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RESEARCH ARTICLE

Dynamic Interaction of Affect and Language in Children's Home Environments

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ABSTRACT

Emotion and language are very common in young children's everyday lives. Hour by hour, they play, listen, vocalize, react, and emote. Despite the centrality of emotion and language to toddlers' local environments, the dynamic interplay of these communicative signals is practically unexplored. Here, we investigated how fluctuations in caregiver and child affect are linked to caregiver–child communication and children's emerging knowledge of words. Multiday household audio recordings and densely-sampled ratings of affect revealed that, in a US-based sample, children (24–30 months) were more likely to know words that they heard frequently in moments with more positive valence or higher arousal. These moments were also associated with denser communication, suggesting that moments of higher valence or arousal facilitate word knowledge in part by supporting mutually engaging communication. This investigation underscores the importance of natural affective states for understanding how children learn language.

1 | Introduction

Children experience language in the context of activities, routines, feelings, and social interactions that change from one moment to the next. Affect (i.e., how a child is feeling) is a particularly salient aspect of children's experiences that supports semantic memory (Guo et al. 2018; Miller et al. 2018; Outters et al. 2023), shapes communicative behaviors (daSilva et al. 2021; Fields-Olivieri et al. 2020; Wass et al. 2022), and provides a rich somatosensory context (Andrews et al. 2009; Nencheva, Nook, et al. 2023). Yet, the natural fluctuations of affect are nearly unexplored as a factor in language learning (Doan 2010). In this investigation, we examined how caregiver and child affect throughout the day dynamically relate to early communication and the words that children know. To do so, we combined (1) ecological momentary assessment of caregivers' perceptions of their own and their child's affect, (2) natural day-long audio recordings of caregiver–child communication, and (3) caregiver reports of children's word knowledge.

Affective information has two components that are theorized to support word learning: *experienced affect* (e.g., feeling down/low) and *displayed affect* (e.g., smiling, happy prosody; Andrews et al. 2009). Both of these components are defined by continuous dimensions of emotional tone, from positive to negative (*valence*), and from deactivated to activated (*arousal*). Prior research has overwhelmingly focused on displayed affect—particularly in lab settings—showing that children and adults prefer emotionally charged (over neutral) affect in various domains, including speech (Singh et al. 2002), faces (Reider et al. 2022), and actions (Zieber et al. 2014). Lab experiments have also shown that infants better recognize words heard with happy (vs. neutral) prosody (Singh 2008) and that toddlers learn novel words equally well when viewing angry, happy, or sad displays (Ogren and Sandhofer

Summary

- Multiday audio and affect experience sampling revealed that caregivers and children talked more in moments when they experienced higher arousal or more positive valence.
- Toddlers were more likely to know words heard more often in moments with higher arousal or more positive valence.
- Associations between affect, language input, and word knowledge highlight the importance of affect as a key factor of the early learning environment.

2021). But little is known about how the real-world affective experiences in children's lives shape their word learning.

Constructivist theories of emotion have long proposed that children's growing language abilities support emotion development, in part by allowing children to conceptualize their dimensional affective experiences as specific emotion categories (e.g., Hoemann et al. 2019; Shablack and Lindquist 2019). Theoretical and empirical work has suggested that the need to express internal affective experiences is one of the driving forces of early language development (Bloom 2013; Bloom and Beckwith 1989; Bloom and Capatides 1987). There is preliminary evidence that the dynamics of experienced affect throughout the day relate to children's vocabulary size (Nencheva, Tamir, et al. 2023). Building on research showing links between affect and learning in adults (for a review, see Storebeck and Clore 2008), positively valenced or moderately high arousal states in adults have been shown to support semantic memory (Gilet and Jallais 2011; Sharot and Phelps 2004), and negative (vs. neutral) moods are associated with worse recall of familiar and novel words (Guo et al. 2018; Miller et al. 2018). In toddlers, physiological arousal following episodes of word learning is associated with better learning (Outters et al. 2023). These findings hint toward the possibility that the child's affective states may dynamically guide learning throughout the day.

What can explain this link? There are two compatible ways that children's affective displays and experiences can shape language development. First, how children and caregivers feel may broadly shape how they communicate. Infants produce more vocalizations in moments of higher physiological arousal (Wass et al. 2022), and toddlers who display more negative affect produce and receive fewer verbalizations (Fields-Olivieri et al. 2020). Further, heightened positive affectivity in infants' temperament is positively associated with language production (Dixon and Smith 2000). Caregivers' affect is also known to shape their own behavior. For example, in moments of heightened stress, adults talk less to each other (daSilva et al. 2021) and to their children (Ellwood-Lowe et al. 2022; Roby and Scott 2022), and global differences in caregiver affect (e.g., depression) alter communicative behavior (Field 2010; Herrera et al. 2004). A limitation of these studies is that they did not systematically examine the effects of valence and arousal on communication at the same time. If caregivers and toddlers engage in less communication in moments of more negative valence or lower arousal, this will likely result in overall less speech input and turn-taking (i.e., contingent back-and-forth utterances between caregivers and children), which has been shown to be an important catalyst of language learning (Donnelly and Kidd 2021; Feurstein et al. 2022; Romeo et al. 2018). Further, different affective states may change the nature or potential value of different types of interactions. For instance, dysregulated child affect (e.g., if the child is throwing a tantrum) may hinder the benefits of structured play, which is typically associated with dense communication (Tamis-LeMonda et al. 2017). Together, these findings suggest that children's and caregivers' affective states may shape learning by modifying how caregivers and children communicate or even by changing the activities that they engage in. However, they also raise additional questions about how valence and arousal come together to shape communication.

