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Contextual Variation in Language Input to Children: A Naturalistic Approach

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Children learn what words mean from hearing words used across a variety of contexts. Understanding how different contextual distributions relate to the words young children say is critical because context robustly affects basic learning and memory processes. This study examined children's everyday experiences using naturalistic video recordings to examine two contextual factors—where words are spoken and who speaks the words—through analyzing the nouns in language input and children's own language productions. The families in the study (n = 8) were two-parent, dual-income, middle-class families with a child between 1 year, 3 months to 4 years, 4 months (age M = 3 years, 5 months) and at least one additional sibling. The families were filmed as they interacted in their homes and communities over 2 weekdays and 2 weekend days. From these videos, we identified when the focal child was exposed to language input and randomly selected 9 hr of contiguous speech segments per family to obtain 6,129 noun types and 30,257 noun tokens in language input and 1,072 noun types and 5,360 noun tokens in children's speech. We examined whether the words that children heard in more variable spatial and speaker contexts were produced with greater frequency by children. The results suggest that both the number of places and the number of speakers that characterized a child's exposure to a noun were positively associated with the child's production of that noun, independent of how frequently the word was spoken.

Keywords: word learning, context, naturalistic, children, language input

Children learn what words mean from hearing them used across a variety of contexts. Notably, children not only remember the names of specific objects in their environment, but they also generalize the meaning of words to new instances they have never encountered before. It is well established that the language learning environment plays an important role in children's vocabulary acquisition (Hart & Risley, 1995; Hoff, 2010; Hurtado et al., 2008; Huttenlocher et al., 1991; Weisleder & Fernald, 2013). Over the last 25 years, a number of studies have demonstrated that children are sensitive to and learn the statistical regularities in their environments (Graf Estes et al., 2007; Saffran et al., 1996; Saffran & Kirkham, 2018; L. B. Smith & Yu, 2008; Thiessen & Saffran, 2003). These studies have increased interest in the content of children's early environments and examination of environmental supports that may contribute to learning (Bergelson et al., 2019; Bergelson & Aslin, 2017; Clerkin et al., 2017; Custode & Tamis-LeMonda, 2020; de Barbaro & Fausey, 2021; Fausey et al., 2016; Laing & Bergelson, 2020; Mendoza & Fausey, 2021; Roy et al., 2015; L. B. Smith et al., 2015, 2018; Tamis-LeMonda et al., 2017, 2019; Warlaumont et al., 2021). This investigation examines an additional source of environmental support that may be hiding in plain sight: the variability in the context of where children hear words and the variability in the context of who says those words.

Contextual regularity and variation are omnipresent in children's environments. For example, in a single day, one child may hear the word *dog* in a wide range of places (e.g., in the car, at the park, in the kitchen) and from a wide range of speakers (e.g., mother, father, sibling). In contrast, another child may hear the word *dog* in a narrow range of places and speakers (e.g., only at the park and only from their father). Understanding how different contextual distributions relate to the words young children say is crucial because research suggests context robustly affects basic learning and memory across a broad range of circumstances (e.g., see Borovsky & Rovee-Collier, 1990; Edgin et al., 2014; Godden & Baddeley, 1975; Hartshorn et al., 1998; Hayne et al., 1997, 2000; Learmonth et al., 2004; Rovee-Collier et al., 1985; Rovee-

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Collier & Dufault, 1991; S. M. Smith, 1982; Suss et al., 2012; Wojcik, 2013).

Contextual Distributions in Everyday Language Input to Children

Developmental psychology has a long history of studying children in their everyday environment, starting with the early baby biographies (Dennis & Dennis, 1937). In the last 50 years, research has increasingly described children's environments through seminaturalistic studies, in which parents might be instructed to "act like you normally do at home" (Tamis-LeMonda et al., 2017). Although corpus (e.g., CHILDES; MacWhinney, 2000) and seminaturalistic studies have been critical for developing a wide knowledge base regarding the linguistic input children hear, such studies are typically constrained by geography (e.g., the study takes place in the laboratory and/or parents are instructed to stay within the range of a fixed camera), scheduling convenience (e.g., a single caregiver interacts with the child), task structure (e.g., children are given a specific set of toys to play with), time (e.g., recorded for 30 min), or a combination of these factors. More recently, technological advances have provided new means to measure and characterize the shape of children's learning environments from a naturalistic lens (see e.g., Bergelson & Aslin, 2017; Bergelson et al., 2019; Clerkin et al., 2017; Custode & Tamis-LeMonda, 2020; de Barbaro & Fausey, 2021; Fausey et al., 2016; Laing & Bergelson, 2020; Mendoza & Fausey, 2021; Roy et al., 2015; L. B. Smith et al., 2015, 2018; Tamis-LeMonda et al., 2017, 2019; Warlaumont et al., 2021). Such approaches aim to characterize children's actual learning environment to better understand language acquisition.

These studies have revealed considerable variability in children's everyday environments and particularly much more variability than is encountered in laboratory-based settings. For example, one study reported that on a given day, infants hear words from seven different speakers on average (Bergelson & Aslin, 2017). Another study examining children's everyday musical soundscapes describes that, remarkably, infants' daily encounters with music included 51 different musical tunes and three different musical voices on average (Mendoza & Fausey, 2021). Similar accounts of variability have been reported with children's experiences with faces (Jayaraman et al., 2015), first-person views of objects (Bambach et al., 2018), and phonology (MacDonald et al., 2020). Variability in children's everyday experiences is noteworthy because variability supports generalization (e.g., Estes & Burke, 1953; Mendoza & Fausey, 2021; Perry et al., 2010).

A second broad finding is that the distributions of experience matter, and children's input and productions are organized in patterns that unfold over time (Warlaumont et al., 2021). Montag et al. (2018), for example, suggested that the conversational contexts of word learning environments are not evenly distributed across time, but rather are "lumpy and bursty" such that there are *lumps* of co-occurring words (e.g., talk of spoons and bowls co-occurring in time) along with individual words repeatedly appearing in *bursts*. Similarly, research examining children's visual environments (Clerkin et al., 2017; L. B. Smith et al., 2018) indicates that although children's visual scenes contain a fair amount of clutter and variability, across time a small set of objects is repeatedly present, and these objects may be among children's first-learned object names.

Altogether, a new frontier of research indicates that children's everyday experiences contain cues to word meaning. Because word learning takes place in context, contextual distributions in children's everyday experiences may affect the words children learn and say. A number of studies indicate that certain words are more likely to appear in some contexts than others; for example, children may be more likely to hear food words when sitting in a high chair (Custode & Tamis-LeMonda, 2020) and words describing body parts when participating in grooming activities (Tamis-LeMonda et al., 2019). Moreover, children's books may be a source of unique words that are unlikely to be encountered in conversational settings (Montag et al., 2015). Evidence for contextual influence on word learning in a naturalistic sample comes from the Human Speechome Project (Roy et al., 2006), a first of its kind study that captured a nearly complete record of a single child's language input and development for the first three years of his life. One major finding was that the distinctiveness of a word predicted the age at which that word was acquired (Roy et al., 2015). Three kinds of distinctiveness were measured: spatial distinctiveness, where in the home a word was said; linguistic distinctiveness, what other words were said with the target word; and temporal distinctiveness, what time of day a word was heard. All three distinctiveness measures predicted the child's age of first production of that word, although spatial distinctiveness and temporal distinctiveness were the strongest predictors. These results suggest that contextual constancy may be a key factor in children's first production of a word. However, less is known about how context is related to children's ongoing word production. The current study examines the role of spatial and speaker context in children's everyday production beyond the first production of the word.

