caregiver's attention.[52,53] For instance, a toddler may point to an object and initiate joint attention in order to communicate "give me that" to their caregiver. Consequently, early gesticulation may rely more on the child's individual neurobehavioral system and less on their caregivers' stress level in comparison to other aspects of language development (eg, receptive vocabulary). Our results collectively suggest that some infants who show signs of stress at birth are at an increased risk for linguistic difficulties during the second postnatal year and may require additional support in regard to their language development.

Contrary to our hypothesis, newborn stress signs were unrelated to toddlers' expressive vocabulary development. This finding may in part reflect differences in the rate at which children acquire receptive vs expressive language skills. Language comprehension typically precedes production[54] and as such, it is possible that a significant association between newborn stress and expressive language may emerge later in development when toddlers are producing more speech. That said, replication research is warranted as it may also be the case that newborn stress differentially relates to various aspects of early language development.

In addition to the novelty of our research objectives, our study has numerous strengths. First, considerable effort was put toward recruiting a large sample of birthing parents from diverse demographic backgrounds, with higher emotion dysregulation, and that have likely experienced a wide range of lifetime stressors.[12,13] Consequently, we included relevant demographic variables in the path analyses to control for factors related to fetal development as well as stress that may be related to socioeconomic adversity. Second, missing data were handled via maximum likelihood. This estimation

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method has been shown to produce unbiased estimates and SEs when the MCAR assumption has been met, which allowed us to confidently retain the large sample of mother-infant dyads in our analyses despite the missing observations.[55] Third, we included measures of toddler gesturing in addition to expressive and receptive vocabulary to better reflect the multifaceted nature of early language development.[26,56]

Our study also has limitations, which provide opportunities for future work to expand upon this research. First, we acknowledge that the measures used to evaluate toddler language in this study may not reflect the full breadth of children's linguistic ability at this age. Future research should replicate our findings with multilingual and atypically developing samples, as well as utilize naturalistic assessments of child language (eg, The Language ENvironment Analysis system[57]) across a wider age range in toddlerhood. Second, it is worth noting that the amount of variance in toddler language that was explained by the predictors was relatively low. This does not negate the importance of the significant effects that were detected, especially in light of the temporal delay between when the predictor and outcomes variables were measured (ie, birth and 7 months vs 18 months). Rather, it does suggest that additional parent/infant factors not included in the current study also play a role in predicting toddler language. Furthermore, causal relations between stress and language were not addressed in the present study, and the mechanisms that may account for the detected relations remain unclear. It is possible that newborn stress signs may predict disruptions in infant memory or attention, which in turn may influence language acquisition. However, this developmental pathway has yet to be evaluated. This presents an exciting avenue for future research to replicate and extend our findings. Third, parenting stress may fluctuate across the postpartum period,[58] however, maternal stress was only measured at 1 timepoint in the current study. Further research is needed to investigate whether changes in parenting stress across the first postnatal year are related to language acquisition. Fourth, although the NNNS is validated for use with low- and high-risk infants,[1] the current study cannot speak to the association between newborn stress and toddler language among high-risk populations (eg, preterm or substance-exposed infants).

Our study's approach to examine newborn neurobehavior, measured 24 hours after birth, as a factor contributing to language outcomes at 18 months is novel. We identified neonatal stress signs as a predictor of gesturing in toddlerhood, which is closely tied to lexical and syntactic development.[56] Our findings also uncovered an interaction between newborn and maternal stress in the prediction of toddler receptive vocabulary, which highlights the importance of interventions to reduce both newborn and caregiver stress with respect for early language comprehension. Coupled with existing research demonstrating a link between newborn neurobehavior and childhood social-emotional outcomes,[1,4] our findings further illustrate the utility in using newborn stress signs to identify groups of children who are at risk for exhibiting adverse developmental outcomes in infancy and early childhood. ■

CRediT authorship contribution statement

Madeleine Bruce: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Anna M. Compton:** Investigation, Methodology, Writing – original draft, Writing – review & editing. **Sarah E. Maylott:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Anna M. Zhou:** Methodology, Writing – review & editing. **K. Lee Raby:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Sheila E. Crowell:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing. **Elisabeth Conradt:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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Data Statement

Data sharing statement available at www.jpeds.com.

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