A second and more specific way in which affect may shape language is by creating contexts that guide children's learning of new words across time. Word learning unfolds over time in diverse communicative contexts, spanning people, spaces, and routines (Custode and Tamis-LeMonda 2020; Goldenberg et al. 2022; Tamis-LeMonda et al. 2019; Roy et al. 2015), and children must integrate these experiences to determine word meanings. Some words they encounter may appear in consistent affective contexts, but others may not appear in any organized fashion. Given this variability, are words more learnable if they appear in variable or stable contexts? Variable contexts may support children's learning by exposing them to the full range of a word's uses, and there is evidence that experiencing a word in more variable contexts supports learning (Goldenberg et al. 2022; Slone et al. 2019). Yet *stable*, routine-based contexts (e.g., room in the house, time of day, or surrounding words) may support learning by facilitating the right amount of predictability (Benitez and Saffran 2018; Benitez and Smith 2012; Roy et al. 2015). Indeed, there is evidence from young children that encountering different exemplars of a word in matching contexts supports word learning (Vlach and Sandhofer 2011). Affect—and its stability or variability across word instances—may operate as a salient contextual cue that shapes children's learning across time. Although researchers have theorized that affect is a part of word-learning contexts (Andrews et al. 2009), prior work has not examined its dynamics over time, which may be important for how we define "context" from the child's perspective. That is, context may extend beyond external features of the environment or the situation to include internal features, such as how the child is feeling.

1.1 | Current Study

The current investigation aims to understand the dynamic links between young children's and caregivers' affect, communication, and word knowledge. Over 2 days, we measured caregivers' perceptions of their own and their child's affect via text-based surveys every 45 min and collected day-long recordings of household language. In addition, we collected child vocabulary reports from caregivers. First, we aimed to characterize caregivers' and children's affect (as perceived by caregivers) over the course of each day. Next, in a preregistered analysis, we predicted that there would be denser communication in moments of either high arousal or positive valence (i.e., more caregiver speech, child vocalizations, and turn-taking). We predicted that if higher arousal or positive valence supported communication and learning, children would be more likely to know words used in those

contexts. It is important to note that although our hypotheses were motivated by prior literature on learning, we only had a window into which words children knew at the time of the study, rather than the learning process itself. Although we only measured 2 days of language use, our assumption was that they would be typical contexts in which children hear early-learned words. Finally, in an exploratory analysis, we examined whether children would be more likely to know words heard in consistent versus variable affective contexts. Together, these three analyses elucidate how the dynamics of affect may shape caregiver–child communication, potentially influencing the words children know.

2 | Methods

2.1 | Resource Availability

2.1.1 | Data and Code Availability

All code and deidentified survey, vocabulary, and communication measures are available at: https://osf.io/fpqgd/?view_only=c294d2a573304e2484564703a90999ea. Raw audio recordings and transcriptions are not available due to identifiable information.

2.1.2 | Exploratory and Preregistered Analyses

We preregistered the broad hypothesis that caregiver-affect fluctuations will track communication density throughout the day, with planned exploratory analyses on the effects of caregiver–child affective dynamics on communication more broadly. We preregistered a specific analysis relating caregiver valence and adult word count; however, we carried out additional analyses in line with the broad hypothesis following the same preregistered template. In addition to these preregistered analyses, we carried out exploratory analyses relating child affect and word knowledge. We did not carry out or report the exploratory analyses outlined in the preregistration. The preregistration can be found here: https://aspredicted.org/7LW_2RZ.

2.2 | Method Details

2.2.1 | Ethics

All research procedures were approved by the Institutional Review Board at Princeton University, and parents provided informed consent before participating.

2.2.2 | Participants

We collected data from 25 families with toddlers between 24 and 30 months. Most of the primary caregivers were mothers (N = 24). Of this sample, 16% were Asian, 8% Black, 4% Hispanic, 64% White, 4% other, and demographic information was missing for one of the families (4%). This was a highly educated sample, with 56% reporting that the child's mother had earned an advanced degree and an additional 36% reporting a college degree. Maternal education information was missing for two of the participants (8%).

The sample size was preregistered based on a power analysis on a separate pilot sample to detect the relation between parent valence and adult word count with power greater than 80%. This sample size also matched recent day-long audio-recording studies exploring toddler affect and communication (Fields-Olivieri and Cole 2019; Fields-Olivieri et al. 2020).

We preregistered that participants would be excluded if they filled out or reported being near their child on fewer than five surveys (out of 26 total) or did not comply with the instructions of the study. None of the participants met these criteria; in fact, the average response rate was 97%. However, since our analyses examine the role of within-person variability in affect throughout the day, we excluded one participant (not counted in the final sample of 25 participants) because they reported the exact same maximum value (100/100) on 100% of survey questions.

2.2.3 | Context of Data Collection

Participants were recruited within Central New Jersey through the Princeton Baby Lab participant pool during the COVID-19 pandemic. Families chose days when the caregiver would spend most of the day with the child; however, other caregivers and siblings could be present.

2.2.4 | Procedure

Before the start of the study, the primary caregiver filled out the MacArthur-Bates Communicative Development Inventory: Words & Sentences (MCDI; Fenson 2007), a parent-report vocabulary questionnaire consisting of 680 words. We then collected back-to-back day-long recordings on two sequential days using the Language Environment Assessment (LENA) system (LENA Foundation 2009), as described below. One participating family could only complete 1 of the 2 days due to a family emergency; however, they met the inclusion criteria of more than five completed surveys. LENA recorders worn by the child in a front-facing pocket captured caregiver speech throughout each day. Families received a text message at 8:00 a.m. each day of the study, instructing them to turn on the recorder and place it in a front-facing pocket of the provided specialized LENA t-shirt. They were asked to keep the recorder on until at least the last text message of the day (at 6:30 p.m.), covering approximately 10.5 h. Families could take off the recorder t-shirt for naps and bath time, but were asked to leave the recorder nearby. Over the course of each day, parents were automatically sent text-message reminders every 45 min from 9:00 a.m. to 6:00 p.m. to fill out the same 1-min-long survey (13 survey reminders total). In each survey, caregivers reported how they were feeling and how they thought their child was feeling (for more information, see the section on caregiver and child affect below). Parents were instructed to skip the survey if their child was asleep or if they were not with their child in the preceding 15 min. We collected 625 affect surveys, an average of 25.4 surveys per participant. Of those, 75% (481) were collected when the child was awake and with the parent and, therefore, were included in the data analysis.