Experimental Findings Regarding Context and Variation

A large body of experimental work indicates that the context in which something is learned has strong effects on encoding and retrieval (e.g., Butler & Rovee-Collier, 1989; Godden & Baddeley, 1975; Rovee-Collier & Dufault, 1991; S. M. Smith et al., 1978; Tulving, 1972). These studies show that performance is positively affected when learning and recall occur in the same context. For example, Hayne et al. (2000) exposed infants to an action in one of two spatial contexts (either in their homes or in the laboratory); subsequently, all infants were prompted to imitate the action (i.e., recall) in the laboratory. Infants who learned the action in the laboratory (context match) outperformed the infants who learned the action in their homes (context mismatch). Thus, recall was stronger when the spatial context was held constant between learning and testing. Indeed, research suggests that learners of all ages benefit from overlapping cues between learning and testing contexts; and conversely, that changes in contextual cues between learning and recall reduce memory performance (Godden & Baddeley, 1975; Hayne et al., 2000; Robinson & Pascalis, 2004; Rovee-Collier et al., 1985; S. M. Smith & Vela, 2001; Tulving & Thomson, 1973; Vlach & Sandhofer, 2011).

Although these types of context effects are common in memory tasks, context effects are also present in tasks that require generalization (Goldenberg & Sandhofer, 2013a, 2013b; Vlach & Sandhofer, 2011; Werchan & Gómez, 2014). In one study (Vlach & Sandhofer, 2011), two- to four-year-old children learned the names for objects of the same category in a distinct context (a colored and patterned fabric square on which the object was placed). Children were then asked to extend the label to a new object. Performance was higher when training and testing took place in the same context (i.e., the same fabric) relative to a condition in which training and testing took place in different contexts (i.e., a new fabric; Goldenberg & Sandhofer, 2013a; Vlach & Sandhofer, 2011). In contrast, when the learning and testing contexts differed, performance suffered. Moreover, similar context effects have been demonstrated with people as the context cue. Goldenberg & Sandhofer (2013b) found that children were more likely to generalize words to objects when the words were trained and tested by the same experimenter than when the words were trained and tested by different experimenters. Altogether, children showed context dependent learning to both spatial and speaker contexts.

In addition, contextual variation during learning also appears to protect children from contextual dependency (Amabile & Rovee-Collier, 1991; Rovee-Collier & Dufault, 1991; S. M. Smith et al., 1978; Vlach & Sandhofer, 2011). For example, when three- and four-year-old children were presented with category exemplars in multiple contexts (i.e., a different background fabric for each exemplar presentation), category identification in a new context was successful (Vlach & Sandhofer, 2011). One explanation for this finding is that exposure to multiple contexts during learning increases the number of encoding cues that can potentially overlap with retrieval cues at test (Tulving & Thomson, 1973), thus improving memory. Altogether, contextual variability seems to benefit learning when training and testing contexts differ.

A number of studies indicate that variability specifically supports word learning (Ankowski et al., 2013; Goldenberg & Sandhofer, 2013a; Perry et al., 2010; Rost & McMurray, 2010; Twomey et al., 2018). For example, in one study (Goldenberg & Sandhofer, 2013a), 2-year-old children were taught novel object categories within a constant or variable context. In the constant condition, objects of a single category were always presented on the same patterned and colored cloth (e.g., all five presentations of the category took place on a cloth with purple swirls). However, in the variable condition (referred to as interleaved in the study), three of the patterned and colored cloths were identical, and the other two cloths differed from all other cloths. The results indicated that the children who learned the labels with some variability in the background context scored significantly higher at test than children who learned the labels without contextual variation. Moreover, in a study testing retention of object labels (Twomey et al., 2018), 2-year-old children learned labels for novel objects under constant or variable conditions. In the constant condition, objects were always presented on the same white background, and in the varied condition, objects were presented with varying background colors. At test, only children in the variable condition showed evidence of retaining label–object associations, suggesting that the variability in background colors facilitated word learning. Thus, evidence from experimental studies indicates that some variability in the background context during learning may support learning and retention of words.

Therefore, although contextual constancy may be important for early aspects of word acquisition, contextual variation may be important for later aspects of word acquisition and use. Goldenberg & Sandhofer (2013b) posited that children may initially benefit from hearing a word repeatedly in the same context because shared context may aid in aggregating discrete instances together in memory—in part due to the compounding effects of multiple correlated cues (Kehoe, 1986; Rescorla & Coldwell, 1995). On the other hand, hearing a word repeatedly in the same context risks developing contextual dependency. A number of studies describe how children's understanding of words gradually progresses from local mappings between context-bound categories to more abstract categories (Barrett, 1986; Hoff, 2013; Huttenlocher et al., 1983). For example, Bloom (1973) described that her daughter only produced the word "car" when viewing cars from her apartment window but did not produce the word for cars viewed from other perspectives or in picture books. Overcoming contextual dependency is aided by learning in varied contexts (Jones et al., 2011; S. M. Smith et al., 1978). Thus, although children may be initially likely to produce words that appear in distinct contexts, hearing words in variable contexts may predict children's later production of words.

The idea that variable contexts may predict production has some support from studies that examine the semantic and linguistic diversity in which words appear (e.g., Hills et al., 2010; Jones et al., 2011). In these studies, greater diversity in the linguistic contexts in which a word appears is associated with faster word identification (Perea et al., 2013; Steyvers & Malmberg, 2003), lexical decision making (Adelman et al., 2006), and reading time (Plummer et al., 2014). Further, in some studies, more diverse semantic contexts have been associated with incidental learning of new words through reading (Rosa et al., 2022) and adult artificial learning (Jones et al., 2012). Notably, one study, (Hills et al., 2010), provides strong support for the idea that the semantic diversity of individual words predicts the age at which those words are acquired. Words from the MacArthur Bates Communicative Development Inventory (CDI; Fenson et al., 1994) were analyzed using a corpus of caregiver speech from the CHILDES database (MacWhinney, 2000) to assess the linguistic context in which words occur (i.e., the other words that are frequently associated with a target word). The results indicated that greater lexical diversity was related to an earlier age of acquisition on the CDI. This was particularly true for nouns, such that more semantically diverse nouns were learned at younger ages. Thus, it may be reasonable to expect that similar variability effects may be found when children's word productions are analyzed in terms of spatial or speaker contextual variation in language input to children.

The Present Study

The goal of this study was to examine how the contextual variability in which young children hear words is associated with children's production of words. In doing so, we aimed to describe two aspects of the contextual variation that surrounds and co-occurs with children's everyday linguistic input: the child's physical location when hearing or producing the word (spatial context) and the speaker who produced the word (speaker context). The types of contexts we examine in this study—the spaces children occupy when they hear words and the people who produce words—are rich and ecologically valid sources of context in children's everyday experience.