2.2.5 | Caregiver and Child Affect

Affect was quantified using caregiver survey responses throughout the day. Caregivers reported their perceptions of their own affective experiences and their child's displayed affect. We refer to these two measures as "caregiver affect" and "child affect" for conciseness. Given that toddlers could not report on their own internal states, we do not have a direct measure of the child's experienced affect; however, we validated parent reports using vocalization-based signals of child affect (for more information, see the section on validating caregiver reports of child affect below). It should be noted that although researchers have successfully used some physiological markers of arousal, physiological measures generally fail to differentiate valence and arousal at the same time (for a review, see Sacrey et al. 2021). Similarly, there are no validated automated behavioral measures of displayed valence and arousal in infants, as most of these measures have been trained on adults. In the current investigation, we measured caregivers' perceptions of two affect dimensions: valence and arousal.

Valence measured how "positively or negatively" the caregiver's or child's affect was at a given moment. Caregivers indicated their responses to the question (parent valence: *How positively or negatively are you feeling in this moment?*; child valence: *How positively or negatively is your child feeling in this moment?*) using a slider with values between 0 (extremely negative) and 100 (extremely positive). This value was centered at 50, resulting in a scale of −50 to +50, with negative numbers indicating negative valence.

Arousal measured how "high or low energy" the caregiver's or the child's affect was at a given moment (parent arousal: *How high or low energy are you feeling in this moment?*; child arousal: *How high or low energy is your child feeling in this moment?*). Like valence, arousal was measured on a slider with values between 0 (indicating extremely low energy) and 100 (indicating extremely high energy). This value was also centered at 50, resulting in a scale of −50 to +50, with positive numbers indicating high activation.

2.2.6 | Standardizing Measures Across Participants

All affective measures were standardized (z-scored) within participants, with 0 indicating the average valence or arousal for the caregiver or the child in the dyad.

2.2.7 | Classification Into Four Quadrants

We classified each data point into one of four quadrants of valence and arousal—*low valence and low arousal* ($V-A-$), *low valence and high arousal* ($V-A+$), *high valence and low arousal* ($V+A-$), *high valence and high arousal* ($V+A+$), in line with the circumplex model of affect (Russel 1980). These values were centered for each dyad, so that the quadrants were defined based on whether the caregiver's or child's valence and arousal values were above or below the average values for the given dyad. Because each child has their own range of affect, we opted not to define a neutral category based on an arbitrary threshold in our exploratory word-level analyses. This was also motivated by the fact that we observed a linear association between affect and communicative behavior in the main preregistered analyses.

2.2.8 | Validating Caregiver Reports of Child Affect

In order to validate whether caregiver reports of child affect tracked objective measures of child affective displays, we correlated caregiver ratings with the LENA system's automated measures of child crying (averaged over the 15 min before and after each survey). Although child crying is an imperfect measure of negative valence (given that toddlers do not always cry when they are feeling negatively), an association between caregiver ratings and crying would suggest that caregiver reports are sensitive to child behavior. A mixed-effects logistic regression with intercepts by dyad showed that caregivers' ratings of children's valence were negatively correlated with children's crying ($\beta = -0.12$, $t(452.84) = -2.51$, $p = 0.01$, $R^2_{\text{marginal}} = 0.01$), suggesting that caregiver reports of affect tracked the dynamics of affect-related behavior. Although this is a weak association, this is not surprising given prior research showing that specific canonical displays of affect (like crying) are weak predictors of internal affective states (Barrett et al. 2019; Fernández-Dols and Crivelli 2013), especially in infants (Camaras and Shutter 2010).

2.2.9 | Caregiver and Child Communication

We collected 2 day-long audio recordings (10–16 h) using the LENA recording system to assess how caregiver and child communication relates to affect measures. Children wore a small audio-recording device in a specialized t-shirt front pocket. The LENA system has software that automatically extracts estimates of *adult word count* (AWC; the number of words spoken by the adult in the child's proximity), *child vocalization count* (CVC; the number of speech-like vocalizations produced by the child), and *conversational turn count* (CTC; the number of times the caregiver and the child changed speech turns within five seconds) in 5-min segments. The estimates of adult speech used in the adult word count and the conversational turn count included any adult speech in the child's proximity, meaning that speech from other adults could have contributed to these estimates. The child vocalizations measured by the LENA system were specific to the child wearing the recorder. It is important to note that LENA's automated tagging of communicative behaviors is an imperfect method compared to manual annotation (Bulgarelli and Bergelson 2020; Cristia et al. 2024; Marchman et al. 2021). While recent work comparing LENA estimates of adult word count to manual transcription suggests moderately high accuracy for adult word count and child vocalization count (Cristia et al. 2020, 2021), inaccuracies in LENA's automated estimates can sometimes arise (Lehet et al. 2021). To test the accuracy of LENA's automated adult word count estimates in our data, we computed the number of words spoken by the primary caregiver in the manually transcribed 5 min before and after each completed survey, and we extracted LENA's automated count for words spoken by speakers of the same gender as the primary caregiver during the same window. These two estimates were highly correlated ($r = 0.89$, $p < 0.001$). Although LENA's automated estimates capture talk by other speakers of the same gender as the primary caregiver, not just that of the primary caregiver, the positive association between automated and manually coded measures suggests that

LENA successfully captured variability in adult vocalizations. In addition, we replicated the associations between affect and adult word count when using adult word counts from the transcribed segments (Supplementary Analysis 3).

To assess links between these three communication measures and caregiver reports of affect, we extracted the 5-min-bin LENA estimates for communicative acts in the 15 min before and after each affect report. We then averaged these estimates, resulting in a single value for each communicative behavior for each survey time point (e.g., for a caregiver affect report completed at 9 a.m., we would extract the average 5-min adult word count from 8:45 a.m. to 9:15 a.m.). All communication measures were standardized (z-scored) within participants, with 0 indicating the average count for the dyad. Because these estimates were normally distributed, we did not log them (as preregistered). We chose the 15 min before and after each survey to avoid overlap with the analysis window for the preceding and following survey (since surveys were administered approximately every 45 min). Further, caregivers were asked to confirm that they spent the previous 15 min with their child.

2.2.10 | Child Word Knowledge

We measured children's word knowledge using caregivers' responses on the MCDI (Fenson 2007). Children were marked as knowing or producing a word if their caregiver indicated that their child understood *and* said a given word.

2.2.11 | Word Affective Context

In order to link the affective contexts in which children hear words and their knowledge of these words, trained research assistants transcribed caregiver speech in the 5 min preceding and following each of the 625 completed affect surveys. Then, for each word on the MCDI questionnaire (regardless of whether the child knew the word or not), we marked all time points where caregivers used that word in the 5-min interval surrounding a survey. For example, we would mark any time the parent used the word "dog" within 5 min of completing an affect survey. On average, a child encountered 382.7 (out of 680) words from the MCDI in caregiver speech at least once within the 5 min before or after a survey during the 2 days of the study. This was the case, on average, for 234.2 of the words the child knows (based on caregivers' MCDI responses). Over the 2 days of the study, children encountered an average of 283.0 words within 5 min of their caregiver reporting that the child was experiencing low valence and low arousal, 246.3 words in low valence and high arousal, 268 words in high valence and low arousal, and 350.2 words in high valence and high arousal. Other words not listed on the MCDI were not included in these analyses.

We computed the proportion of instances of each word that occurred in each of the four affective quadrants. Further, we averaged the standard deviation of valence and the standard deviation of arousal across all instances of the word for each dyad, resulting in a value combining valence and arousal variation as a measure of overall variability in affective context.

2.3 | Quantification and Statistical Analysis

2.3.1 | Linking Affect Reports and Communicative Behaviors

All analyses linking affect and communicative behavior tested whether affect reported at a given time of the day was associated with the prevalence of a given communicative behavior in the moments surrounding it. We used the preregistered mixed-effect model: *communicative behavior measure ~ affect measure (standardized valence or arousal) at the current time point + affect measure at the previous time point*, with random intercepts by participant. As preregistered, we first ran this model with random intercepts and slopes for the affect measure at the current time point by participant. If the model failed to converge (which was the case for all analyses we ran), we opted for a simpler model with random intercepts only. We used FDR correction for multiple comparisons and reported standardized regression coefficients. The degrees of freedom were computed using the Satterthwaite approximation (Satterthwaite 1946), built into the lmerTest package.

2.3.2 | Linking Words' Affective Context and Children's Word Knowledge

For the exploratory analyses linking the affective contexts of words to the child's word knowledge, we used a mixed-effects logistic regression with random intercepts by word, predicting whether or not the child knew the word (based on MCDI), controlling for the overall frequency of the word (the number of times the child heard the word over the 2 days of the study), with the proportion of time the child encountered that word in each of the four quadrants as the predictor: *child knows word (yes/no) ~ proportion of word instances in quadrant + word frequency + (1|word)*. We constructed separate regressions for each of the four quadrants, with the proportion of time children heard each word in the quadrant as the predictor of interest and random intercepts by participant. We did not include a random slope by word because it resulted in a singular fit error.

3 | Results

3.1 | Caregiver and Child Affect Fluctuate Over the Course of a Day

First, we characterized the dynamics of child and caregiver affect throughout the day along two dimensions: (1) valence, from negative to positive, and (2) arousal, from low energy to high energy. Similarly to prior ecological momentary assessment studies on child (Nencheva, Tamir, et al. 2023) and adult (Thornton and Tamir 2017) emotion dynamics, we found that caregivers reported fluctuations in affect over the course of the day for themselves and their child (Figure 1). We then categorized each report of child affect into one of four quadrants, based on whether it was higher or lower than the average valence and arousal for the participant. The greatest proportion of child affect timepoints fell in the high valence and high arousal quadrant ($V+A+$; 43%), followed by low valence and low arousal ($V-A-$; 28%), high valence and low arousal ($V+A-$; 17%), and low valence and high arousal

FIGURE 1 | Caregiver and child valence varied over days and across the 25 dyads. This descriptive plot illustrates how affect changed over the course of the day for each dyad (*x*-axis), as well as how the dynamics of affect differed between dyads (*y*-axis). Each colored rectangle on the plot represents the affect quadrant for a given child (left panels) or caregiver (right panels) at each hour (*x*-axis) on the first (top panels) or second (bottom panels) day of the study. The rows on the *y*-axis represent the affect of a given dyad.

($V-A+$; 12%). This indicates that most of the time, caregivers perceived their child to be experiencing high arousal and high valence. From the 100-point scale, child affect showed an average 40-point range in valence and a 31-point range in arousal between the highest and lowest value for valence and arousal, respectively, on a given day. Adults self-reported an average 42-point range in valence and a 36-point range in arousal.

Ratings of caregiver and child affect were moderately correlated. In a linear mixed-effects regression with random intercepts by the participant, we found significant relations between child and caregiver valence ($\beta = 0.54$, $t(252.5) = 12.61$, $p = 1.28 \times 10^{-28}$, $R^2_{\text{marginal}} = 0.30$) and arousal ($\beta = 0.33$, $t(399) = 6.84$, $p = 2.89 \times 10^{-11}$, $R^2_{\text{marginal}} = 0.12$). Together, these descriptive results show that on an average day, (1) caregivers perceived fluctuations in their child's affect, and (2) caregivers perceived their own and their child's affect to be a coupled system.