To examine variability in spatial contexts and speaker contexts, we analyzed naturalistic video recordings of children's everyday spontaneous interactions in family settings across multiple days. Participants were recorded going about their daily lives without restrictions on language usage, the people present, activities, or spaces occupied. Capturing the range of spatial variation requires naturalistic video recordings of language input to children and cannot be captured with audio-only recordings. Thus, the current study contributes authentic observations of language contexts and behaviors from a sample of young children (Repetti et al., 2013) and adds to a growing base of studies that have sought to describe children's everyday language learning environments (Bergelson & Aslin, 2017; Bergelson et al., 2019; Clerkin et al., 2017; Custode & Tamis-LeMonda, 2020; Fausey et al., 2016; Laing & Bergelson, 2020; Mendoza & Fausey, 2021; Roy et al., 2015; L. B. Smith et al., 2015, 2018; Tamis-LeMonda et al., 2017, 2019; Warlaumont et al., 2021).

We specifically focused our analyses on the nouns children hear and produce. Nouns dominate young children's vocabulary and were expected to occur in children's language productions at both the youngest (i.e., 1 year, 3 months) and oldest ages (i.e., 4 years, 4 months) in our sample (Bornstein et al., 2004; Dale & Goodman, 2005; Fenson et al., 1994; Golinkoff et al., 1994; Hansen, 2017; Huttenlocher et al., 1991). Nouns are more frequent than verbs in parent's speech to children (Cameron-Faulkner et al., 2003; Goldfield, 1993), specifically noun tokens (Gentner, 1982), and were the most frequent type of words produced by children in the present sample. Further, nouns have shown strong semantic diversity effects (e.g., Hills et al., 2010), suggesting that they may be susceptible to other types of contextual diversity effects.

The current study offers a naturalistic description of the spatial and speaker contexts of young children's everyday linguistic environments, focusing on noun input and production. We predicted that independent of the frequency with which a word was heard, children would produce nouns more frequently when the nouns were heard in more varied contexts. That is, greater contextual variation in exposure to a noun is associated with an increased likelihood that a child says that noun.

Method

The data consisted of 6,129 noun types and 30,257 noun tokens in language input and 1,072 noun types and 5,360 noun tokens in children's productions. The families in this study were selected from a larger sample of 32 middle-class, two-parent families who participated in a study conducted by the University of California, Los Angeles Sloan Center on Everyday Lives of Families (CELF; Ochs & Kremer-Sadlik, 2013). For our analyses, we selected all families that included a child older than a year and younger than four and a half years old. This resulted in a subsample of eight focal children (age ranging from 1 year, 3 months to 4 years, 4 months; 3 female and 5 male) from eight different families. The families in this subsample lived in monolingual English-speaking households and held mortgages on their homes in a large metropolitan area. Table 1 presents the demographic characteristics of the families. Participants were recruited through school flyers, newspaper ads, and word of mouth.

Design

The CELF study captured families in their natural environments on two weekend days and two weekdays. Recordings were not made when the parents were at work or when the focal children were at daycare. Two videographers—trained not to disrupt or interfere with the families' daily activities—collected the recordings. Wireless microphones worn by family members were used to capture all dialogue. The families were instructed to go about their daily activities as if the videographers were not there; no intervention, direction, or stimuli were provided. Filming took place both inside and outside of the home. Families attended swim lessons at their local recreation center and visited zoos, parks, and stores while being recorded; many also interacted with extended family members or friends during filming (see Saxbe et al., 2011 for further description of the activities in the dataset). Informed consent was obtained from all participants who were recorded in a home. One videographer followed each parent; if either parent was

Table 1
Sociodemographic Characteristics of Families

Characteristic	Mother *n*	Father *n*	*M* (*SD*)	Range
Age				
Focal child			3 years, 5 months (1 year, 2 months)	1 year, 3 months–4 years, 4 months
Mother			38 years, 1 month (5 years, 4 months)	28 years, 10 months–43 years, 9 months
Father			40 years, 3 months (5 years, 6 months)	32 years, 1 month–48 year, 6 months
Sibling 1 (*n* = 8)			8 years, 4 months (0 year, 5 months)	7 years, 8 months–9 years, 3 months
Sibling 2 (*n* = 3)			11 years, 1 month (5 years, 11 months)	5 years, 3 months–17 years, 2 months
Family income			$105,937 ($34,411)	$58,500–$164,999
Parents' marital status				
Married (*n* = 8)				
Parents' ethnicity				
European American	6	5		
African American	1	1		
Hispanic	1	2		
Parents' highest educational level				
High school	1	2		
Some college	2	3		
College graduate	3	2		
Graduate degree	2	1		

absent, that camera was free to film other family interactions (Ochs et al., 2006). The study was not preregistered, and the data are not currently available online.

Procedure

Identifying Language Input

To capture families' everyday lives within a naturalistic focus, participants were allowed to freely move about multiple environments. The videographers default was to follow the parents rather than the focal child, which necessitated a unique language input identification procedure. Thus, the child may have received language input during these times (e.g., interacting with Grandma or a sibling) that is not available in the recordings.

Trained research assistants identified the video footage in which a focal child was potentially exposed to language input. Language input was conservatively defined as any word a focal child could likely hear based on the location of the speaker and focal child. For example, if the speaker and child were in the same room or adjacent open rooms (e.g., speech produced in the breakfast nook could be overheard by the child in the adjacent kitchen), the speaker's language would be counted as language input to the child. Importantly, the focal child need not have actively listened nor attended to the speaker for the words to be categorized as language input to the child. Thus, nouns in the child's input could have been directed to the focal child or to someone other than the focal child. Interrater reliability was computed for the onset and offset timestamps of segments in which the focal child was potentially exposed to speech, based on the 20% of the recordings that were double coded, and was strong ($\kappa = .87$, $p < .001$).

Selecting Video Footage

Once all times the focal child potentially heard language input were identified, the second step was to choose comparable subsamples of video footage for the eight families. Although all eight families were filmed across 4 days (approximately 40 hr of recordings from two cameras per family), the amount of time that the focal children received language input was unequal across families (Camera A range = 5:34–17:13; Camera B range = 8:59–13:55), and there was some amount of overlap between the two cameras such that both Camera A and Camera B could capture the same events. To address this, we selected roughly nine hours of language input footage for each family, which spanned the four days of filming ($M = 8$ hr, 59 min, $SD = 4$ min; 2 weekdays and 2 weekend days). Care was taken to ensure that the sample did not include repetitions of the same time segments captured separately by Cameras A and B. Video recordings from Camera A contributed to 1 weekday and 1 weekend day, and data representing the other weekday and weekend day were drawn from Camera B. The amount of video selected from each camera was proportional to the amount of language input the child received from each camera. For example, if 70% of the child's total language input came from Camera A and 30% from Camera B, the same proportions were conserved when selecting the 9 hr of video to code. Nine hours of language input was selected because it was the largest number of language input hours overall that allowed for equal samples of weekend and weekday hours (with proportion matching for Camera A and Camera B) across the eight families. When more than 9 hr of language input were available, contiguous exposure segments were randomly selected within the constraints outlined above until a total of 9 hr of language input were selected.