3.2 | Valence and Arousal Are Associated With Caregiver–Child Communication

Next, we investigated whether fluctuations in reported affect throughout the day related to caregiver–child communication. Specifically, we examined whether caregiver and child affect were associated with their communicative behaviors in the 15 min before and after each survey (Figure 2). In a mixed-effects linear model with random intercepts by participant, controlling for affect at the previous time point, we found modest positive associations between higher adult word count and caregiver arousal ($\beta = 0.13$, $t(347) = 2.92$, $p_{\text{FDR}} = 0.007$, $R^2_{\text{marginal}} = 0.04$), caregiver valence ($\beta = 0.1$, $t(346) = 2.17$, $p_{\text{FDR}} = 0.04$, $R^2_{\text{marginal}} = 0.02$), and child arousal ($\beta = 0.17$, $t(344) = 3.79$, $p_{\text{FDR}} = 0.0007$, $R^2_{\text{marginal}} = 0.04$), but not with child valence ($\beta = 0.07$, $t(346) = 1.66$, $p_{\text{FDR}} = 0.09$, $R^2_{\text{marginal}} = 0.007$). Higher child vocalization count was similarly associated with child arousal ($\beta = 0.29$, $t(344) = 6.91$, $p_{\text{FDR}} = 9.08 \times 10^{-11}$, $R^2_{\text{marginal}} = 0.13$), and child valence ($\beta = 0.10$, $t(346) = 2.34$, $p_{\text{FDR}} = 0.04$, $R^2_{\text{marginal}} = 0.02$), but not with caregiver arousal ($\beta = 0.08$, $t(347) = 1.84$, $p_{\text{FDR}} = 0.08$, $R^2_{\text{marginal}} = 0.02$) or caregiver valence ($\beta = 0.07$, $t(346) = 1.69$, $p_{\text{FDR}} = 0.09$, $R^2_{\text{marginal}} = 0.02$). Conversational turn count was significantly associated with child arousal ($\beta = 0.25$, $t(344) = 5.6$, $p_{\text{FDR}} = 1.73 \times 10^{-7}$, $R^2_{\text{marginal}} = 0.09$), but not with child valence ($\beta = 0.08$, $t(346) = 1.80$, $p_{\text{FDR}} = 0.14$, $R^2_{\text{marginal}} = 0.01$), caregiver arousal ($\beta = 0.06$, $t(347) = 1.48$, $p_{\text{FDR}} = 0.15$, $R^2_{\text{marginal}} = 0.01$), or caregiver valence ($\beta = 0.06$, $t(346) = 1.44$, $p_{\text{FDR}} = 0.15$, $R^2_{\text{marginal}} = 0.01$).

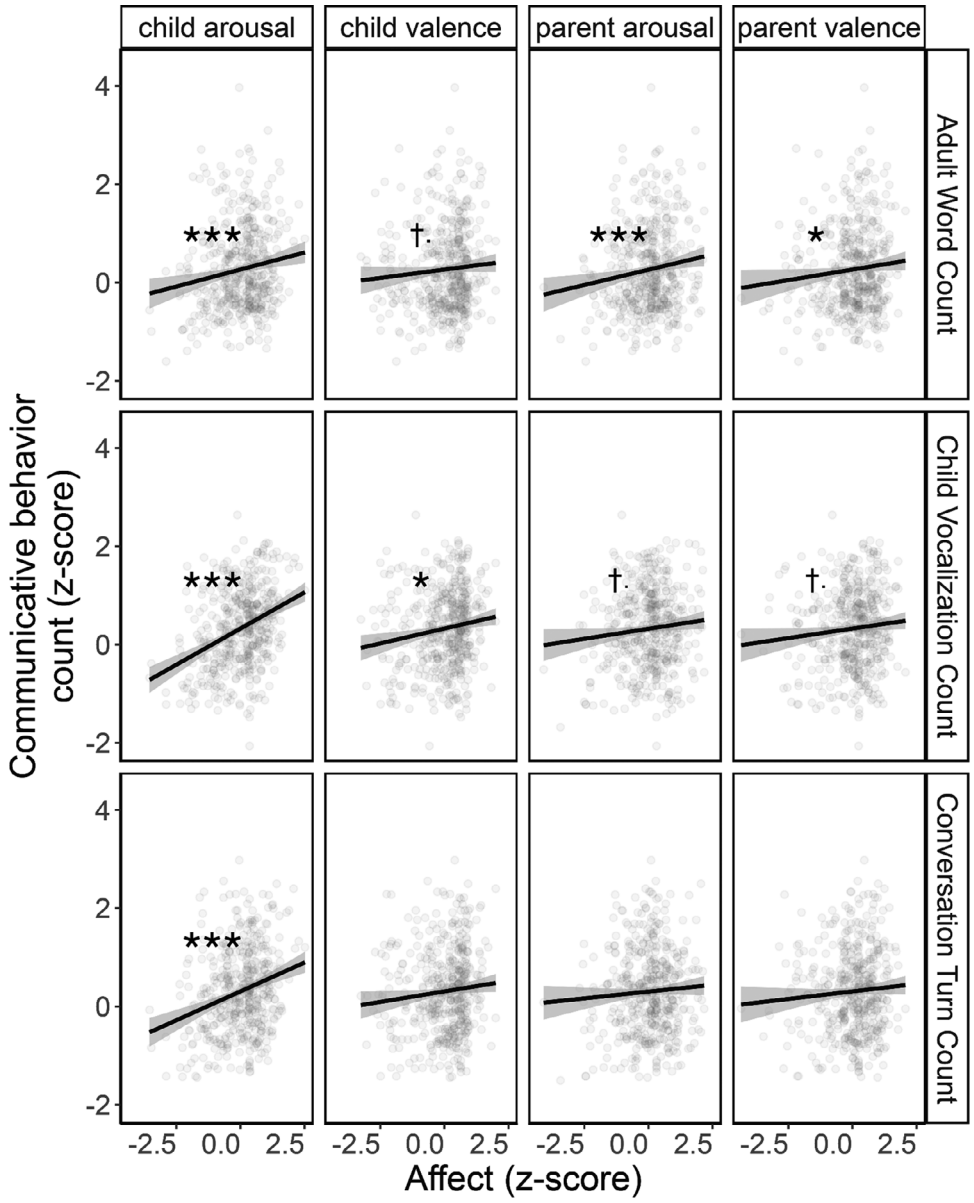

FIGURE 2 | High arousal and high valence were associated with more adult speech and child vocalizations. Each point represents affect at a given time. The *y*-axis shows the standardized score of the communicative behavior listed to the left of each panel (adult word count for the first row of plots, child vocalization count for the second, and conversational turn count for the third row). The *x*-axis shows a standardized rating of affect for child arousal (1st column), child valence (2nd column), caregiver arousal (3rd column), and caregiver valence (4th column). The regression line is plotted in black, with a shaded 95% confidence interval, and the significance of each model is noted above each line (***$p < 0.001$, *$p < 0.05$, and $^{\dagger}p < 0.1$). Communicative behaviors were highest in moments with either higher valence or higher arousal.

While not every effect was statistically significant, these results collectively suggest that moments of either high valence or high arousal were associated with increased density of verbal communicative behaviors. The increased communication at these moments may support word learning. In contrast, moments with negative valence and low arousal contained less speech and child vocalization. Although our main preregistered analysis focused on the association between caregiver affect and adult word count, we found strong associations between caregivers' perceptions of child affect (especially arousal) and adult and child productions and turn-taking. This suggests that child affect (or at least caregivers' perceptions of it) might shape communication more strongly than caregiver affect.

3.3 | Children Know Words That They Hear in High-Valence and/or High-Arousal Contexts

Given the observed differences in communication surrounding different affective contexts, we investigated in an exploratory analysis whether individual differences between participants in the affective contexts surrounding particular words relate to children's knowledge of those words. Given the stronger associations between perceived child affect and communication observed in the previous analysis, our main analyses focused on child affect.

We tested the extent to which hearing a given word within each of the four valence-arousal quadrants of child affect ($V+A+$, V

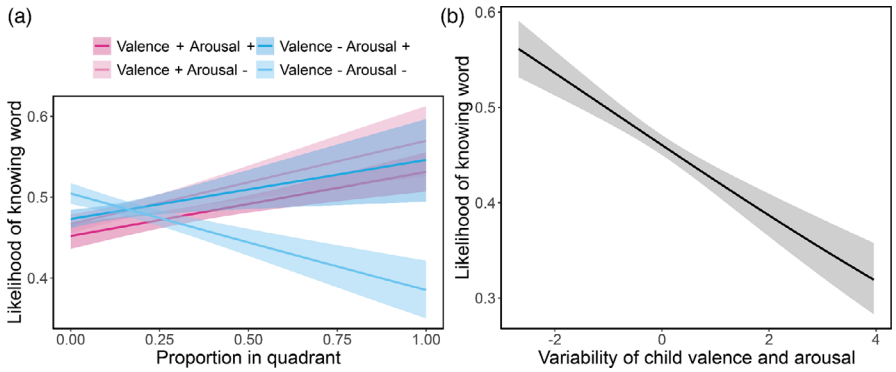

FIGURE 3 | Child affect relates to word knowledge. Panel (a) shows the likelihood of a child producing a given word on the *y*-axis and the proportion of word instances that appeared in the interval surrounding an affective survey within each of the four quadrants on the *x*-axis (pink: higher valence; blue: lower valence; and more saturated colors represent higher arousal, and less saturated colors represent lower arousal). Each logistic regression line (with shaded 95% CI) corresponds to each of the quadrants, respectively. Children were more likely to know a word if they heard it a greater proportion of time with higher-valence or higher-arousal contexts and less likely to know it if they heard it a greater proportion of time with lower-valence and lower-arousal contexts. Panel (b) plots the likelihood of the child knowing a given word on the *y*-axis and the variability in child affect across all instances of the word on the *x*-axis (*z*-scored). Variability in child affect was computed as the average of the standard deviation of valence and the standard deviation of arousal across all instances of a word for a given dyad. Children were more likely to know words heard in more stable affective contexts.

$+ A-$, $V - A+$, and $V - A-$) predicts children's knowledge of the word. We did so using a mixed-effects logistic regression with random intercepts and slopes by word, controlling for the overall frequency of the word (i.e., the number of times the child heard the word over the 2 days of the study).

We found that children were somewhat more likely to know words that they heard more often when their own affect was in a high arousal *or* high valence quadrant [$V + A+$: $\beta = 0.12$, $z = 2.65$, $p = 0.008$, $R^2_{\text{marginal}} = 0.13$; $V - A+$: $\beta = 0.08$, $z = 1.74$, $p = 0.08$, $R^2_{\text{marginal}} = 0.13$; $V + A-$: $\beta = 0.10$, $z = 2.28$, $p = 0.02$]. Conversely, they were *less* likely to know words they heard more often in the $V - A-$ quadrant ($\beta = -0.23$, $z = -5.15$, $p = 2.6 \times 10^{-8}$, $R^2_{\text{marginal}} = 0.13$). These findings suggest that children are more likely to know words that they hear more often during periods when the child was in a state of higher arousal and/or higher valence in their everyday lives. Although our main focus was on child affect, we carried out related exploratory analyses based on caregiver affect, and found the same results for 3 of the 4 quadrants ($V + A-$, $V - A+$, and $V - A-$); however, this analysis showed that children were less likely to know words heard more often when the caregiver was experiencing high positive valence and high arousal (see Supplementary Analysis 1). Additionally, we note that in a supplementary analysis, we did not observe effects of individual differences in *average* valence or arousal on vocabulary size (Figure S1); rather, our results speak to the dynamics of affect and language throughout the day. In another exploratory analysis, we examined the effects of hearing words with very extreme versus neutral affect. This analysis served to evaluate a finding by Bloom (2013) showing that more neutral expressions of affect in young children were associated with better language outcomes. In order to keep the scale of affective measures consistent, we used raw scores (on a scale from 0 to 100). Neutral affect was defined as scoring between 40 and 60 on arousal and valence (corresponding to neutral valence and mid-levels of arousal). Extreme affect was defined as scoring above 75 on arousal, and over 75 or under 25 on valence (corresponding to extreme positive or negative states, respectively). We observed that children were moderately more likely to know words heard more often with extreme affect ($\beta = 0.45$, $z = 18.86$, $p < 0.001$, $R^2_{\text{marginal}} = 0.17$). There was a slight negative association between children's word knowledge and the proportion of instances in moments of neutral affect ($\beta = -0.12$, $z = -5.25$, $p < 0.001$, $R^2_{\text{marginal}} = 0.13$). Although this suggests that neutral affect in our data was not associated with greater word knowledge, our sample may not include sufficiently extreme values of arousal and valence.