Coding Scheme

The child's linguistic environment was described by identifying speakers and locations in the recordings. Coding of the child's language input and language production focused on nouns. The coding manual is not currently available online.

Noun Input and Production

Coders transcribed and coded all common nouns (i.e., all nouns excluding proper nouns and pronouns) present in the focal child's language input and all common nouns produced by the child. All nouns analyzed in the current study were listed in the New Oxford American Dictionary (Stevenson & Lindberg, 2010). The coders first identified each noun by watching the preselected video footage and concurrently consulted preexisting transcriptions (created by trained research assistants for the larger CELF study) to disambiguate any noun instances. Each noun was coded for spatial context and speaker context. All coders were blind to any study hypotheses.

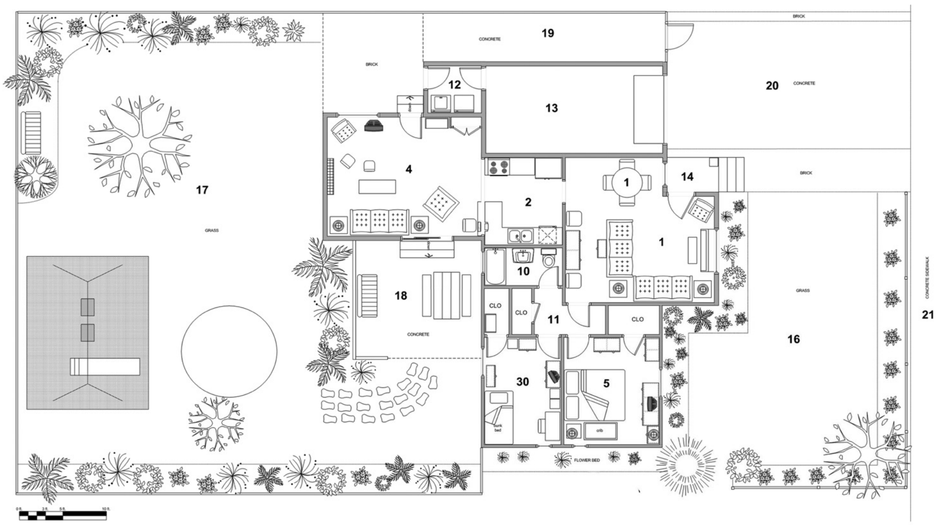
Spatial Context

For each noun (input and production), we coded the space the child was in when the noun was spoken (i.e., the spatial context). There are multiple ways to define spatial context, both specific and broad. We took a broad approach to defining spatial context. Spatial context was coded as the room or outdoor space where the child was located within a home (e.g., kitchen, backyard), car, or community setting (e.g., park) when the noun was produced. When the focal child was at home, coders were instructed to use a previously plotted family floor plan to determine the exact room the child was in (see Figure 1; Ochs et al., 2006). The coders did not have a floor plan when the focal child was in someone else's home (e.g., grandmother's house). Instead, they used visual cues from the video recordings to code which room the focal child occupied (e.g., grandmother's kitchen, babysitter's living room). The coders specified who drove the car when the child was in a car (e.g., mother's car). The coders recorded the general location when the focal child was in a store or other community setting (e.g., store, bank, park). If the coder could identify which store the child was in, they recorded the specific store name (e.g., Costco, Staples). If the community dwelling was large enough to have multiple functionally discrete sections, the coders specified which area the focal child was in (e.g., petting area of the zoo, pool at YMCA). Further, when the child was in a parking lot, the coders recorded that the focal child was in a parking lot and the community setting (e.g., the bank parking lot). If the child was walking in a neighborhood, the coders denoted that the child was on the sidewalk and in whose neighborhood (e.g., sidewalk in grandma's neighborhood).

Speaker Context

For each noun, we coded the speaker who uttered the noun (i.e., the speaker context). The speakers were primarily members of the immediate family (i.e., mother, father, Sibling 1, Sibling 2), but

Figure 1
Example of Family Floor Plan Used to Code Spatial Context



Standardized Space Codes

1 = Living Room
2 = Kitchen/nook
4 = Family Room/Den
5 = Parent's (A, B) Bedroom
10 = Bathroom
11 = HomeGen - Hallway/Stairs/Landing
12 = HomeGen - Utility/Laundry Room
13 = Garage
14 = HomeOutdoor - Porch (Front)
16 = HomeOutdoor - Front Yard
17 = HomeOutdoor - Back Yard
18 = HomeOutdoor - Patio/Deck (Back)
19 = HomeOutdoor - Exterior Side Space
20 = HomeOutdoor - Driveway
21 = NotHomeOutdoor - Sidewalk (city)
30 = ChildBedroom - Child C & D Bedroom

Note. Source: CELF data archive.

also included other relatives (e.g., aunt, cousin), friends, or persons in the community (e.g., mail carrier, grocery clerk).

Percentage Agreement

For each noun transcription (input and production) and the corresponding context codes, percent agreement on the location and speaker was assessed. All coders were trained to a 95% agreement level, as compared to an expert coder (i.e., the first author of this paper), prior to completing any coding for the study. Once coding began for the study, two coders were randomly paired and checked to confirm a 95% agreement between them for all codes, including context codes and noun tokens. The two coders achieved 95% agreement regularly, and in the rare cases they did not, they recoded until they reached a 95% agreement level.

Results

The first goal of this study was to describe the frequency of nouns in language input to children and the natural contexts in which children heard and produced nouns. Here the individual family is the unit of analysis. Though this section addresses descriptive goals, we include some statistical tests with the caveat that they are constrained by a very small sample size and can detect only very large effects. Table 2 summarizes this descriptive data by family. Subsequently, we move from an individual-differences approach to analyses with words as the unit of analysis to test our main hypothesis: words heard in more variable contexts are produced with greater frequency.

Frequencies of Noun Types and Tokens Across Families

Figure 2 provides the overall noun input counts (separated by type and token count). *Noun types* refer to the count of unique nouns in speech, and *noun tokens* refer to the overall count of noun instances in speech (Tardif et al., 1997). On average, there were 766 noun types per family (SD = 123, range = 592–910) and 3,782 noun tokens per family (SD = 730, range = 2,754–4,697). A partial correlation that controlled for child's age found that type and token counts were significantly correlated, $r(5) = .95$, $p < .001$. This suggests that children who heard more noun types also heard more noun tokens. There were no significant correlations between children's age and either type or token counts of nouns in language input to children.

As Figure 2 indicates, the number of nouns children produced was highly variable, which was expected given the wide range of children's ages. Children's age was correlated with both noun type and token production: type $r(6) = .89$, $p = .003$; token $r(6) = .78$, $p = .018$, and a partial correlation controlling for child's age found that the children's type and token production counts were significantly correlated with each other, $r(5) = .81$, $p = .029$. The

Table 2
Type/Token Counts and Unique Contexts Per Family

		Noun type count		Noun token count			
Family number	Age of focal child	Input	Child production	Input	Child production	Unique spatial contexts	Unique speaker contexts
1	1 year, 3 months	764	5	3,869	20	26	17
2	1 year, 7 months	650	13	3,468	174	31	18
3	1 year, 10 months	909	61	4,698	178	16	7
4	2 years, 3 months	836	155	4,450	859	13	7
5	2 years, 7 months	897	204	4,638	839	27	28
6	2 years, 8 months	646	147	2,754	1,110	27	17
7	4 years, 4 months	826	204	3,827	888	28	13
8	4 years, 4 months	594	271	2,807	1,238	25	9
M (*SD*)	3 years, 5 months (1 year, 2 months)	765 (121)	133 (97)	3,786 (732)	670 (472)	24.1 (6.2)	14.5 (7.1)

child with the lowest number of production noun counts, both types and tokens, was the youngest in the sample (i.e., 1 year, 3 months). Conversely, the child with the greatest number of production noun counts, both types and tokens, was one of the oldest children in the sample (i.e., 4 years, 4 months).