We next evaluated whether the association between child affect context and word knowledge may be explained in part by the properties of caregiver–child communication in different affective contexts. When we controlled for average adult word count, child vocalization count, and conversational turn count surrounding the instances of each word, the association between the child's knowledge of the word and the proportion of word instances in a given quadrant was no longer significant for three of the quadrants of child affect ($V + A+$: $\beta = 0.01$, $z = 0.26$, $p = 0.78$, $R^2_{\text{marginal}} = 0.13$; $V - A+$: $\beta = 0.03$, $z = 1.19$, $p = 0.23$, $R^2_{\text{marginal}} = 0.13$; $V + A-$: $\beta = 0.01$, $z = 0.65$, $p = 0.51$). There was still a significant association for $V - A-$ after controlling for these communication variables (child affect: $\beta = -0.22$, $z = -5.28$, $p = 1.24 \times 10^{-7}$). Therefore, one possible interpretation is that moments of higher child valence and/or arousal may relate to word knowledge in part by engendering denser communication both from the caregiver *and* the child (operationalized as more words spoken by the adult, more child vocalizations, and more turn-taking). However, communication during moments of lower child valence and arousal may not fully explain children's knowledge of words encountered in these moments. This raises the question of what other contributors there may be to children's lower likelihood of knowing words used in low-valence and low-arousal contexts.

In sum, children were somewhat more likely to know words that they heard more often while experiencing higher valence and/or higher arousal, and less likely to know words that they heard while experiencing lower arousal and lower valence (as perceived by caregivers). The relation between affect and word knowledge was, in part, explained by the denser communication associated with high arousal and high valence.

3.4 | Children Know Words That They Hear in More Stable Affective Contexts

In addition to exploring which affective moments were most strongly associated with children's word knowledge, we also examined whether hearing words with stable versus variable affect over 2 days was more strongly associated with word knowledge. We found that children were somewhat *less* likely to know words that they heard with greater variability (standard deviation of valence and arousal across all instances of the word for a given child) in a mixed logistic regression with intercepts by word ($\beta = -0.14$, $z = -2.95$, $p = 0.003$; Figure 3b). This suggests that children were more likely to know words that they heard in moments with more similar affect across time.

4 | Discussion

Many aspects of children's home environments matter for word learning, such as patterns in the time of day or room in the home in which children hear a word (Roy et al. 2015). The current investigation expands current conceptions of the "contexts" that support children's learning by considering the dynamic interplay between caregivers' and children's affect and communication in everyday life. The two key findings were that in a US-based sample of caregivers and toddlers vocalized and exchanged conversational turns more in moments of higher arousal or valence, and children were more likely to know words heard in these moments (controlling for each word's overall frequency). These findings highlight the constant presence and important role of affect in the early language environment.

Higher valence and arousal were generally associated with denser communication. Specifically, in moments of higher child arousal (and to a lesser extent valence), adults and children vocalized more and took more conversational turns. Caregivers' valence and arousal, on the other hand, were primarily related to their own communicative behavior. One interpretation of this relation is that affect shapes communication—an idea that converges with research linking higher physiological arousal with more infant and caregiver vocalizations (Wass et al. 2022) and negative affect with fewer vocalizations in infants (Fields-Olivieri et al. 2020) and decreased communication in adults (daSilva et al. 2021; Ellwood-Lowe et al. 2022; Roby and Scott 2022). Further, more positive or higher arousal states in the child may provide more opportunities for caregivers to engage using child-directed communication or play. An alternative interpretation is that communication shapes affect. For example, if a child is engaged in back-and-forth communication with their caregivers, they may begin to feel more positively or more activated. There is empirical evidence that social interactions are associated with more smiling in infants (Ellsworth et al. 1993) and greater well-being in adults (Sun et al. 2020), although causality is unknown in this prior work. Regardless of directionality, the coupling between affect and communication suggests that these two components of experience should be considered simultaneously to understand how children learn in early communicative interactions.

Children were also more likely to know words that they heard in moments of more positive valence and/or higher arousal. A likely interpretation is that experiences of higher valence and arousal support word learning via attention and memory processes (Guo et al. 2018; Miller et al. 2018; Outters et al. 2023). Relatedly, there is evidence that when children are interested in a topic, they learn novel words more easily (Ackermann et al. 2023; Madhavan et al. 2024). In contrast, there is also empirical evidence that neutral affect is optimal for learning (Bloom 2013). In our supplementary analyses, we did not find that neutral affect was a better predictor of word knowledge than more extremely positive or negative affect. However, it is possible that we did not capture moments of truly extreme affect during our 2 days of recording. In addition to any direct effects of valence and arousal on learning, the greater amount of caregiver speech, child vocalizations, and turn-taking that we observed during moments of higher child arousal may help explain children's learning (Donnelly and Kidd 2021; Feurstein et al. 2022). That is, the density of caregiver–child communication may—alongside other factors such as the playfulness of the interaction—explain why children are more likely to know words heard in contexts with more positive valence or higher arousal. Conversely, lower arousal and less positive valence may hinder learning and communication or serve as a rest period when learners consolidate learned memories rather than receive new input. Another possibility is that certain modes of conversation (e.g., discussing favorite topics or toys) may bring about more positive or high-arousal feelings. Although we cannot disentangle these possibilities, we found that children were more likely to know words heard in stable affective contexts over time, across the continuum of valence and arousal. This suggests that, in addition to shaping communication and learning, affect can serve as a context that helps children link experiences hearing particular words across time. These findings highlight the importance of understanding the rich connections between the dynamics of word learning and affect throughout the day to gain a complete picture of early learning.