At the individual child level, there were no significant correlations between the number of noun types or tokens children heard and the number of noun types or tokens children produced (p range = .29–.85). Children who were exposed to more noun types and tokens were not more likely to produce noun types and tokens, likely in part due to the broad age range between the eight children.

Spatial and Speaker Contexts Across Families

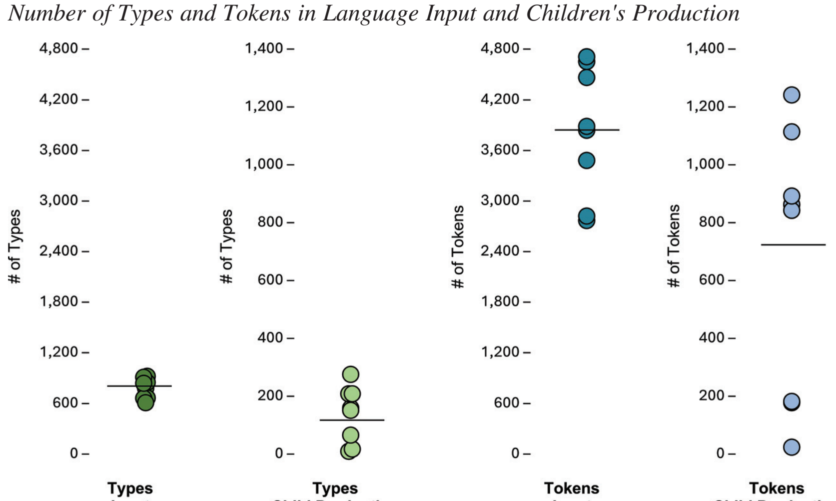
As Figure 3 shows, children were exposed to language in multiple spatial and speaker contexts in their everyday lives. On average, children in our sample heard nouns uttered in 24 different spatial contexts and 14 different speaker contexts. There was a marginally significant correlation between the number of spatial contexts and speaker contexts, $r(6) = .71$, $p = .06$, indicating that, in language input, nouns that were said in more spatial contexts were also said by more speakers. The association between the two types of contexts may be because families encountered different people as they traveled to new locations.

In all families, mothers produced the most language input, as measured in both types and tokens (type: $M = 502$, $SD = 110$, range = 349–625; token: $M = 1923$; $SD = 673$, range = 1,069–2,779). The second largest contributors to children's language input were either a sibling ($n = 4$ families) or father ($n = 4$ families; type: $M = 296$, $SD = 82$, range = 180–402; token: $M = 882$, $SD = 302$, range = 415–1,326).

Children heard the most language input in communal spaces of the family home: the living room ($n = 5$), kitchen ($n = 2$), or dining room ($n = 1$). The second most frequent location for language input was more variable across families: either a room within the home—living room ($n = 2$), breakfast nook ($n = 1$), dining room ($n = 1$), parents' bedroom ($n = 1$), child's bedroom ($n = 1$)—or a car (i.e., mother's car, $n = 1$; father's car, $n = 1$).

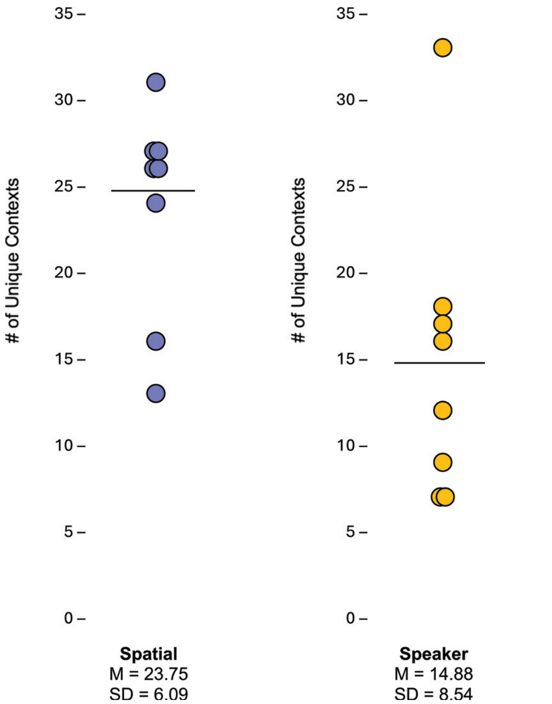
We examined associations between the number of unique contexts in which a child was exposed to language and their overall

Figure 2
Number of Types and Tokens in Language Input and Children's Production



Note. Horizontal lines denote group means. Note that input and production have different scales. See the online article for the color version of this figure.

Figure 3
The Number of Unique Spatial and Speaker Contexts Per Family



Note. Dots represent the number of unique spatial and speaker contexts observed for each family. Horizontal lines denote group means. See the online article for the color version of this figure.

language input and production and found no significant associations. There were no significant correlations between the total number of unique spatial contexts in which a child was exposed to language and the number of nouns the child heard, whether measured as types, $r(6) = .29$, $p = .48$, or tokens, $r(6) = .42$, $p = .30$. Similarly, there was no association between the number of unique speakers that children heard and the number of nouns to which they were exposed, in terms of both types, $r(6) = .06$, $p = .86$, and tokens, $r(6) = .03$, $p = .99$.

There were also no significant correlations between the number of unique contexts in which children were exposed to language and the number of nouns they produced. The number of unique spatial contexts in which a child heard language was not significantly associated with either their type, $r(6) = .38$, $p = .36$, or their token production, $r(6) = .17$, $p = .69$. The same was the case for the number of different speakers that a child heard and both indicators of noun production: types, $r(6) = .49$, $p = .26$, or tokens, $r(6) = .35$, $p = .43$. Thus, there was no correlation at the between-subjects level between contextual variability in a child's overall linguistic exposure and their overall language production.

There was a relationship between the number of words children produced and the number of unique spatial contexts in which children produced those words. There were significant correlations between the number of unique spatial contexts in which children produced words and word types produced, $r(6) = .88$, $p = .004$, as well as word tokens produced, $r(6) = .76$, $p = .03$, indicating that the more words children said, the more places children said those words. This strong correlation is likely due to the broad age and language production differences between the children in the study; some children produced less than 200 words in total, whereas others produced more than 1,000 words. Altogether, there were no clear relationships at the family level between the overall frequency of input or production and the number of unique spaces or speakers in which children heard or produced words.

Semantic Categories, Individual Words, and Variation in Contexts

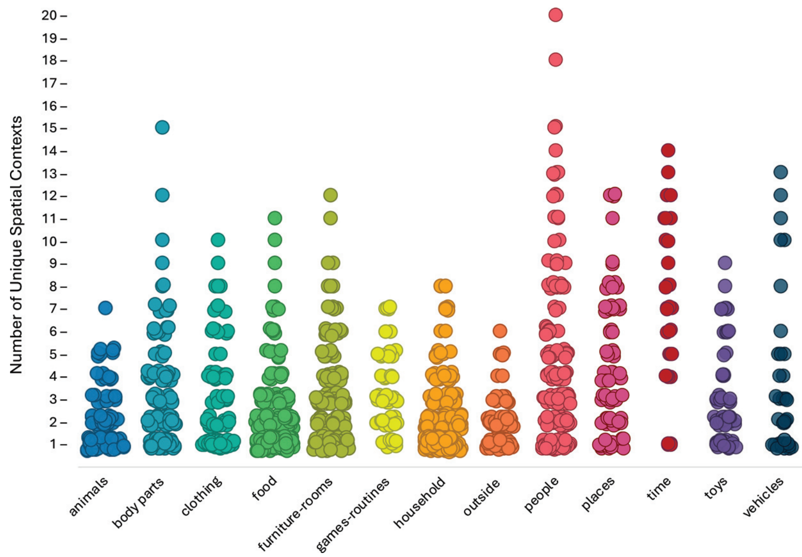
We next asked whether certain types of words in language input appeared in more variable contexts. Perhaps contextual diversity is limited to some types of words but not others. To answer this, we used the semantic categories described in the MacArthur Bates Communicative Development Inventory (CDI; Fenson et al., 1994). The CDI lists the words known by 50% of children at 30 months of age and organizes these words into 22 semantic categories. For our analysis, we only considered the 13 semantic categories that included nouns (i.e., animals, body parts, clothing, food, furniture and rooms, games and routines, household items, outside, people, places, time, toys, vehicles). We matched each word in our study with the nouns in the CDI and their corresponding semantic category. Words that were not listed on the CDI (e.g., drywall, waffle) were not categorized. Figure 4 depicts the distributions of spatial contextual variation in the language input, summed across families, and Figure 5 depicts the distributions of speaker contextual variation in language input, summed across families. As the figures show, there is contextual variability in all 13 categories. That is, within each category, children were exposed to some words that appeared in only a few unique contexts and other words that appeared in many unique contexts. Thus, it does not appear to be the case that contextual variability is confined to certain types of words.

Importantly, our study sought to understand the relationship between individual words and the contexts in which those words were heard. To do so, the dataset was organized with noun type as the unit of analysis ($n = 6{,}129$). As illustrated in Table 3, each row in the analysis represented a different noun type. Each noun could appear once for each child and, therefore, any particular noun (e.g., *bike*) could appear up to eight times in the dataset. The columns represented the variables in the analysis: *family number, noun token production* (i.e., the total number of tokens for which the child produced that particular noun type, which included zero if the child never uttered that noun), *noun token input* (i.e., the total number of tokens the child was exposed to for that noun type), *spatial context input* (i.e., the total number of spatial contexts in which the child was exposed to that noun type), and *speaker context input* (i.e., the total number of speakers who exposed the child to that noun type).

There was a strong correlation between the frequency of a particular word and the number of unique contexts in which that word was heard for both spatial, $r(6{,}127) = .80$, $p < .001$, and speaker contexts $r(6{,}127) = .65$, $p < .001$, indicating that the words that were said the most appeared in the greatest number of unique contexts. This is likely the case, in strong part, because the frequency with which a word was produced constrained the number of contexts in which the word could appear—a word that is only heard once can only be heard in a single context. Thus, the words that were heard in the most variable contexts also tended to be words that were most frequent in input, including references to people

Figure 4

The Number of Unique Spatial Contexts in Language Input in 13 Semantic Categories of Words



Note. The figure depicts distributions of spatial contextual variation in language input. Words in the language input were matched with the nouns from thirteen of the semantic categories listed in the CDI. Words that were not listed on the CDI were not categorized. Data are summed across families and are not adjusted for frequency. See the online article for the color version of this figure.

(e.g., baby, dad), words about time (e.g., day, minute, time), and places (e.g., school, home).

However, the critical test for our hypothesis regarding the link between contextual variability in exposure and frequency of production is at the level of individual words, independent of frequency. Are words that appear in more variable contexts more likely to be produced than words that appear in less variable contexts?

Associations Between Variability in Contexts and Children's Production

The primary goal of this study was to test whether there is a link between the contextual variability in a noun's input and children's production of that noun. The unit of analysis here is individual noun types. Within each family, we counted the number of different spaces in which a word was spoken and the number of different speakers who uttered it. On the production side, we counted the number of times the noun was spoken by the target child and the number of different spatial contexts in which the child uttered that noun. Data were analyzed using a fixed effect negative binomial count regression model. The outcome variable of the model was the number of times a particular *word* was produced. The predictor variables were the number of tokens of a particular word in input, the number of unique spatial contexts in which the word appeared in language input, and the number of unique speaker contexts in which the word appeared in language input.

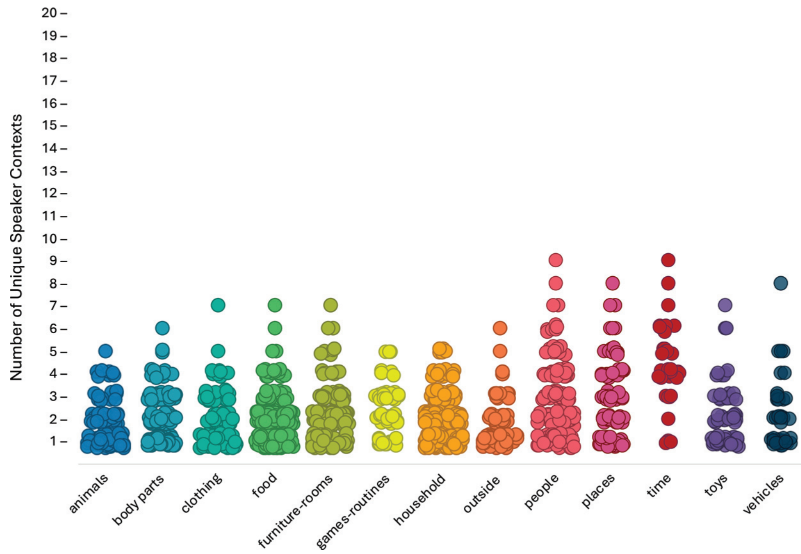
To account for the nonindependence of observations between focal children (i.e., repeated-measures nature of the data), we used a fixed effect model (Allison, 2005) with family as a grouping variable. Therefore, all conclusions regarding these analyses are at the within-subjects level. As before, the dataset was organized with noun type ($n = 6{,}129$) as the unit of analysis (see Table 3). To account for the fact that the outcome variable (noun token production counts) was measured on a count scale, we used a count regression model rather than a linear regression model. Further, because the outcome variable was overdispersed (observed variance was higher than the variance of a theoretical model), the data were analyzed using a negative binomial count model.