Although our study design enabled us to measure the real-world dynamics of affect and speech, there were several key limitations. First, although caregivers' perceptions of child affect are interesting as a window into caregivers' responses to the behaviors they perceive, they do not perfectly reflect the child's experiences. Relying on caregivers' perceptions of children's affect is just one method for capturing children's affective experiences and displays and may have even altered natural behavior in the home. For example, a supplementary analysis comparing adult word count in the 15 min before and after a survey showed that caregiver speech tended to increase after filling out a survey (Figure S2). We chose our approach for several reasons: (1) alternative measures of affect (such as physiology) are limited in capturing both valence *and* arousal (e.g., distress and excitement have overlapping physiological fingerprints; Sacrey et al. 2021); (2) self-report is not possible with children this young; (3) caregiver report is widely used to assess the development of young children (Bricker et al. 1999; Parade and Leerkes 2008); and (4) caregiver report of child emotion is moderately correlated with child self-report in slightly older children (Nauta et al. 2004). Even though our data showed a weak correlation between caregivers' reports of child valence and the frequency of children's crying, future research should combine caregiver reports with a wider array of child physiological and behavioral measures, along with contextual variables, in order to measure different components of affect more robustly. This work could identify moments where caregiver reports and physiology converge or diverge, as

well as the types of behavioral and situational features that caregivers use to perceive child affect. Prior research, which relied on physiological measures of arousal, has shown that infants vocalize more in moments of higher arousal (Wass et al. 2022), but this approach is limited as well. In the current investigation, it is unclear how parents determined their child's internal state. They may have perceived their child's vocalizations as an expression of high arousal (thus inflating the association between arousal and vocalizing) or may have relied on a combination of features, including vocalizations, body movements, and emotion-related signals.

Another limitation is the observational design. Although this served the crucial purpose of allowing us to characterize natural fluctuations in affect and communication, it limited our ability to infer causal links. Future research could use mood inductions (e.g., watching a sad video clip; Devilly and O'Donohue 2021) or communicative interventions (e.g., reminders to engage with the child; Roberts and Kaiser 2011) while retaining the naturalistic design of the study. Combined with time-lagged analyses, this approach would allow researchers to disentangle the effects of affect on communication and vice versa. In addition, a limitation of the study is that we measured only two important components of children's rich contextualized experiences: language and affect. It will be crucial for future work to examine related variables that may shape the dynamics of both affect and language in children's everyday lives, such as children's routines, sleep/wakefulness, and motivational states.

A further limitation of observational data in the child's home environment comes from the inherent noisiness and multicausal nature of real-world observational data. The relatively weak associations we observe are not surprising in this context. Everyday communicative behaviors are associated with a multitude of factors in addition to affect, and weak associations are more common when psychological research moves beyond controlled, unicausal lab environments (Gandhi et al. 2024; Götz et al. 2022). However, it is important to note that in addition to the variability that comes from other causal factors that were not measured in the study, there were multiple layers of measurement noise throughout our automated analysis pipeline. For example, LENA may underestimate or overestimate caregiver and child vocalizations, and affective behaviors overlapping with particular affective states (e.g., crying, playing loudly with blocks, or running around the house) may further bias these estimates.

The relatively short time span of the study is another limitation. Although the densely-sampled design of the study allowed us to investigate the dynamics of affect and speech over the course of the day, it only captured 2 days of the child's life during a particular moment in development. Future longitudinal research can assess developmental change and stability of word-level affective contexts, which would allow us to better understand how input may give rise to (or be a reflection of) children's word learning.

A final limitation of the current investigation is its relatively homogeneous sample. The participating families were US-based, highly educated, and 64% White. Our findings, therefore, should be interpreted with this context in mind, and we hope they spark efforts to understand how affect and communication interact in other communities. There are known cultural differences in how affect is expressed and valued (Mesquita and Frijda 1992; Safdar et al. 2009; Tsai et al. 2006). Therefore, it is likely that valence and arousal may have different effects on communication across different cultural contexts. For example, in our study we found that more positive and higher arousal states, known to be preferred by the majority of people in the United States (Tsai 2007), were most strongly associated with word knowledge. Our findings may not be generalizable to cultures with a weaker preference for positive over negative states or higher over lower arousal states. Future research should examine how infants tune in to their local community's affective and speech context.

5 | Conclusion

This investigation combined day-long audio recording and ecological momentary assessment to understand how the dynamics of affect in the home relate to children's early communicative experiences and word knowledge. Higher arousal and valence were positively associated with more dense communication between caregivers and children, and children were more likely to know words that they heard in these contexts. This research broadens current definitions of learning contexts to include affective experiences and displays from caregivers and children. Together, the findings indicate that affect and communication are interdependent systems that should be studied in tandem in order to understand children's learning.

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Ethics Statement

All research procedures were approved by the Institutional Review Board at Princeton University, and parents provided informed consent before participating.

Conflicts of Interest

The authors declare no conflicts of interest.

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Data Availability Statement

All code and deidentified survey, vocabulary, and communication measures are available here: https://osf.io/fpqgd/. Raw audio recordings and transcriptions are not available due to identifiable information.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting File 1: desc70083-sup-0001-SuppMat