All three input variables (number of tokens, spatial contexts, and speaker contexts) for a noun type were tested as simultaneous predictors of that noun's token production. The likelihood ratio chi-square test of the overall model was statistically significant ($\chi^2 = 892.60$, $p < .001$). All three input variables were significant predictors of children's production of noun tokens (see Table 4)[1]. As expected, the noun tokens in language input to children positively predicted the noun tokens in children's production (incidence rate ratio [IRR] = 1.01, $p < .001$), indicating that for every additional token of a particular word in language input, the number of tokens of that word a child produced increased by a rate of 1.01, with the other predictor variables held constant. Spatial context also positively predicted children's production (IRR = 1.09, $p < .001$), indicating that for every additional spatial context in which a word was heard, children's production of that noun increased by a rate of 1.09, with the other predictor variables held constant. Last, speaker context positively predicted children's noun token production (IRR = 1.26, $p < .001$),

[1] Because the model uses the natural log of the outcome variable, all results are presented as incidence rate ratios, which are the exponentiated beta coefficients.

Figure 5

The Number of Unique Speaker Contexts in Language Input in 13 Semantic Categories of Words



Note. The figure depicts distributions of speaker contextual variation in language input. Words in the language input were matched with the nouns from thirteen of the semantic categories listed in the CDI. Words that were not listed on the CDI were not categorized. Data are summed across families and are not adjusted for frequency. See the online article for the color version of this figure.

indicating that for every additional speaker context in which a word appeared, children's production of that noun increased by a rate of 1.26, with all other predictor variables held constant. In summation, the number of different spatial contexts a child occupied while exposed to a noun and the number of different speakers who exposed a child to a noun each predicted an increase in the number of times the child produced that noun, independent of the total number of times the child was exposed to that noun.

Finally, we tested the association between the number of spatial contexts in which a child was exposed to a noun and the number of spatial contexts in which the child produced that noun. For this analysis, we used a fixed effect Poisson count regression. A Poisson regression was appropriate because the outcome variable (spatial context output) was not overdispersed. This model was tested with a dataset similar to the one described above, but this model included only the nouns that children were both exposed to and also produced themselves (n = 826 nouns across the eight families). The outcome variable was the number of spaces in which the child produced that noun type. The predictor variables were noun token input (i.e., the total number of tokens in language input for that noun type) and spatial context input (i.e., the total number of unique spatial contexts in language input for that noun type). The analysis revealed a significant positive association with the number of spatial contexts in which the child heard the noun (IRR = 1.10, $p < .001$); indicating that for every additional spatial context in which a word was heard, the number of spatial contexts in which the child produced that noun increased by a rate of 1.10, with the frequency of that noun in language input to children held constant. However, there was no significant association between the number of noun tokens in language input to children and the number of spatial contexts in which children produced the word (IRR = 1.00, $p > .05$). These results suggest that the number of spaces a child occupied when exposed to a noun positively predicted the number of spaces in which the child produced that

Table 3

Example Matrix Used to Analyze the Association Between Spatial and Speaker Context Input and Noun Token Production

Noun type	Family number	Noun token production	Noun token input	Spatial context input	Speaker context input
Bike	1	0	5	2	4
Chicken	1	3	9	5	3
Gift	1	0	1	1	1
Airplane	2	0	2	1	1
Bike	2	0	1	1	1
Napkin	2	3	4	2	2

Note. Each row represented a different noun type for each child. Thus, any particular noun (e.g., bike) could appear up to eight times in the dataset. The columns represented the variables in the analysis: family number, noun token production, noun token input, spatial context input (i.e., the total number of unique spatial contexts in which the child heard the noun type), and speaker context input (i.e., the total number of unique speakers who said the noun type).

Table 4
Negative Binomial Fixed Effect Regression With Noun Token Production as Outcome Variable

Predictor variable	IRR	*SE*	*Z*
Intercept	0.03	.002	−50.06***
Number of tokens	1.01	.002	4.78***
Number of unique spatial contexts	1.09	.023	4.00***
Number of unique speaker contexts	1.26	.045	6.69***

Note. IRR = incidence rate ratio.
*** $p < .001$.

noun. To summarize, the analyses indicate that, controlling for frequency of exposure to a word, contextual variation may be beneficial to early word production; children were more likely to say nouns that were heard in more spaces and from more people. Further, nouns were more likely to be produced by children in different spaces if they heard those nouns in diverse settings.

Discussion

The current study examined the role of contextual variability in young children's everyday language environments. Specifically, we aimed to investigate the association between variability in the contexts that children heard words and children's word production using a large sample of nouns. The results suggest that contextual variability is positively associated with children's production of a particular word. That is, words that children heard in multiple places and uttered by multiple speakers were more likely to be produced than words heard in more narrow contexts. Importantly, the effects of contextual variability were independent of how frequently a word was spoken in the child's environment.

A goal of our study was to begin to document the range of contexts in which children hear words in their everyday lives. We found that children in our sample heard nouns spoken in many different spatial contexts (on average 24 different contexts over 9 hr of recordings) – both inside and outside their homes, other people's houses, and places in their community. Children also heard language from many different speakers (on average 15 different speakers), including their parents, older siblings, other family members, and community members. Thus, even within a small sample of their everyday lives, children heard words in many different contexts. The contextual description afforded by the current study adds to the small but growing body of research examining contextual variation in children's everyday lives (Montag et al., 2018; Roy et al., 2015; Tamis-LeMonda et al., 2017, 2019). Descriptions of the world as it exists in children's lives are critical to theory development and are as important as experiments that test causal hypotheses because "naturalistic methods can indicate whether two variables covary in everyday life, whereas experimental methods can indicate whether one variable causes changes in the other" (Dahl, 2017, p. 82). In doing so, the current study opens a window to understanding the spatial and speaker contexts of children's real-world linguistic environments.

We also found that contextual distributions differed for individual words. Some words occurred in a wide variety of settings. For example, the word *car* was heard and produced in many locations. Other words occurred in much more narrow contexts. For example, the word *toothpaste* was only produced in the bathroom. The primary goal of our study was to investigate how the diversity of contexts in which children hear words is related to the frequency with which they produce those words. The current study suggests that more contextual variation in children's language input may benefit children's language production. Our results indicate that the words that occurred with the greatest contextual variation were the words that children were most likely to produce, regardless of the number of times they heard the word spoken. These results are consistent with past research suggesting that learning benefits from contextual variability (Amabile & Rovee-Collier, 1991; Rovee-Collier & Dufault, 1991; S. M. Smith et al., 1978; Vlach & Sandhofer, 2011; but see also Roy et al., 2015). For example, infants trained to kick when presented with a crib mobile failed to do so when tested with a context other than the one they had been trained (Butler & Rovee-Collier, 1989). However, infants successfully recognized the mobile and kicked when trained in multiple contexts prior to testing in a novel context (Amabile & Rovee-Collier, 1991).

Further, the results are consistent with research showing that diversity in lexical contexts may be important for word learning (Hills et al., 2010; Jones et al., 2012). This suggests that contextual diversity may be a broader, more domain-general, force that may simultaneously operate at multiple levels, including the semantic and lexical (Fausey et al., 2016; Hills et al., 2010; Montag et al., 2018; L. B. Smith et al., 2018; Warlaumont et al., 2021).

One way that contextual diversity may support learning and production is by preventing words from becoming context-bound and allowing learners to decontextualize to-be-learned information. A number of observational studies suggest that children's initial understandings of words may be bound to specific contexts (Barrett, 1986; Bloom, 1973) and only become decontextualized over time. Context dependent learning and memory effects are well documented (Bjork, 1994; Pessin, 1932; S. M. Smith et al., 1978) and indicate that experiencing a to-be-learned item repeatedly in the same context can impair memory retrieval in other contexts. Learning in varied contexts can protect against context dependency in laboratory experiments (Goldenberg & Sandhofer, 2013b; Jones et al., 2011; S. M. Smith et al., 1978). It seems likely that contextual variation may also aid in word retrieval in children's everyday lives.

Contextual variation may have differential effects at different developmental points in language learning. Children (age range = 1 year, 3 months–4 years, 4 months) in the current study were more likely to produce words that appeared in more variable speaker and spatial contexts in language input. Similarly, Hills et al.,'s (2010) model finds that the earliest learned words are the most semantically diverse in the learning environment. However, a study of six-month-old infants (Bergelson & Aslin, 2017) did not find a link between how object words were distributed across speakers and infants' nascent comprehension of the words, perhaps suggesting that other factors may play a larger role very early in language development. Moreover, the Roy et al. (2015) analysis of one child from from the age of 9 to 24 months found contextual distinctiveness, rather than contextual variability, was associated with the first production of a word, what Roy et al. (2015) called *word births*. This term suggests that contextual cues may function differently when facilitating the initial acquisition of a word versus facilitating the production of the word once it has entered the child's lexicon.

One potential explanation for the differences between Roy et al.'s (2015) findings and those of the current study comes from a laboratory study of 2-year-old children (Goldenberg & Sandhofer, 2013b). The children successfully learned novel words when the word was presented in varied and repetitive background contexts. This may be the case because contextual variation and contextual repetition provide different types of support for word learning. Contextual repetition may aid in aggregating different category instances. It is well established that performance is enhanced when encoding and retrieval conditions match. Because context is associated with objects in memory, contextual cues can aid in aggregating discrete instances together in memory. For example, hearing the word *spoon* in the kitchen context may help children aggregate all the different instances of spoons that they may experience and increase their ability to retrieve the word *spoon* when they are in the kitchen. In this way, contextual distinctiveness, that is, hearing a word repeatedly in a narrow context, may aid a child with the initial acquisition of a word. Further support for this idea comes from studies showing that infants have difficulty finding an object if they encounter the object in multiple spatial contexts (Osina et al., 2014) and are more likely to learn names for objects that have predictable rather than varied spatial locations (Benitez & Smith, 2012). More broadly, object repetition in visual distributions has been proposed as a potential support for early visual learning (L. B. Smith et al., 2018). These findings are consistent with Roy et al.'s (2015) finding that contextual distinctiveness supports children's initial acquisition of a novel word.

However, once children have learned a word, they may not need the same support for aggregation. Contextual variation may support the abstraction of a novel noun from its surrounding contextual factors. In this way, the role of contextual cues may change across experience: narrow contexts may aid in acquisition, and broader contexts may facilitate later production and use of the word. It was not possible to examine whether contextual distributions have a differential effect on word births versus later production within our dataset. Future work should examine differences in children's acquisition, comprehension, retrieval, and production of words that occur in broader versus narrower contexts. Further, the hypothesis that learning in multiple contexts facilitates performance when testing occurs in those particular multiple contexts has not been tested yet in the experimental literature and provides a novel prediction that arises from children's everyday circumstances.

Another direction for future research involves a better understanding of the time scales between the language input and children's production. Roy et al.'s (2015) study suggests that input operates on a long time scale. For example, 17,529 instances of the word *water* were produced in language input before Roy's son first produced the word *water*. However, input and production can be more tightly coupled, such that words within a topic of conversation may be more likely to be produced by children. Future work could seek to understand whether contextual diversity has a stronger effect on spontaneous speech than on words that are prompted directly or indirectly within conversation.

In addition, future studies should examine additional contextual cues, including more fine-grained contexts. The kitchen, for example, might consist of subcontext geographies, such as the kitchen table or the kitchen sink. The activities that take place in the kitchen might themselves comprise different contexts, such as eating versus cooking. Tamis-LeMonda et al.'s (2019) analysis of the language used by mothers in different activities (i.e., feeding, grooming, book sharing, object play, and transition) found that mothers' language systematically differed across activities. Further, the same activity in the same place might differ in a myriad of ways, such as when eating breakfast versus eating dinner—words like *cereal* or *waffle* are likely associated with both particular spaces and particular times of day. Likewise, considering speaker context at the level of individual speakers might be appropriate because children hear language input from a broad range of speakers (Bergelson et al., 2019) and are sensitive to talker variability (Creel & Jimenez, 2012). However, the same person may also offer a variety of subcontexts. Hearing a word spoken by one person might be contextually different if said in a happy or angry voice (Ogren & Sandhofer, 2021). Although the contextual categories we chose were less granular, they are nevertheless indicative of the range of contextual variability that accompanies different words.

One question is why some words are produced in more contextually diverse settings, whereas others are more contextually bound? Certainly, pragmatic and environmental constraints affect contextual variability. Recent research (Custode & Tamis-LeMonda, 2020) notes that certain words may be spatially bound (e.g., food words are more likely to be said when an infant is in a highchair). Perhaps words that are said in more variable contexts may be words that index concepts that are more widely applicable or of greater importance to the family. At the same time, other words may be of immediate importance only in specific contexts. We found some evidence for this point. For example, the word *car* occurred in multiple spatial contexts, which corresponds to the car physically moving around the environment. On the other hand, the word *goal* was primarily produced at the soccer field, when the environment included features that semantically fit with goals: goalposts, a soccer ball, soccer players, and additionally, the salience of scoring a goal became heightened.

Moreover, these constraints may be family-specific. For many families, the word toothbrush may be talked about within a narrow set of spatial contexts, but perhaps those contexts are broader for families with a cavity-prone child. In other cases, the relationship between words and their spatial contexts was less clear. Words such as *dinner* were often spoken outside of the kitchen and dining room—perhaps because dinner, including making dinner and having dinner ready on time, was of great importance to families. This variability was captured in our contextual analyses. We found contextual diversity in all thirteen of the semantic categories we assessed. One factor that should be considered is the relationship between frequency and contextual diversity. The most frequent words (e.g., minute, home, thing) also tended to occur in more contexts and can indicate concepts of importance to families (e.g., getting to work on time; people coming home). Other words, such as *wall*, despite being physically present in most instances, are less frequently uttered. Because it is well documented that the words that are most frequent in language input to children are the words that are most likely to be produced by children (Huttenlocher et al., 1991), contextual diversity likely interacts with frequency in the natural distribution of language input.

In sum, the current study examined the role of contextual variation in early language learning. We used a naturalistic methodology to describe contexts that background children's language environments and to examine associations between the number of contexts in which children are exposed to nouns and the frequency with which children produce those nouns. We suggest that contextual variation has a role in language learning and find that nouns are more likely to be produced when children are exposed to them in diverse contexts.

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